Transition Metal-Catalyzed Aerobic Dehydrogenation of Heterocycles

and

Development, Implementation, and Evaluation of a Student-Generated ChemWiki and its Impact on Student Performance

By

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Acknowledgments

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Section I: Transition Metal-Catalyzed Aerobic Dehydrogenation of Heterocycles

Abstract

This section describes progress towards the dehydrogenation of heterocycles, specifically tetrahydroquinolines and imidazolines. Chapter 1 details the development of an aerobic Pd catalyst system capable of aromatizing substituted tetrahydroquinolines in moderate to good yields. This catalyst system generally works well for substituted tetrahydroquinolines, although elimination of heteroatom substituents remains problematic. Chapter 2 describes the development of a copper-based catalyst system for the dehydrogenation of substituted imidazolines to imidazoles. This catalyst system is based upon the Cu^{I}/bpy/TEMPO/NMI system developed in the Stahl group, which has shown excellent reactivity towards alcohol oxidation.[1] Efforts to adapt this system to imidazolines are described herein.

Chapter 1

Synthesis of Substituted Quinolines via Pd-Catalyzed Dehydrogenation of Tetrahydroquinolines

1.1 Introduction

Heteroaromatic molecules are ubiquitous in both biologically active molecules and pharmaceutically relevant targets.[2] The prevalence of this motif has rendered much investigation into the functionalization of aromatic ring systems. Six of the ten top-selling drugs in 2010

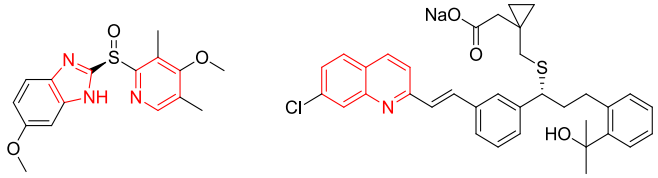


Figure 1.1. Representative top-selling drugs of 2010.

include a heteroaromatic motif (Figure 1.1). The high demand for access to substituted arenes has resulted in a multitude of synthetic efforts toward their construction. Both electrophilic and nucleophilic aromatic substitution,[3] in addition to more modern cross-coupling methodologies,[4] have been thoroughly explored as a means to access functionalized arenes. These methods are known to suffer from a variety of constraints such as regioselectivity limitations or, in the case of cross-coupling, the requirement of an aryl halide, triflate, or analogous leaving group.[5] The burgeoning field of C–H activation has risen as a means to address the atom-inefficiency of cross-coupling methodologies, and a wide range of synthetically useful transformations has been established in recent years.[6] However, a common characteristic in the synthesis of substituted arenes is the presence of an aromatic starting material. We envisioned that the synthesis of complex aromatics could be approached by an alternative strategy in which the substitution or functionalization is installed prior to aromatization. This new approach would circumvent regioselective limitations found in traditional aromatic substitutions as well as take advantage of the diverse organic methods for ring construction. For example, in the case of electrophilic aromatic substitution (EAS), the presence of a strongly electron-donating group, such as a

hydroxy or alkoxy group, limits substitution to *o*- and *p*-substituted derivatives. However, if the substituent of interest were to be installed prior to aromatization, *m*-substituted derivatives could be constructed. As a first step towards utilizing this tandem substitution/aromatization approach, our group has recently disclosed the aerobic dehydrogenation of cyclohexenones and cyclohexanones towards the synthesis of substituted phenols.[7] While precedents for dehydrogenation of cyclohexanones and cyclohexenones to phenols exist, the yields of these reactions are very low (< 30% in the case of cyclohexanones)[8,9,10] or require the use of stoichiometric chemical oxidants.[11] The research performed in our group has led to a synthetically useful dehydrogenation of 3-substituted cyclohexanones, thus affording the corresponding *m*-substituted phenol (Figure 1.2). This method portends the utility of using a

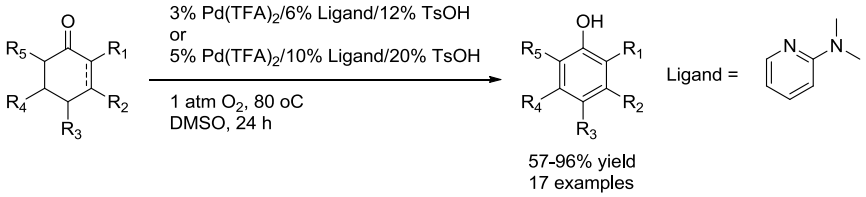


Figure 1.2. Aerobic dehydrogenation of cyclohexenones and cyclohexanones.

functionalization/aromatization approach as a means of constructing polysubstituted arenes, and the extension of this methodology towards the formation of highly desired heteroaromatic molecules emerges as a worthwhile target.

Of the various classes of heteroarenes, six-membered *N*-heteroaromatics are uniquely prevalent in biologically active molecules and pharmaceutical targets (see Figure 1.1). The synthesis of quinoline analogues presents a unique opportunity to highlight the functionalization/aromatization approach established by our group. Traditional methods for the synthesis of substituted quinolines involve formation of the *N*-containing ring *in situ* (Figure 1. 3).[12] A commonly employed synthesis of quinolines is the Doebner-Miller synthesis. This

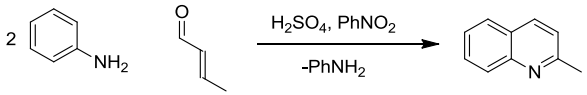


Figure 1.3. The Doebner-Miller Synthesis

method involves condensation between aniline and an α,β-unsaturated aldehyde, which is either pre-formed or generated *in situ* from glycerol via heat and strong acid. The nitrogen-containing ring is formed during the course of the reaction, but full aromatization of the molecule can only be achieved through use of a stoichiometric chemical oxidant such a nitrobenzene. Quinone-based oxidants such as 2,3-dichloro-5,6-dicyano-1,4-benzoquinone (DDQ) and chloranil have found widespread use in the oxidation of heterocycles to the corresponding heteroaromatic. While the reliability of such oxidants on a laboratory scale has been well established, the poor atom economy and toxic byproducts resulting from their use implores the development of an alternative method of oxidation. One such approach that has been thoroughly explored by our group is the use of molecular oxygen as the terminal oxidant in palladium-catalyzed oxidation reactions.[13,14] Oxygen is the ideal oxidant - it is the cheapest oxidant available and has the added

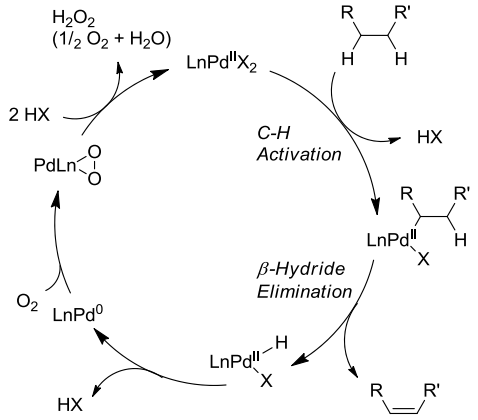


Figure 1.4. Catalytic cycle for Pd-catalyzed aerobic dehydrogenation.

benefit of producing water as the sole byproduct (Figure 1.4). Also, the use of palladium catalysts, which are known to operate via clean two-electron chemistry, has the potential to exhibit a different mode of reactivity that contrasts with possible one-electron oxidants such as DDQ. For example, the dehydrogenation of tetrahydroquinolines has been shown to undergo DDQ-mediated aromatization with concomitant elimination of heteroatom substituents.[15] By utilizing a palladium-catalyzed system, we hoped to avoid this manner of reactivity and preserve the incorporated substituents. We envisioned this transformation proceeding through two sequential dehydrogenations (Figure 1.5). First, N–H activation by the catalyst followed by β-hydride elimination affords an imine intermediate, a transformation that resembles widely

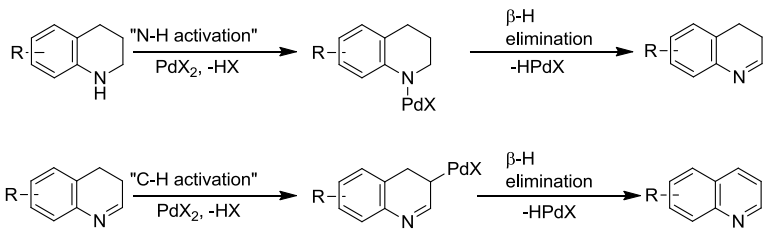


Figure 1.5. Key steps associated with heterocycle dehydrogenation.

established alcohol oxidation. A second dehydrogenation would then be initiated by C–H activation of the intermediate and subsequent β-hydride elimination would then render the desired aromatized product.

In approaching the synthesis of substituted quinolines, a diverse method for constructing the corresponding tetrahydroquinoline is necessary. Fortunately, many methods for the synthesis of tetrahydroquinolines currently exist,[16] including preparation by ring contraction,[17] ring expansion,[18,19] cycloaddition,[20,21] and C–N[22,23] or C–C[24] bond-forming heterocyclization reactions. The Povarov reaction[25] has emerged as a convergent strategy for assembling the

nitrogen-containing ring (Figure 1.6). This method, which is formally an inverse electron

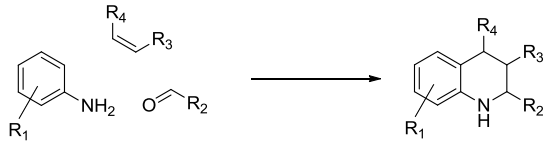


Figure 1.6. Synthesis of tetrahydroquinolines via the Povarov reaction.

demand aza Diels-Alder reaction, involves condensation of aniline derivatives with the corresponding aldehyde. The resulting imine then reacts as the diene component in a [4+2] cycloaddition with an electron-rich dienophile. Examples of the Povarov reaction in the literature are primarily restricted to strongly electron rich dienophiles (e.g. vinyl ethers),[15,26-28] although reports of unactivated olefins as the dienophilic partner have also been documented.[29] The high convergence and ability to incorporate substitution at every position of the quinoline ring makes the Povarov reaction an extremely attractive approach towards the rapid assembly of substituted quinolines.

1.2 Results and Discussion

As a starting point for developing aerobic dehydrogenation of tetrahydroquinolines, the catalyst system developed for cyclohexanone dehydrogenation was first tested (3% $Pd(TFA)_2$, 6% 2-*N,N*-dimethylaminopyridine, 3% *p*-toluenesulfonic acid, DMSO, 80 °C, 1 atm O_2, 24 h). The parent 1,2,3,4-tetrahydroquinoline was used to determine the viability of this catalyst system. Gratifyingly, the unsubstituted tetrahydroquinoline was aromatized in 71% yield. Various methylquinolines were then subjected to the reaction conditions in order to explore the tolerance of this catalyst system towards substitution, and it was found that substitution at the 2-, 3-, or 4-position could be tolerated (53-68% yield).

During the course of screening, several key issues were identified. In contrast to the catalyst system used for cyclohexanone dehydrogenation, exogenous acid was found to have a detrimental effect on the yield of aromatized product, while base was found to be beneficial. The detrimental effect of acid is presumably due to its prevention of catalyst N–H activation (pK_a = 4.27). Basic conditions would facilitate binding of the substrate to the catalyst by deprotonation.

Another issue was the observation of low mass balance throughout the process. A series of controls was performed to rule out undesirable side reactions with the solvent and additives, and it was found that in the presence of DMSO as solvent, significant product decomposition occurred within 24 hours. Although the byproduct of the reaction between DMSO and the product was not identifiable by GC-MS or NMR spectroscopy, it was recognized that a DMSO-mediated oxidation was occurring. Further time course studies revealed product yield degradation began at 4.5 hours and resulted in a considerable decrease in yield within 24 hours (90% to 66% yield). Since DMSO was ruled out as a suitable solvent for product stability, various other solvents were examined. Both starting material and product were found to be completely stable in toluene when exposed to heat (80 °C) and 1 atm O_2; however, the stability of the palladium catalyst in a non-coordinating solvent was problematic. Thus, a variety of ligands were tested next. During the course of screening, it was found that sulfoxide ligands were superior in stabilizing the catalyst, with DMSO as a co-solvent in toluene (4:1) providing both

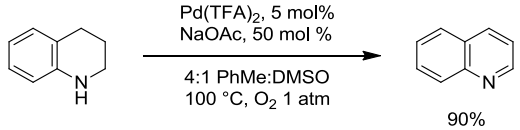
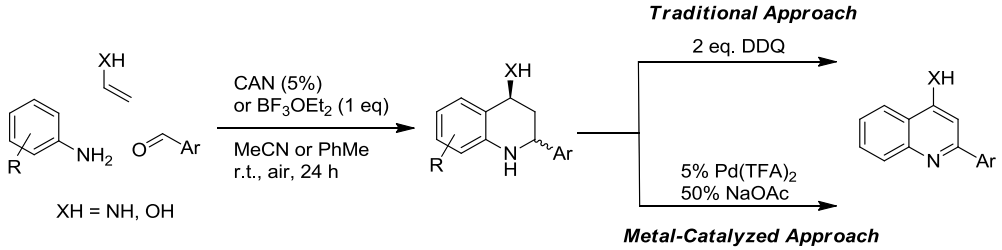


Figure 1.7. Optimized aromatization conditions.

high catalyst reactivity and increased mass balance. It was also established that lower catalyst

loadings could be offset by increased temperatures, and optimized reaction conditions were established (Figure 1.7).

With optimized reaction conditions in hand, the search for a method in which tetrahydroquinolines could be rapidly constructed began. An ideal methodology would fulfill the following requirements: 1) utilize readily available starting materials, 2) assemble the starting materials in a highly convergent manner, and 3) have the ability to incorporate substituents at any position in the *N*-heterocycle. Of the known methods for constructing tetrahydroquinolines, the one-pot, three-component inverse electron demand Diels-Alder reaction, also known as the Povarov reaction, seemed ideal for these purposes, as alternate routes to tetrahydroquinolines often require functionalized starting materials or multistep syntheses. Aromatization to the corresponding quinoline has shown potential; however, stoichiometric oxidants remain the standard method to achieve aromatization (Scheme 1.1).[30-32] A variety of Brønsted and Lewis



Scheme 1.1. Alternative approach to quinoline formation.

acid catalyst systems have been identified to mediate or catalyze the formation of the nitrogen-containing ring.[15,27,33-37] Unfortunately, despite the wide variety of acid catalysts that have been reported, no unified catalyst system has been established across a broad range of substrates. With this in mind, preliminary work in this research aimed to find a universal catalyst that was highly effective for a diverse array of substrates. Of the many reports of Lewis acid catalysts, cerium (IV) ammonium nitrate (CAN) and $BF_3 \cdot OEt_2$ exhibited the widest range of substrate generality,

and this was confirmed as the substrate scope was explored. Using this method, a variety of substituted tetrahydroquinolines were synthesized (Figure 1.8). It was discovered during the course of the substrate synthesis that this method was restricted to the use of strongly electron-rich dienophiles, as is precedented in the literature. *N*-Vinylphthalimide and electron-rich or electron-poor styrenes were unsuitable dienophiles for this transformation. Due to this limitation, 4-alkoxysubstituted tetrahydroquinolines (derived from the corresponding vinyl ether as dienophile) were a primary focus. Unfortunately, syntheses in which acyclic vinyl ethers were employed exhibited very poor yields (5-30%), a pattern of reactivity that has been documented in the literature. Also, 4-alkoxy-derived tetrahydroquinolines proved troublesome to manipulate in lab due to the extremely viscous nature of product. Gratifyingly, 4-acetamido derivatives (from *N*-vinylacetamide) exhibited much higher, acceptable yields (50-74%) and thus were pursued as well. It is also noteworthy that pre-formation of the imine led to higher yields, most likely due to the slower rate of condensation in the case of electron poor anilines. The requirement of facile imine formation was illustrated further in the poor conversion of more electron rich aldehydes (e.g. formaldehyde) to the desired tetrahydroquinoline. As a result of this limitation, the substrate synthesis was primarily restricted to the formation of 2-arylsubstituted tetrahydroquinolines.

As the synthesis of substrates progressed, each tetrahydroquinoline was subjected to

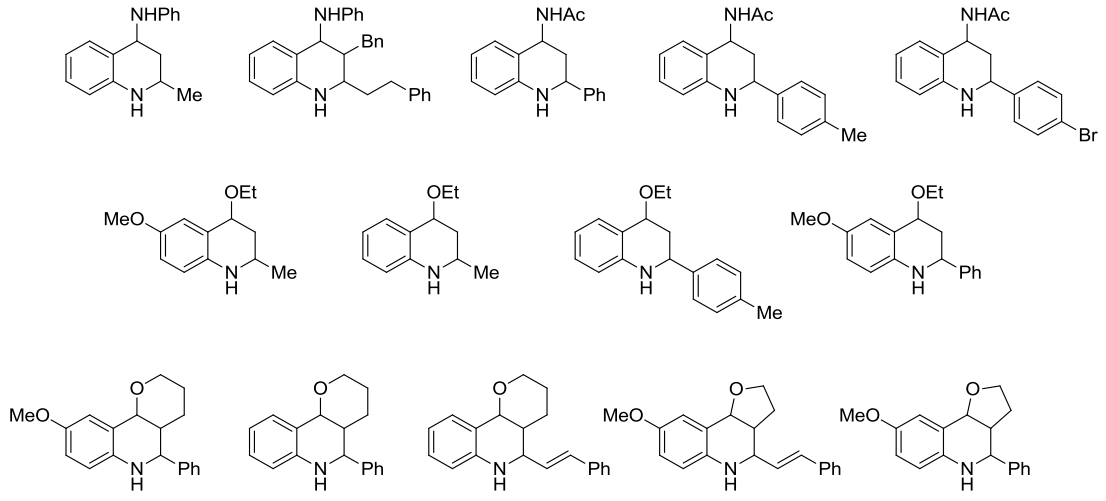


Figure 1.8. Substrate scope of substituted tetrahydroquinoline formation.

optimized dehydrogenation conditions. In the case of substrates containing heteroatom substitution, elimination products (Figure 1.9) were the major aromatization products. This type of reactivity has been reported previously when Pd/C is used as a dehydrogenation catalyst.[15]

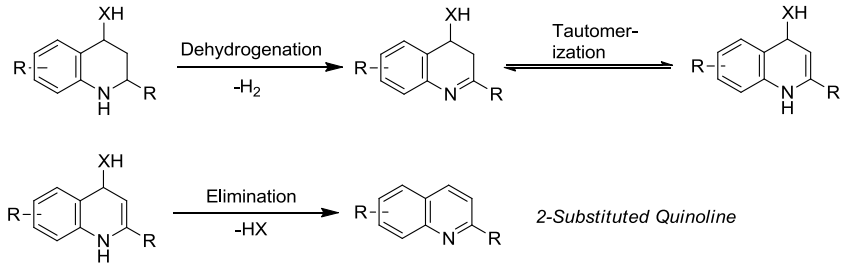


Figure 1.9. Elimination of heteroatom substituents.

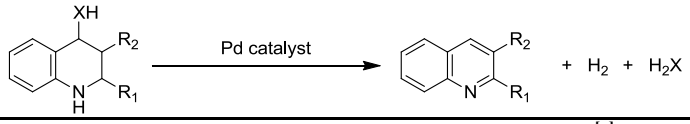
Attempts to supress elimination using bulkier, more electron-rich vinyl ethers (e.g. butyl vinyl ether) were not successful in producing the alkoxy-substituted quinoline. Moreover, during the reaction time course, the formation of decomposed, elemental palladium ("palladium black") was observed upon substrate addition to the catalyst solution.

Surprisingly, evaluation of the reaction mixture at regular time intervals indicated no loss of catalyst activity towards dehydrogenation. The similarity in reactivity with Pd/C suggests that

Entry	Catalyst	% Yield*
1	$Pd(TFA)_2$ (5%) (10% Ligand)	9
2	$Pd(OH)_x/Al_2O_3$	7
3	$Pd(OH)_x/CuO$	6
4	$Ru(OH)_x/Al_2O_3$	70
5	$Ru(OH)_x/CuO$	4
6	$Ru(OH)_x/Al_2O_3$	77
7	**$Ru(OH)_x/Al_2O_3$**	**85**
8	$Ru(OH)_x/TiO_2$	64
10	$Ru(OH)_x/CeO_2$	37
11	$Ru(OH)_x/ZnO$	28
12	$Ru(OH)_x/MgO$	20
13	$Ru(OH)_x$/Zeolite 13X	50
14	$Ru(OH)_x$/Mordonite	47

Table 1.1. Heterogeneous dehydrogenation of 1,2,3,4-tetrahydroquinoline.

a heterogeneous catalyst may be the active catalyst. During the course of catalyst optimization, heterogeneous catalysts (Ru or Pd on various solid supports) had been explored as an alternative to the homogeneous $Pd(TFA)_2$ system. These catalysts were chosen due to their availability from our lab's research with heterogeneous alcohol oxidation, which closely resembles the mechanism of this research. Of the tested catalysts, $Ru(OH)_x/Al_2O_3$ showed superior reactivity in the aromatization of the unsubstituted, parent tetrahydroquinoline (Table 1-1, entry 7). Unfortunately, aromatization of the substituted analogues was greatly decreased (29% yield) with $Ru(OH)_x/Al_2O_3$. Pd/C showed major decomposition and poor selectivity for the aromatization of the parent tetrahydroquinoline. However, subsequent tests of substituted substrates revealed that Pd/C was comparable to the optimized $Pd(TFA)_2$ system in performing aromatization. Moreover, slightly higher selectivity was achieved using Pd/C under anaerobic conditions. With this in mind, two catalyst systems were utilized in the aromatization of substituted tetrahydroquinolines. Due to higher yields and practical manipulation in the lab, 4-acetamidotetrahydroquinolines were the first class of substrates to be tested for aromatization. Unfortunately, although the synthesis of this class of substrates was higher yielding, the 4-



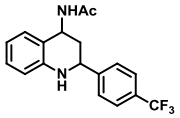
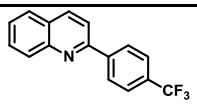
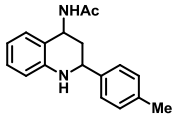
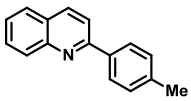
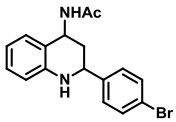
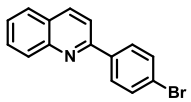
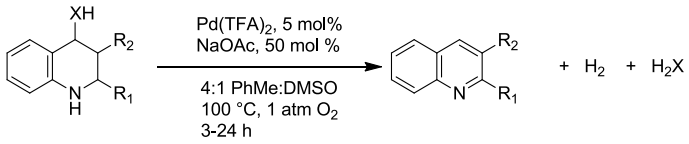
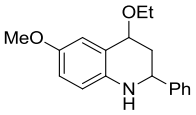
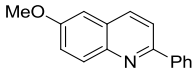
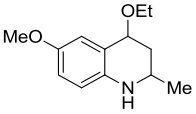
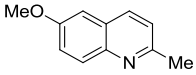
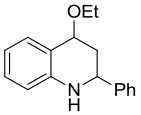
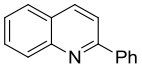
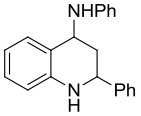
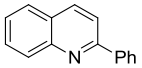
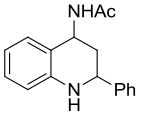
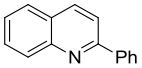
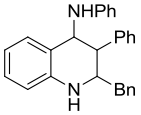
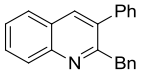
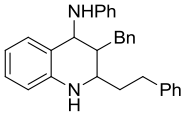
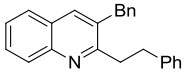
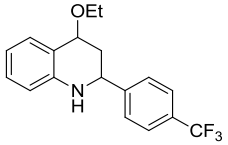
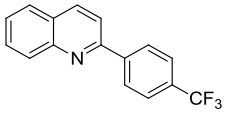
Entry	Substrate	Product	Yield[a] ($Pd(TFA)_2$)[b]	Yield[a] (Pd/C)[c]
1			21	8
2			64	42
3			33	14

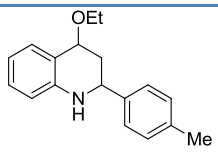
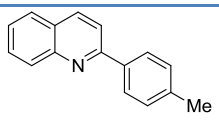
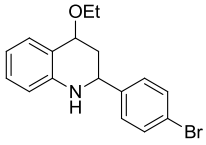
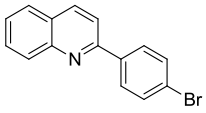
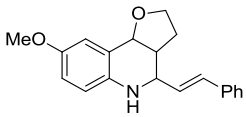
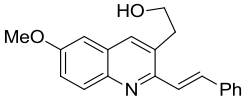
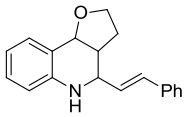
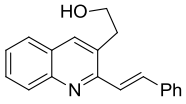
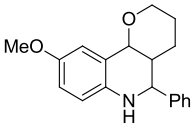
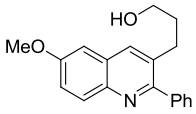
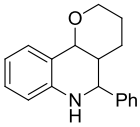
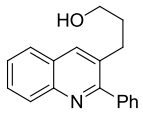
Table 1.2. Comparison of homogeneous vs. heterogeneous catalysts.

[a] Yields determined by ^1H NMR spectroscopy using phenyltrimethylsilane as internal standard.
[b] 5 mol% $Pd(TFA)_2$, 50 mol% NaOAc, PhMe:DMSO (4:1), 100 °C, 1 atm O_2, 6 h.
[c] 5 mol% Pd/C, 200 mol% ᵗbutylethylene, PhMe, 100 °C, air, 6 h.

acetamidotetrahydroquinolines proved to be less suited for dehydrogenation (Table 1-2). Neither $Pd(TFA)_2$/NaOAc nor Pd/C conditions were as high yielding as the 4-alkoxysubstituted tetrahydroquinolines. This trend was also consistent with other substrates in which a nitrogen substituent was present. However, when vinyl ether derived tetrahydroquinolines were subjected to aerobic Pd^{II} dehydrogenation conditions, moderate to good yields of aromatized product could be obtained (Table 1-3).



Entry	Substrate	Product	Yield[a]
1			92
2			84
3			89
4			67
5			22
6			17
7			35
8			76

9			86
10			63
11			58
12			79
13			78
14			81

[a] Yields determined by ^{1}H NMR spectroscopy using phenyltrimethylsilane as internal standard

Table 1.3. Scope of aerobic oxidative dehydrogenation of tetrahydroquinolines.

The reaction time was also significantly reduced from 24 hours to 4-6 hours. This stark contrast in reactivity indicates that the identity of the substituents on the tetrahydroquinoline ring can greatly influence the extent of dehydrogenation. Notably, there was an absence of a correlation with the pK_a of the conjugate acid of the heteroatom substituent. The decreased reactivity of substrates containing nitrogen functional groups implies that coordination of the amino or amido substituent to the catalyst strongly hinders the catalyst's ability to perform a second dehydrogenation.

1.3 Conclusions

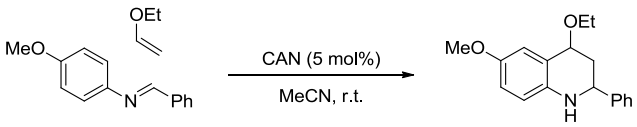
Although the Povarov reaction appeared at first glance to be a suitable method for quickly constructing substituted tetrahydroquinolines, the low yields of the substrate synthesis have rendered this tandem ring formation/dehydrogenation method less than ideal for the synthesis of quinolines. The elimination of substitution also severely limits the utility of this method. While examples of tetrahydroquinoline dehydrogenation where no substituents are eliminated do exist, these examples are limited to substrates that are less reactive (e.g. allysilanes) in the formation of the nitrogen-containing ring.[38] Due to the limitation of the substrate synthesis, it appears that any further pursuit of this type of approach to dehydrogenating tetrahydroquinolines would be better suited to *in situ* formation of the ring.

1.4 Experimental Protocols

1.4.1 General considerations

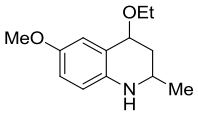
All commercially available compounds were purchased and used as received. Solvents were dried over alumina columns prior to use. ^{1}H and ^{13}C NMR spectra were recorded on Bruker or Varian 300 MHz spectrometers and chemical shifts are reported in parts per million relative to internal tetramethylsilane (0.00 ppm for ^{1}H) or $CDCl_3$ (77.23 ppm for ^{13}C). Flash chromatography was performed using SiliaFlash® P60 (Silicycle, particle size 40-63 μm, 230-400 mesh) or activated basic aluminum oxide (Brockmann I, standard grade, particle size 58Å, ~150 mesh) from Sigma Aldrich.

1.4.2 Representative procedure for the preparation of tetrahydroquinolines

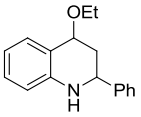


1-1

1-1: Imine (200 mg, 0.85 mmol, 1 eq.) and 2,3-dihydrofuran (100 μL, 1.3 mmol, 1.5 eq.) were added to a 100 mL oven-dried round bottom flask and dissolved in MeCN (10 mL, 0.1 M). Cerium (IV) ammonium nitrate (CAN) (23 mg, 0.043 mmol, 0.05 eq) was then added at room temperature and the reaction allowed to stir for 24 hours or until deemed complete by TLC. The reaction mixture was then diluted with 20 mL CH_2Cl_2 and washed three times with 20 mL H_2O. The combined organic layers were dried with $MgSO_4$, the solvent removed, and the resulting residue purified by column chromatography (Si neutralized prior to loading with 1% NEt_3 solution) using an 80:20 mixture of hexanes:EtOAc as eluant. Yielded 90 mg of a yellow oil (34% yield, 1.85:1 mixture of *cis*:*trans* diastereomers). Tetrahydroquinolines could also be prepared by a three-component, one-pot procedure by adding aniline (105 mg, 0.85 mmol, 1 eq) and aldehyde (107 μL, 0.85 mmol, 1 eq.) rather than preformed imine with a slight decrease in yield. ^{1}H NMR: (300 MHz, $CDCl_3$) δ 7.441 (m, 2H), 7.341 (m, 3H), 7.009 (d, J = 2.9 Hz, 1H), 6.682 (d, J = 8.6, 2.9 Hz, 1H), 6.484 (d, J = 8.6 Hz, 1H), 4.823 (dd, J = 10.8, 6.0 Hz, 1H), 4.465 (dd, J = 12.1, 2.5 Hz, 1H), 3.768 (s, 3H), 3.692 (dt, 16.2, 6.7 Hz, 1H), 3.567 (dt, 16.2, 6.7 Hz, 1H), 2.403 (ddd, J = 12.1, 6.0, 2.9 Hz, 1H), 2.058 (dd, J = 12.1, 10.8 Hz, 1H), 1.264 (t, J = 6.7 Hz, 3H). MS (ESI): $[C_{18}H_{21}NO_2 + H]^+$ requires *m/z* 284.17, found 284.1.

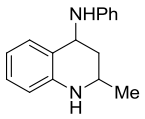


1-2: Prepared from a modified procedure: anisidine (200 mg, 1.63 mmol, 1 eq.) and ethyl vinyl ether (390 μL, 4.07 mmol, 2.5 eq.) were dissolved in MeCN (10 mL, 1.6 M) at room temperature. CAN was then added and the reaction stirred until the reaction was deemed complete by TLC. The reaction mixture was then diluted with 20 mL CH_2Cl_2 and washed three times with 20 mL H_2O. The combined organic layers were dried with $MgSO_4$, the solvent removed, and the resulting residue purified by column chromatography (Si neutralized prior to loading with 1% NEt_3 solution) using a 80:20 hexane:EtOAc solvent system. Yielded 151 mg of a yellow oil (42% yield). ^{1}H NMR: (300 MHz, $CDCl_3$) δ 6.961 (d, *J* = 2.9 Hz, 1H), 6.648 (dd, *J* = 8.6, 2.9 Hz, 1H), 6.449 (d, *J* = 8.6 Hz, 1H), 4.671 (dd, *J* = 10.8, 6.2 Hz, 1H), 3.748 (s, 3H), 3.552 (m, 4H), 2.232 (ddd, *J* = 12.2, 6.2, 2.3 Hz, 1H), 1.646 (d, *J* = 12.2, 11.0 Hz, 1H), 1.286 (t, *J* = 7.0 Hz, 3H), 1.231 (d, *J* = 6.2 Hz, 3H).

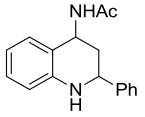


1-3: Prepared from the aniline (200 mg, 2.15 mmol, 1 eq.), benzaldehyde (220 μL, 2.15 mmol, 1 eq.), and ethyl vinyl ether (310 μL, 3.22 mmol, 1.5 eq.) according to the general procedure. Purification with 98:2 hexanes:EtOAc yielded 105 mg of a yellow oil (20% yield). ^{1}H NMR: (300 MHz, $CDCl_3$) δ 7.375 (m, 6H), 7.046 (bt, 7.9 Hz, 1H), 6.735 (td, *J* = 7.4, 1.1 Hz, 1H), 6.506, (dd, *J* = 7.9, 1.1 Hz, 1H), 4.814 (dd, *J* = 10.5, 5.6 Hz, 1H), 4.522 (dd, *J* = 11.5, 2.7 Hz,

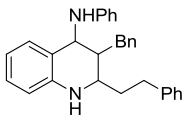
1H), 3.925 (bs, 1H), 3.678 (m, 1H), 3.575 (m, 1H), 2.406 (ddd, *J* = 12.4, 5.6, 2.7 Hz, 1H), 2.068 (dd 12.4, 11.5 Hz, 1H), 1.252 (t, 7.0 Hz, 3H).



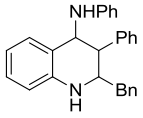
1-4: Prepared as described by Medina *et al.* [39]



1-5: Imine (250 mg, 1.38 mmol, 1 eq.) and *N*-vinylacetamide (117 mg, 1.38 mmol, 1 eq.) were dissolved in PhMe and the reaction mixture cooled to -78 °C. $BF_3{\cdot}OEt_2$ was then added via syringe and the reaction mixture warmed to room temperature slowly. The reaction was monitored via TLC until deemed complete (21 h). Evaporation of the solvent and chromatography of the crude reaction mixture with 98:2 hexanes:EtOAc as mobile phase yielded 188 mg of a yellow oil (51% yield). ^{1}H NMR: (300 MHz, $CDCl_3$) δ 7.331 (m, 5H), 7.133 (d, *J* = 7.6 Hz, 1H), 7.066 (t, *J* = 7.7 Hz, 1H), 6.702 (t, *J* = 7.6 Hz, 1H), 6.561, (d, *J* = 7.7 Hz, 1H), 5.665, (d, *J* = 8.9 Hz, 1H), 5.401 (dt, *J* = 9.7, 6.0 Hz, 1H), 4.570 (dd, *J* = 10.3, 2.6 Hz, 1H), 4.109 (bs, 1H), 2.408 (ddd, *J* = 12.6, 5.8, 2.8 Hz, 1H), 1.931 (s, 3H). MS (EI): $[C_{17}H_{18}N_2O]^+$ requires *m/z* 266.14, found 266.00.

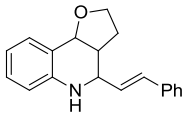


1-6: Aniline (500 mg, 5.38 mmol, 1 eq) and hydrocinnamaldehyde (710 μL, 5.376 mmol, 1 eq.) were dissolved in EtOH (50 mL, 0.1 M) at room temperature. The reaction was monitored via TLC until deemed complete (18 h). Evaporation of the solvent and chromatography of the crude reaction mixture with 90:10 hexanes:EtOAc as mobile phase yielded 184 mg of a yellow oil (16% yield). ^{1}H NMR: (300 MHz, $CDCl_3$) δ 7.276 (m, 6H), 7.124 (m, 6H), 6.985 (t, *J* = 7.8 Hz, 2H), 6.700 (td, 7.2, 1.1 Hz, 1H), 6.601 (t, *J* = 7.2 Hz, 1H), 6.523 (d, *J* = 7.8 Hz, 1H), 6.069 (d, *J* = 7.8 Hz, 2H), 4.168 (d, *J* = 3.8 Hz, 1H), 3.498 (td, *J* = 7.1, 1.9 Hz, 1H), 3.482 (bd, *J* = 4.8 Hz, 1H), 2.869 (d, *J* = 12.4 Hz, 1H), 2.738 (m, 2H), 2.239 (m, 1H), 2.182 (q, *J* = 11.3 Hz, 1H), 1.988 (m, 2H).

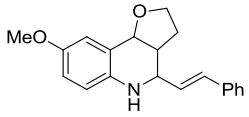


1-7: Aniline (500 mg, 5.38 mmol, 1 eq) and hydrocinnamaldehyde (625 μL, 5.376 mmol, 1 eq.) were dissolved in EtOH (50 mL, 0.1 M) at room temperature. The reaction was monitored via TLC until deemed complete (18 h). Evaporation of the solvent and chromatography of the crude reaction mixture with 90:10 hexanes:EtOAc as mobile phase yielded 184 mg of a yellow oil (16% yield). ^{1}H NMR: (300 MHz, $CDCl_3$) δ 7.221 (m, 10H), 7.034 (m, 3H), 6.627 (dd, *J* = 14.4, 7.5 Hz, 2H), 6.440 (d, *J* = 7.5 Hz, 3H), 6.394 (d, *J* = 8.0 Hz, 1H), 4.767 (dd, *J* = 7.5, 1.1 Hz,

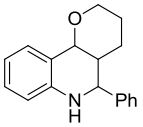
1H), 3.916 (s, 1H), 3.836 (m, 2H), 3.089 (t, *J* = 9.6 Hz, 1H),2.746 (dd, J = 13.9, 2.7 Hz, 1H), 2.423 (dd, J = 10.7, 2.7 Hz, 1H).



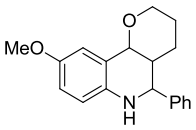
1-8: Prepared as described by Menendez *et al.*[39]



1-9: Prepared from the imine (500 mg, 2.11 mmol, 1 eq.) and 2,3-dihydrofuran (480 μL, 6.32 mmol, 3 eq.) according to the general procedure. Purification with 80:20 hexanes:EtOAc yielded 90 mg of a yellow oil (34% yield). ^{1}H NMR: (300 MHz, $CDCl_3$) δ 7.394 (m, 2H), 7.328 (t, *J* = 7.1 Hz, 2H), 7.267 (m, 1H), 6.909 (d, *J* = 3.0 Hz, 1H), 6.718 (dd, *J* = 8.8, 3.0 Hz, 1H), 6.639 (d, *J* = 15.9 Hz, 1H), 6.541 (d, *J* = 8.8 Hz, 1H), 6.301 (dd, *J* = 15.9, 8.0 Hz, 1H), 5.060 (d, *J* = 7.4 Hz, 1H), 4.104 (dd, *J* = 7.8, 3.5 Hz, 1H), 3.795 (m, 3H), 3.769 (s, 3H), 2.740 (ddd, *J* = 15.9, 8.4, 3.5 Hz, 1H), 2.146 (m, 1H), 1.999 (m, 1H).

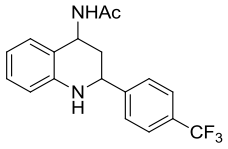


1-10: Imine (250 mg, 1.38 mmol, 1 eq.) and 3,4-dihydro-2H-pyran (380 μL, 4.14 mmol, 3 eq.) were dissolved in PhMe and the reaction mixture cooled to -78 °C. $BF_3 \cdot OEt_2$ was then added via syringe and the reaction mixture warmed to room temperature slowly. The reaction was monitored via TLC until deemed complete (24 h). Evaporation of the solvent and chromatography of the crude reaction mixture with 90:10 hexanes:EtOAc as mobile phase yielded 156 mg of a yellow oil (43% yield, 8.75:1 mixture of *zf:trans* diastereomers). ^{1}H NMR: (300 MHz, $CDCl_3$) δ 7.390 (m, 5H), 7.228 (dd, *J* = 7.6, 1.1 Hz, 1H), 7.091 (td, *J* = 7.6, 1.1 Hz, 1H), 6.705 (td, *J* = 7.4, 0.9 Hz, 1H), 6.526 (d, *J* = 7.9 Hz, 1H), 4.718 (d, *J* = 10.5 Hz, 1H), 4.396 (d, *J* = 2.7 Hz, 1H), 4.105, (m, 1H), 4.076 (bs, 1H), 3.726 (td, *J* = 11.5, 2.6 Hz, 1H), 2.095 (ddd, *J* = 10.2, 4.7, 2.5 Hz, 1H), 1.855 (qt, *J* = 13.4, 4.7 Hz, 1H), 1.653 (tt, *J* = 13.4, 4.7 Hz, 1H), 1.401 (m, 2H).

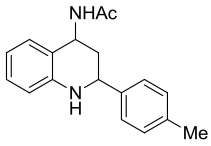


1-11: Prepared from the imine (200 mg, 0.893 mmol, 1 eq.) and 3,4-dihydro-2H-pyran (245 μL, 2.68 mmol, 3 eq.) according to the general procedure. Purification with 90:10 hexanes:EtOAc yielded 162 mg of a yellow oil (68% yield). ^{1}H NMR: (300 MHz, $CDCl_3$) δ 7.331 (m, 5H), 7.030 (dd, *J* = 3.0, 0.9 Hz, 1H), 6.720 (ddd *J* = 8.6, 3.0, 0.9 Hz, 1H), 6.560 (d, *J* = 8.6 Hz, 1H), 5.302

(d, J = 5.7 Hz, 1H), 4.611 (d, J = 2.4 Hz, 1H), 3.771 (s, 3H), 3.614 (m, 2H), 3.424 (td, J = 10.9, 2.4 Hz, 1H), 2.153 (m, 1H), 1.493 (m, 4H).

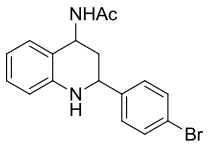


1-12: Prepared from aniline (500 mg, 5.37 mmol, 1 eq.), *p*-CF_3benzaldehyde (744 μL, 5.37 mmol, 1 eq.), and *N*-vinylacetamide (457 mg, 5.37 mmol, 1 eq.) according to the general procedure. Purification with 90:10 hexanes:EtOAc yielded 1.1 g of a yellow solid (61% yield). ^{1}H NMR: (300 MHz, $CDCl_3$) δ 7.614 (d, J = 8.4 Hz, 2H), 7.529 (d, J = 8.4 Hz, 2H), 7.148 (d, J = 7.7 Hz, 1H), 7.094 (t, J = 7.7 Hz, 1H), 6.743 (t, J = 7.7 Hz, 1H), 6.604 (d, J = 8.1 Hz, 1H), 5.670 (bd, J = 9.1 Hz, 1H), 5.416 (ddd, 12.8, 5.7, 2.7 Hz, 1H), 4.649 (dd, J = 10.8, 2.7 Hz, 1H), 4.174 (bs, 1H), 2.430 (ddd, J = 12.8, 5.7, 2.7 Hz, 1H), 2.034 (s, 3H), 1.865 (m, 1H). MS (EI): $[C_{18}H_{17}F_3N_2O]^+$ requires *m/z* 334.13, found 334.0.

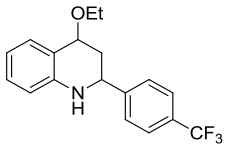


1-13: Prepared from the imine (200 mg, 1.02 mmol, 1 eq.) and *N*-vinylacetamide (87 mg, 1.024 mmol, 1 eq.) according to the general procedure. Purification with 98:2 hexanes:EtOAc yielded 214 mg of a yellow solid (75% yield). ^{1}H NMR: (300 MHz, $CDCl_3$) δ 7.287 (d, J = 8.1 Hz, 2H), 7.166 (d, J = 8.1 Hz, 2H), 7.143 (d, J = 7.3 Hz, 1H), 7.074 (dd, J = 8.0 Hz, 7.3 Hz, 1H), 6.712 (t, J = 7.3 Hz, 1H), 6.562 (d, J = 8.0 Hz, 1H), 5.532 (d, J = 9.2 Hz, 1H), 5.432 (ddd, J = 15.2, 9.7,

5.8 Hz, 1H), 4.563 (dd, *J* = 10.7, 2.6 Hz, 1H), 4.056 (s, 1H), 2.417 (ddd, *J* = 12.8, 5.6, 2.6 Hz, 1H), 2.348 (s, 3H), 1.965 (s, 3H), 1.921 (ddd, *J* = 15.2, 12.8, 10.7 Hz, 1H). MS (EI): $[C_{18}H_{20}N_2O]^+$ requires *m/z* 280.16, found 280.00.

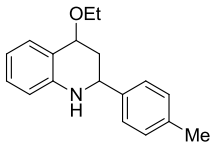


1-14: Imine (200 mg, 0.768 mmol, 1 eq.) and *N*-vinylacetamide (65 mg, 0.768 mmol, 1 eq.) were dissolved in PhMe and the reaction mixture cooled to -78 °C. $BF_3{\cdot}OEt_2$ (95 μL, 0.768 mmol, 1 eq.) was then added via syringe and the reaction mixture warmed to room temperature slowly. The reaction was monitored via TLC until deemed complete (24 h). Evaporation of the solvent and chromatography of the crude reaction mixture with 80:20 hexanes:EtOAc as mobile phase yielded 133 mg of a white solid (50% yield). ^{1}H NMR: (300 MHz, $CDCl_3$) δ 7.465 (d, *J* = 8.5 Hz, 2H), 7.270 (d, *J* = 8.5 Hz, 2H), 7.128 (d, *J* = 7.6 Hz, 1H), 7.071 (t, *J* = 8.0 Hz, 1H), 6.720 (t, *J* = 7.4 Hz, 1H), 6.570 (d, *J* = 7.4 Hz, 1H), 5.719 (d, *J* = 8.9 Hz, 1H), 5.391 (ddd, *J* = 15.2, 9.7, 5.8 Hz, 1H), 4.523 (dd, *J* = 11.0, 2.5 Hz, 1H), 4.089 (bs, 1H), 2.377 (ddd, *J* = 12.6, 5.7, 2.7 Hz, 1H), 1.970 (s, 3H), 1.857 (m, 1H).

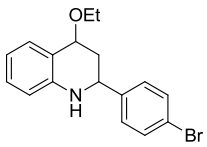


1-15: Prepared from the imine (218 mg, 0.874 mmol, 1 eq.) and ethyl vinyl ether (250 μL, 2.62 mmol, 3 eq.) according to the general procedure. Purification with 95:5 hexanes:EtOAc yielded

99 mg of a white solid (36% yield). ^{1}H NMR: (300 MHz, $CDCl_3$) δ 7.613 (d, *J* = 8.6 Hz, 2H), 7.547 (d, *J* = 8.6 Hz, 2H), 7.378 (d, *J* = 7.8 Hz, 1H), 7.069 (td, *J* = 7.8, 1.1 Hz, 1H), 6.757 (td, *J* = 7.5, 1.1 Hz, 1H), 6.545 (dd, *J* = 8.0, 1.0 Hz, 1H), 4.776 (dd, *J* = 10.0, 5.5 Hz, 1H), 4.601 (dd, *J* = 10.9, 3.0 Hz, 1H), 4.001 (bs, 1H), 3.625 (m, 1H), 3.550 (m, 1H), 2.387, (ddd, *J* = 12.6, 5.5, 3.0 Hz, 1H), 2.084 (m, 1H), 1.203 (t, *J* = 6.9 Hz, 3H).



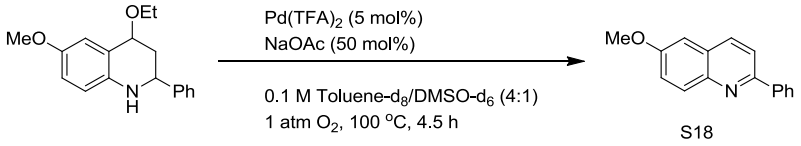
1-16: Prepared from the imine (100 mg, 0.512 mmol, 1 eq.) and ethyl vinyl ether (145 μL, 1.54 mmol, 3 eq.) according to the general procedure. Purification with 95:5 hexanes:EtOAc yielded 62 mg of a yellow oil (45% yield). ^{1}H NMR: (300 MHz, $CDCl_3$) δ 7.394 (d, *J* = 7.6 Hz, 1H), 7.320 (d, *J* = 8.2 Hz, 2H), 7.171 (d, *J* = 8.2 Hz, 2H), 7.036 (td, *J* = 7.3, 1.0 Hz, 1H), 6.728 (dd, *J* = 7.3, 1.0 Hz, 1H), 6.490 (dd, *J* = 7.9, 1.0 Hz, 1H), 4.808 (dd, *J* = 10.8, 5.7 Hz, 1H), 4.484 (dd, *J* = 11.9, 2.7 Hz, 1H), 3.885 (bs, 1H), 3.684 (dq, *J* = 8.9, 7.1 Hz, 1H), 3.574 (dq, *J* = 8.9, 7.1 Hz, 1H), 2.384 (ddd, *J*= 12.4, 5.7, 2.7 Hz, 1H), 2.354 (s, 3H), 2.047 (dd, *J* = 11.9, 10.8 Hz, 1H) 1.258 (t, *J* = 7.1 Hz, 3H).



1-17: Prepared from the imine (227 mg, 0.874 mmol, 1 eq.) and ethyl vinyl ether (250 μL, 2.62 mmol, 3 eq.) according to the general procedure. Purification with 95:5 hexanes:EtOAc yielded

86 mg of a yellow oil (30% yield). ^{1}H NMR: (300 MHz, $CDCl_3$) δ 7.475 (d, *J* = 8.4 Hz, 2H), 7.304 (d, *J* = 8.4 Hz, 2H), 7.184 (d, *J* = 7.0 Hz, 1H), 7.050 (t, *J* = 7.7 Hz, 1H), 6.742 (td, *J* = 8.1, 1.0 Hz, 1H), 6.514 (dd, *J* = 7.7, 1.0 Hz, 1H), 4.775 (dd, *J* = 10.3, 5.6, 1H), 4.488 (dd, *J* = 11.3, 2.9 Hz, 1H), 3.916 (bs, 1H), 3.654 (m, 1H), 3.558 (m, 1H), 2.360 (ddd, *J* = 12.4, 5.6, 2.9 Hz, 1H), 2.021 (m, 1H), 1.234 (t, *J* = 7.0 Hz, 3H).

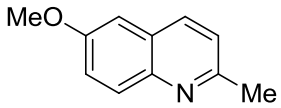
1.4.3 Representative procedure for the dehydrogenation of tetrahydroquinolines to quinolines.



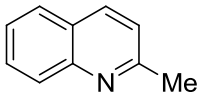
S18

1-18: $Pd(TFA)_2$, (0.8 mg, 0.0025 mmol, 0.05 equiv), and NaOAc (2.1 mg, 0.05 mmol, 0.5 eq) were added to a 13 x 100 mm thick-walled test tube at room temperature and placed in a parallel reactor shaker. The headspace was purged 5 times with O2, after which 0.2 mL of solvent (4:1 d_8-PhMe:d_6-DMSO) was added via syringe. The solution was shaken while the reaction vessel was heated to the 100 °C. After the desired reactor temperature had been reached, a solution of tetrahydroquinoline (15.8 mg, 0.05 mmol, 1 eq) and phenyltrimethylsilane (internal standard) in 0.3 mL solvent were added via syringe and the reaction monitored by taking a small aliquot (approx. 50 μL) of the solution and subjecting to ^{1}H NMR spectroscopy. After the reaction was deemed complete, the yield of the reaction was calculated using NMR spectroscopy. The product was then isolated by filtering the reaction mixture through celite (approx. 0.5 g) and then washing with EtOAc. After solvent removal, the reaction mixture was purified via column chromatography, yielding 11.5 mg of a viscous yellow oil (74% yield). ^{1}H NMR: (300 MHz,

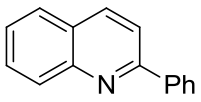
$CDCl_3$) δ 8.126 (d, *J* = 7.6 Hz, 2H), 8.030 (d *J* = 9.2 Hz, 1H) 7.961 (d, *J* = 8.8 Hz, 1H), 7.719 (d, *J* = 8.8 Hz, 1H), 7.431 (m, 5H), 7.376 (s, 3H). MS (EI): [$C_{16}H_{13}NO^+$] requires *m/z* 235.10, found 234.95.



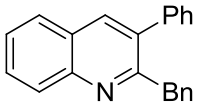
1-19: ^{1}H NMR: (300 MHz, $CDCl_3$) δ 8.054 (t, *J* = 8.8 Hz, 2H), 7.784 (d, *J* = 7.9 Hz, 1H), 7.687 (ddd, *J* = 7.9, 6.7, 1.1 Hz, 1H), 7.481 (d, *J* = 7.9 Hz, 1H). 7.327 (d, *J*, = 6.7 Hz, 1H). MS (EI): [$C_{15}H_{11}N]^+$ requires *m/z* 205.09, found 205.0.



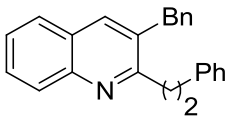
1-20: ^{1}H NMR: (300 MHz, $CDCl_3$) δ 8.235 (d, *J* = 8.7 Hz, 1H), 8.178 (m, 3H), 7.890, (d, *J* = 8.6 Hz, 1H), 7.841 (dd, *J* = 8.2, 1.5 Hz, 1H), 7.737 (ddd, *J* = 8.6, 7.0, 1.5 Hz, 1H), 7.515 (m, 4H). MS (EI): [$C_{10}H_9N^+$] requires *m/z* 143.07, found 143.1.



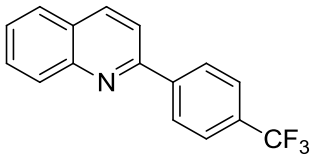
1-21: ^{1}H NMR: (300 MHz, $CDCl_3$) δ 8.235 (d, *J* = 8.7 Hz, 1H), 8.178 (m, 3H), 7.890, (d, *J* = 8.6 Hz, 1H), 7.841 (dd, *J* = 8.2, 1.5 Hz, 1H), 7.737 (ddd, *J* = 8.6, 7.0, 1.5 Hz, 1H), 7.515 (m, 4H). MS (EI): [$C_{15}H_{11}N]^+$ requires *m/z* 205.09, found 205.0.



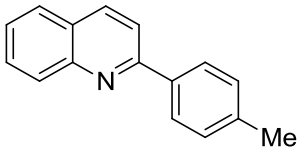
1-22: ^{1}H NMR: (300 MHz, $CDCl_3$) δ 8.126 (d, *J* = 8.6 Hz, 1H), 7.779 (s, 1H), 7.649 (d, *J* = 8.4 Hz, 1H), 7.593 (ddd, *J* = 8.1, 7.1, 1.3 Hz, 1H), 7.397 (ddd, *J* = 8.1, 7.3, 1.3 Hz, 2H), 7.120 (m, 9H), 4.292 (s, 2H).



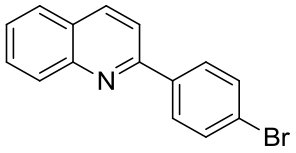
1-23: ^{1}H NMR: (300 MHz, $CDCl_3$) δ 8.070 (d, *J* = 8.5 Hz, 1H), 7.623 (s, 1H), 7.558 (m, 2 H), 7.353 (td, *J* = 8.0, 1.2 Hz, 1H), 7.111 (m, 10H), 3.933 (s, 2H), 3.145 (m, 2H), 3.048 (m, 2H).



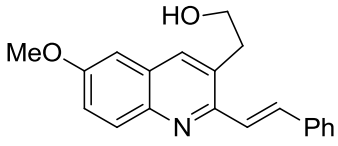
1-24: ^{1}H NMR: (300 MHz, $CDCl_3$) δ 8.294 (d, *J* = 8.0 Hz, 1H), 8.268 (d, *J* = 8.7 Hz, 2H), 8.189 (d, *J* = 8.6 Hz, 1H), 7.905 (d, *J* = 8.6 Hz, 1H), 7.867 (d, *J* = 8.0 Hz, 1H), 7.788 (d, *J* = 8.7 Hz, 2H), 7.75a (dd, *J* = 7.0 Hz, 1.5 Hz, 1H), 7.575 (ddd, *J* = 7.5, 7.0, 1.0 Hz, 1H). MS (EI): $[C_{16}H_{10}F_3N]^+$ requires *m/z* 273.08, found 273.00.



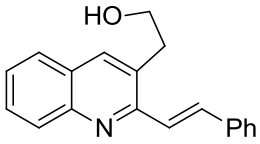
1-25: ^{1}H NMR: (300 MHz, $CDCl_3$) δ 8.206 (d, *J* = 8.9 Hz, 1H), 8.159 (d, *J* = 8.5 Hz, 1H), 8.076 (d, *J* = 8.1 Hz, 2H), 7.867 (d, *J* = 8.5 Hz, 1H), 7.820 (dd, *J* = 8.0, 1.3 Hz, 1H), 7.718 (ddd, *J* = 8.5, 6.9, 1.3 Hz, 1H), 7.514 (ddd, *J* = 8.5, 6.9, 1.3 Hz, 1H), 7.337 (d, *J* = 8.0 Hz, 2H), 2.439 (s, 3H). MS (EI): $[C_{16}H_{13}N]^+$ requires *m/z* 219.10, found 219.00.



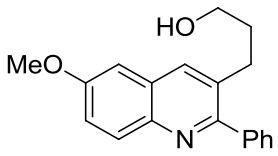
1-26: ^{1}H NMR: (300 MHz, $CDCl_3$) δ 8.228 (d, *J* = 8.9 Hz, 1H), 8.155 (d, *J* = 8.6 Hz, 1H), 8.059 (d, *J* = 8.9 Hz, 2H), 7.842 (d, *J* = 8.6 Hz, 1H), 7.833 (dd, *J* = 8.1, 1.0 Hz, 1H), 7.654 (d, *J* = 8.6 Hz, 2H), 7.541 (ddd, *J* = 8.1, 6.3, 1.1 Hz, 1H), 7.451 (d, *J* = 8.6 Hz, 1H). MS (EI): $[C_{15}H_{10}BrN]^+$ requires *m/z* 283.00, found 282.85.



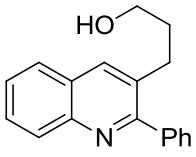
1-27: ^{1}H NMR: (300 MHz, $CDCl_3$) δ 7.979 (d, *J* = 3.5, Hz, 1H), 7.937 (d, *J* = 3.5 Hz, 1H), 7.822 (s, 1H), 7.634 (d, *J* = 7.6 Hz, 2H), 7.557 (d, *J* = 15.2 Hz, 1H), 7.484 (m, 5H), 3.892 (t, *J* = 7.1 Hz, 2H), 3.846 (s, 3H), 3.140 (t, *J* = 7.1 Hz, 2H). MS (EI): $[C_{20}H_{19}NO_2]^+$ requires *m/z* 305.14, found 305.1.



1-28: ^{1}H NMR: (300 MHz, $CDCl_3$) δ 8.090 (d, *J* = 8.1 Hz, 1H), 8.039 (d, *J* = 15.7 Hz, 1H), 7.962 (s, 1H), 7.715 (d, *J* = 8.3 Hz, 1H), 7.650 (m, 3H), 7.576 (d, *J* = 15.7 Hz, 1H), 7.346 (m, 4H), 3.929 (t, *J* = 6.9 Hz, 2H), 3.184 (t, *J* = 6.9 Hz, 2H). MS (EI): $[C_{19}H_{17}NO]^+$ requires *m/z* 275.13, found 275.2.



1-29: ^{1}H NMR: (300 MHz, $CDCl_3$) δ 8.018 (d, *J* = 9.0 Hz, 1H), 7.958 (s, 1H), 7.477 (m, 5H), 7.328 (dd, *J* = 9.0, 2.7 Hz, 1H), 7.067 (d, *J* = 2.7 Hz, 1H), 3.947 (s, 3H), 3.530 (t, *J* = 6.4 Hz, 2H), 2.86 (dd, *J* = 6.4, 1.0 Hz, 2H), 1.761 (m, 2H).



1-30: ^{1}H NMR: (300 MHz, $CDCl_3$) δ 8.117 (d, *J* = 8.5 Hz, 1H), 8.041 (s, 1H), 7.771 (d, *J* = 8.5 Hz, 1H), 7.622 (m, 2H), 7.436 (m, 5H), 3.486 (t, *J* = 6.4 Hz, 2H), 2.854 (t, *J* = 8.2 Hz, 2H), 1.747 (m, 2H). MS (EI): $[C_{18}H_{17}NO]^+$ requires *m/z* 263.13, found 263.0.

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Chapter 2

Synthesis of Imidazoles via Dehydrogenation of Imidazolines: Studies in Base Metal-Catalyzed Aerobic Amine Oxidation

2.1 Introduction

Five-membered *N*-heteroaromatic rings have a special significance in the context of biologically active molecules. This class of molecules, known as azoles, is found in numerous pharmaceutical compounds, with biological activities ranging from antifungal agents to

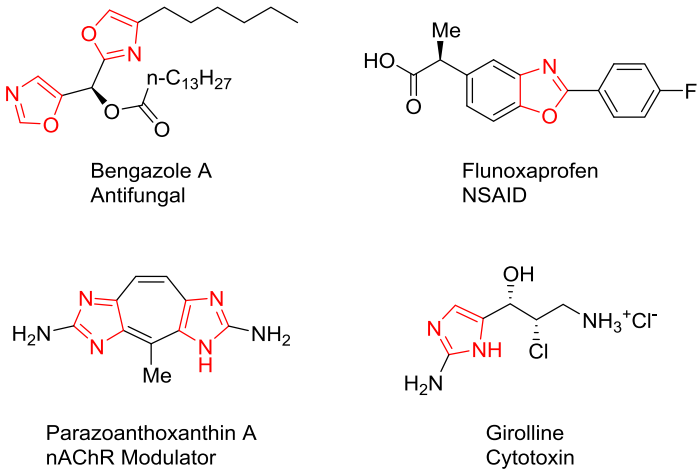
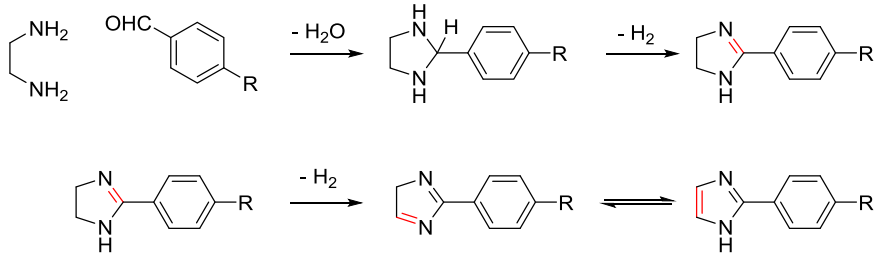


Figure 2.1. Azoles in pharmaceutical drugs.

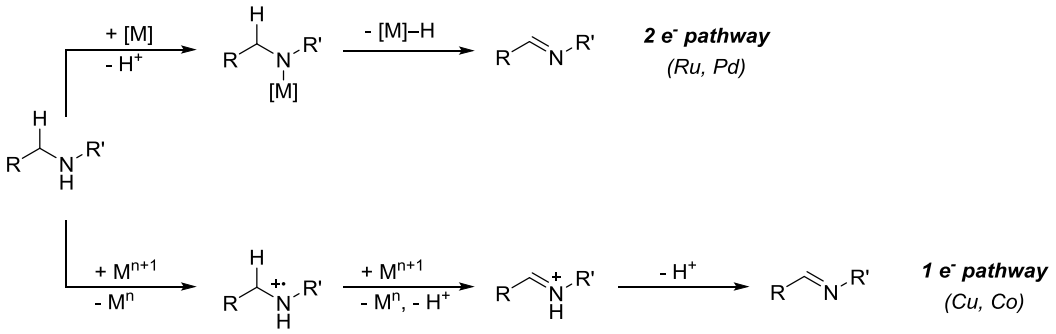
cytotoxins (Figure 2.1).[1-3] Partially saturated azoles ("azolines") consist of oxygen-containing oxazolines, sulfur-containing thiazolines, and nitrogen-containing imidazolines. Imidazolines in particular provide an excellent framework for the study of amine oxidation. First, imidazolines are easily accessible via acyclic precursors such as ethylene diamine and aldehydes (Scheme 2-1).[4,5] Second, the dehydrogenation of azolines involves the oxidation of a secondary amine.



Scheme 2.1. Synthesis of imidazoles from acyclic precursors.

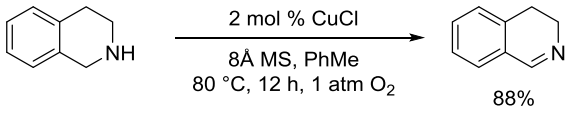
Since no subsequent dehydrogenation of the imine can occur, the aromatization process should proceed selectively. Third, while many reports of amine oxidation have been reported,[6] these oxidations generally involve highly activated C–H bonds, thus facilitating oxidation. 2-Substituted imidazolines do not provide the same scaffold as many previously investigated systems and offer a more challenging aliphatic oxidation than those previously reported.[7-17] Lastly, the dehydrogenation of imidazolines would hypothetically involve the formation of an imine intermediate which would tautomerize to the highly stable aromatic azole product. This driving force towards aromatization should facilitate oxidation as well.

The desirability of a robust amine oxidation method as a means to access functionalized amines has led to a burst of research activity towards this goal. Amine oxidation of coordinating amine ligands by transition metals has been known since the 1970's but was initially viewed as undesirable ligand degradation.[18-23] In 1978, the first catalytic example of amine oxidation using a homogeneous hydrated $RuCl_3$ catalyst was reported by Tang *et al.*[20] This simple catalyst, under aerobic conditions (2-3 atm O_2), was capable of generating the nitrile from the corresponding primary amine. These early examples resulted in a domination of Ru catalysts as the predominant metal of choice for amine oxidation and are proposed to operate via a 2 electron, β-hydride elimination mechanism (Scheme 2-2). While this mechanism of operation has been

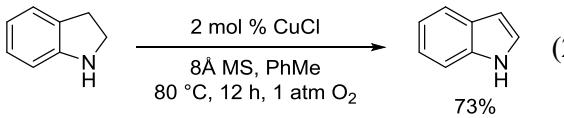


Scheme 2.2. Mechanistic pathways for amine dehydrogenation.

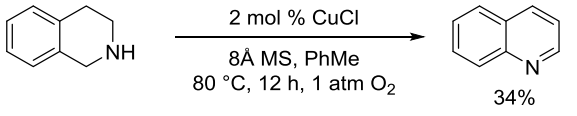
exploited quite successfully in the oxidation of alcohols, the analogous use of homogeneous Ru catalysts toward amine oxidation has been much less developed. Alternatively, base-metal catalysts such as copper have been employed for amine oxidation, but to a much lesser extent than Ru. These catalyst systems typically consist of a copper (I) or copper (II) salt to facilitate a single electron transfer (SET) from nitrogen, and subsequent H-atom abstraction yields a new double bond. If additional β-hydrogens are present, a second dehydrogenation may occur. Kametani *et al.*[24] first reported using stoichiometric CuCl in pyridine to facilitate dehydrogenation of benzylamine to benzonitrile under aerobic conditions. This method was rendered catalytic over 20 years later by Uemura.[25] By utilizing toluene as solvent and increasing the temperature to 80 °C, both benzylic and aliphatic amines could be oxidized to the corresponding nitriles in > 70% yields. The authors also disclosed that heterocyclic amines could be dehydrogenated as well in comparable yields (eq. 2-1, 2-2). However, when substrates with non-activated α-C–H bonds (i.e. non-benzylic) were employed, a sharp decrease in yield was observed (eq. 2-3). While many other examples of copper-catalyzed amine dehydrogenations have been disclosed since Uemura's seminal work, these reports generally demonstrate an



(2-1)

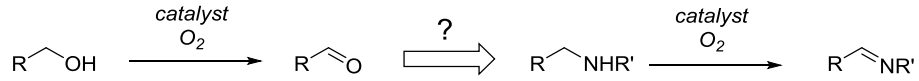


(2-2)



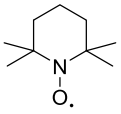
(2-3)

increased selectivity for imine formation as opposed to nitrile formation that is commonly seen with Ru catalysts. Since the formation of imidazoles from imidazolines requires a single dehydrogenation, the use of a base-metal catalyst such as copper may be feasible as well as desirable to prevent competing over-oxidations by a more active Ru catalyst. In addition, Ru as a precious metal is relatively expensive (58 USD/oz.) compared to copper (3 USD/oz.).[26] In keeping with our group's goal to utilize cheap, sustainable catalysts in "green" chemical reactions, base-metal oxidation catalysts are ideal. Our group's interest in aerobic oxidation chemistry strongly overlaps with many literature reports of base metal-catalyzed aerobic oxidations of alcohols to aldehydes, an isoelectronic reaction to amine monodehydrogenation (Scheme 2-3).



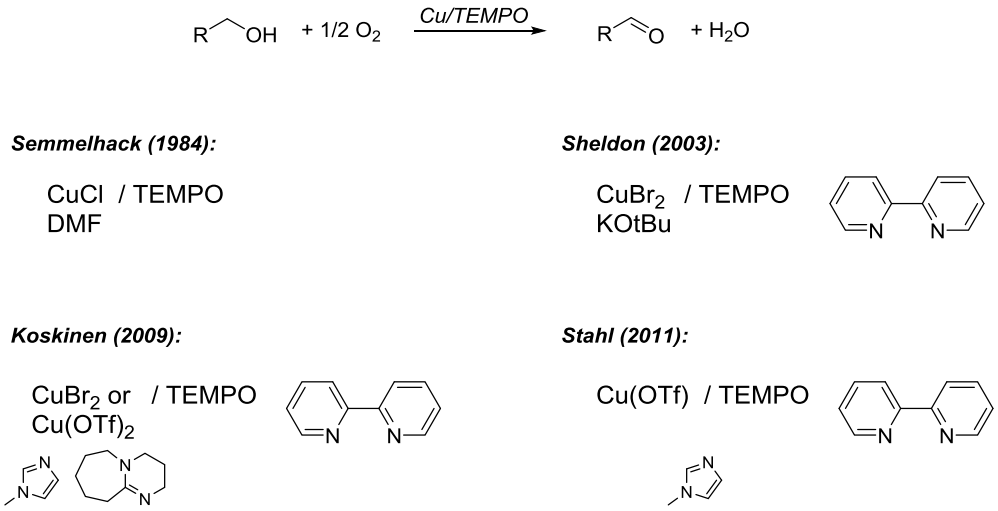
Scheme 2.3. Analogy of alcohol oxidation to amine oxidation.

The resemblance of amine oxidation to alcohol oxidation prompted an investigation into the application of existing alcohol oxidation methods. Of these methods, the copper catalyst systems appeared especially promising. Copper-catalyzed aerobic oxidations of alcohols are well-documented in the literature. In 1984, Semmelhack *et al*.[27] first described the use of



TEMPO
2-1

stoichiometric copper in combination with TEMPO **2-1** (2,2',6,6'-tetramethylpiperydinyl-1-oxy) to oxidize primary alcohols to aldehydes (Scheme 2-4). This system has the benefit of being extremely selective for the aldehyde and does not overoxidize to the carboxylic acid. Work by Sheldon *et al.*[28] demonstrated that chelating ligands such as 2,2'-bipyridine (bpy, **2-2**) could be used to render the reaction catalytic in copper (II) salts. The authors also noted that using potassium *tert*-butoxide greatly increased the rate of reaction, presumably by rapidly deprotonating the alcohol to an alkoxide that would bind effectively with copper. Koskinen *et al.*[29] also observed this sensitivity towards base. When excess nitrogen-ligands such as DBU **2-3** (1,8-diazabicyclo [5.4.0]undec-7-ene) were employed in the aerobic oxidation of *trans*-2-hexen-1-ol, the reaction rate decreased dramatically, presumably due to competitive coordination of the amine base to the copper center and preventing binding of the alkoxide species. This observation has clear implications for the translation of Cu/TEMPO oxidations of amine substrates, as displacement of the catalyst's ligands with substrate appears to be key to reactivity. Our group has also made contributions to the field of Cu/TEMPO-catalyzed aerobic oxidation of alcohols by significantly expanding the scope of this catalyst system by utilizing copper (I) salts to increase the rate of reactivity.[30] Given these precedents for facile aerobic alcohol oxidation, this methodology should be translatable to amine oxidation.



Scheme 2.4. Promising catalyst systems for aerobic alcohol oxidation.

2.2 Results and Discussion

2.2.1 Optimization of Catalyst and Reaction Conditions for the Aerobic Dehydrogenation of 2-Phenylimidazoline: Cu/TEMPO System

In initial efforts to extend the Cu/TEMPO system to amine oxidation, conditions analogous to those developed in our lab for aerobic alcohol oxidation were explored. Gratifyingly, the use of the standard conditions resulted in 73% yield of the desired imidazole after 18.5 h (Table 2-1). A survey of solvents indicated that toluene might be a promising solvent; however, subsequent tests with other substrates revealed that the beneficial effect of toluene was substrate specific. TEMPO derivatives were also tested with surprising results. The yield of the reaction correlated well with the redox potential of TEMPO derivatives. Higher yields were observed for nitroxyl radicals with higher redox potentials. A high redox potential for these nitroxyl radicals corresponds to a more difficult oxidation from TEMPO-H to the oxammonium species (Figure 2.2).

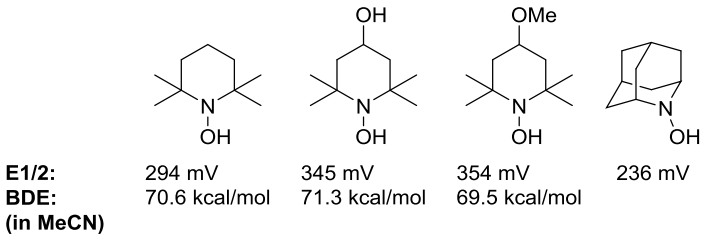
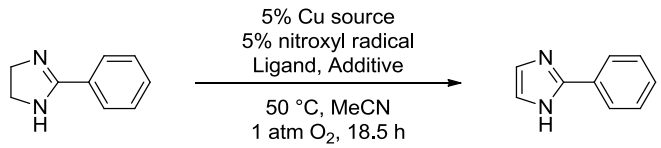


Figure 2.2. Redox potentials of TEMPO–H derivatives (to oxammonium species) and their O–H bond dissociation energies.[31]



Entry	Cu source	Nitroxyl radical	Solvent	Ligand (mol %)	Additive (mol %)	Yield[b]
1	CuOTf	TEMPO	MeCN	bpy (5)	NMI (10)	73
2	CuOTf	TEMPO	PhMe	bpy (5)	NMI (10)	100
3	CuOTf	TEMPO	Dioxane	bpy (5)	NMI (10)	31
4	CuOTf	TEMPO	MeCN:H_2O (1:1)	bpy (5)	NMI (10)	72
5	CuOTf	4-OH TEMPO	MeCN	bpy (5)	NMI (10)	80
6	CuOTf	4-MeO TEMPO	MeCN	bpy (5)	NMI (10)	86
7	CuOTf	TEMPO	MeCN	bpy (5)	NMI (10)	73
8	CuOTf	TEMPO	MeCN	Pyr (10)	NMI (10)	86
9	CuOTf	TEMPO	MeCN	2-F pyr (10)	NMI (10)	92
10	CuOTf	TEMPO	MeCN	2-NMe Pyr (10)	NMI (10)	96
11	CuOTf	TEMPO	MeCN	2,6-Lutidine (10	NMI (10)	95
12	CuOTf	TEMPO	MeCN	4-Picoline (10)	NMI (10)	91
13	CuOTf	TEMPO	MeCN	bipyrimidine (5)	NMI (10)	80
14	CuOTf	TEMPO	MeCN	4,4'-diMeO bpy (5)	NMI (10)	97
15	CuOTf	TEMPO	MeCN	Neocuproine (5)	NMI (10)	86
16	CuOTf	TEMPO	MeCN	4,4'-di^{t}Bu bpy (5)	NMI (10)	88
17	CuOTf	TEMPO	MeCN	Phenanthroline (5)	NMI (10)	94
18	CuOTf	TEMPO	MeCN	none	NMI (10)	94
19	CuOTf	TEMPO	MeCN	bpy (5)	none	89
20	CuOTf	TEMPO	MeCN	none	none	100
21	$Cu(OTf)_2$	TEMPO	MeCN	bpy (5)	NMI (10)	100
22	CuCl	TEMPO	MeCN	bpy (5)	NMI (10)	89
23	CuSPh	TEMPO	MeCN	bpy (5)	NMI (10)	62
24	$Cu(PF_6)$	TEMPO	MeCN	bpy (5)	NMI (10)	83
25	$CuCl_2$	TEMPO	MeCN	bpy (5)	NMI (10)	91
26	CuBr	TEMPO	MeCN	bpy (5)	NMI (10)	76
27	$CuBr_2$	TEMPO	MeCN	bpy (5)	NMI (10)	75
28	$Cu(TFA)_2$	TEMPO	MeCN	bpy (5)	NMI (10)	75
29	$Cu(OAc)_2$	TEMPO	MeCN	bpy (5)	NMI (10)	94
30	$Cu(eh)_2$	TEMPO	MeCN	bpy (5)	NMI (10)	100
31	CuCN	TEMPO	MeCN	bpy (5)	NMI (10)	87
32	$Cu(eh)_2$	TEMPO	PhMe	bpy (5)	NMI (10)	78
33	$Cu(OTf)_2$	TEMPO	PhMe	bpy (5)	NMI (10)	83
34	**$Cu(eh)_2$**	**TEMPO**	**MeCN**	**none**	**none**	**100[c]**
35	$Cu(eh)_2$	none	MeCN	none	none	18[c]
36	none	TEMPO	MeCN	none	none	9[c]

Table 2.1. Catalyst Optimization Data for the Aerobic Dehydrogenation of 2-Phenylimidazoline.

[a] Conditions: [**1**] = 0.2 M (14.6 mg, 0.1 mmol), 5% Cu source (0.005 mmol), 5% nitroxyl radical (0.005 mmol), 5 or 10% ligand (0.005 or 0.01 mmol), 10% additive (0.01 mmol), solvent (0.5 mL), 1 atm O_2, 50 °C, 18.5 h. [b] Determined by GC, external standard = phenyltrimethylsilane. [c] Reaction time is 4 h.

However, when comparing the bond dissociation energies of these TEMPO derivatives, there is no consistent trend. This observation indicates that the thermodynamic propensity for the nitroxyl radical to abstract an H atom is not the governing factor for its role in this reaction, i.e. other influences may be contributing to a more active catalyst system (e.g. coordination of the nitroxyl radical to copper or the involvement of an oxammonium-based pathway). Given the cheaper cost of TEMPO compared to its derivatives, the use of TEMPO as the nitroxyl radical source was preferred. Due to the sensitive nature of the Cu/TEMPO system on added ligands, a screen of both monodentate and bidentate ligands was performed (Scheme 2-3). Remarkably, when no added ligand was employed, quantitative yield was obtained. While this result indicated the ease of the dehydrogenation of 2-phenylimidazoline, this observation has greater implications for the reaction's dependence on the substrate identity. Copper sources were also explored, and it was determined that copper (II) sources were superior to copper (I) salts, possibly due to a stronger coordination of the amine substrate with the copper center. $Cu(eh)_2$ (eh = 2-ethylhexanoate) and $Cu(OTf)_2$ (OTf = trifluoromethanesulfonate) both gave quantitative yield under the reaction conditions and were tested with new substrates. Control experiments were then performed to confirm the synergistic effect of copper and TEMPO. Indeed, when TEMPO was omitted from the reaction mixture, only 18% yield was obtained and 9% yield when copper

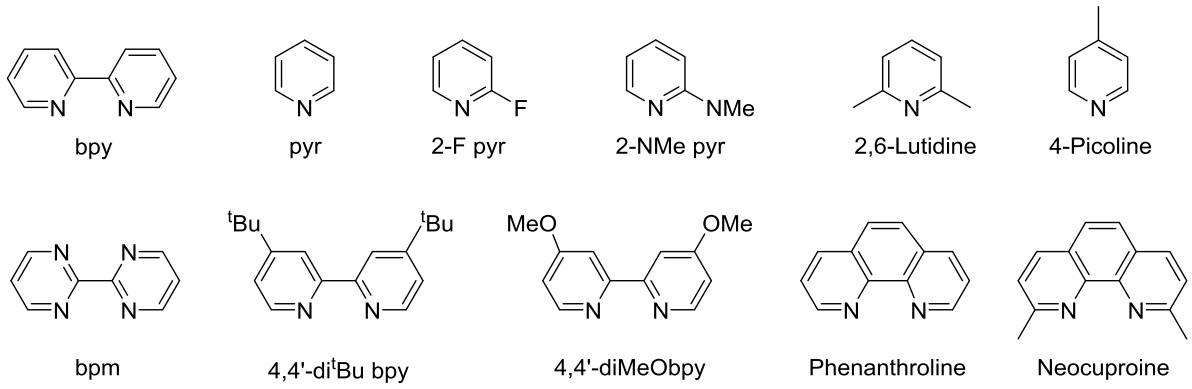
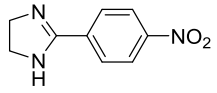


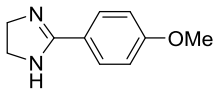
Figure 2.3. Ligands screened for aerobic dehydrogenation.

was omitted.

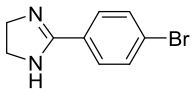
Once optimized conditions had been established for 2-phenylimidazoline (5 mol % $Cu(eh)_2$, 5 mol % TEMPO, 0.2 M in MeCN, 50 °C, 1 atm O_2), other substrates were subjected to these conditions to determine the generality of this method. 4-Nitrophenylimidazoline **2-2**, 4-methoxyphenylimidazoline **2-3**, and 4-bromophenylimidazoline **2-4** were initially chosen as test substrates due to their varying degree of electronic character. The brominated **2-4** was also chosen to test for functional group (i.e. halogen) compatibility. Surprisingly, both the electron-



2-2



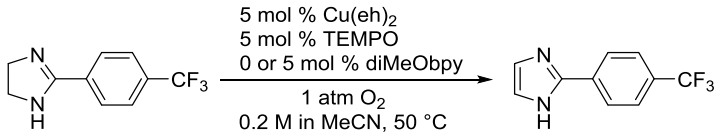
2-3



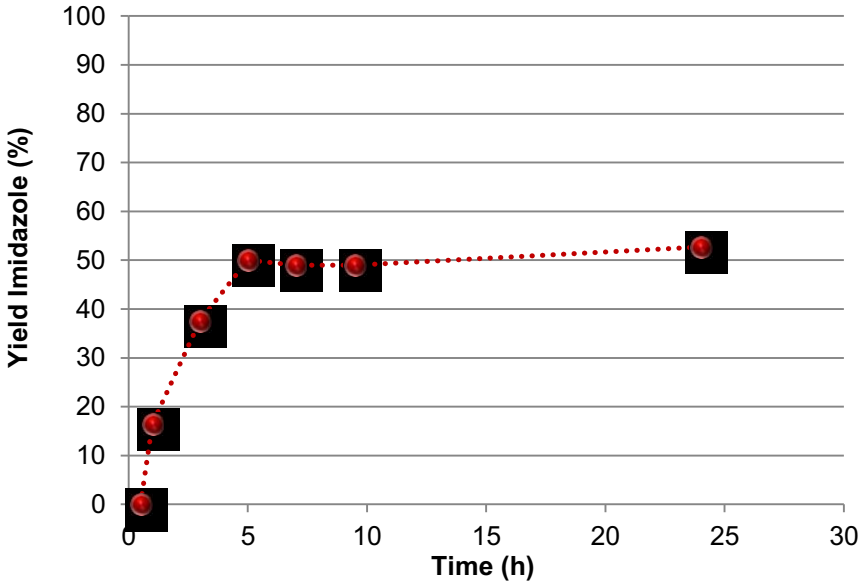
2-4

rich (–OMe) and electron-poor ($–NO_2$) substrates performed poorly under the optimized conditions, yielding only 3% and 36%, respectively. The bromo-substituted imidazole was produced in 74% yield under the optimized conditions, and no cross-coupling products were detected. This lack of reactivity with two electronically distinct substrates led to further investigation of these two substrates. Increasing the reaction time to 20 h and temperature to 70 °C did increase the yield of –OMe (22%) and $–NO_2$ (58%) product, but further increases in temperature to 90 °C in propionitrile as solvent had a detrimental effect for both substrates, and brown reaction mixtures were observed, which was empirically indicative of a dead catalyst. Active catalyst solutions of copper (II) salts, TEMPO, and imidazoline are typically green or blue in color for these amine oxidation reactions. The sharp decrease in yield for both substrates could be rationalized by weak binding of the substrate to the copper catalyst under high temperatures. To address this limitation, the temperature was kept at 70 °C in subsequent

optimizations. The use of a ligand was also explored in an attempt to generate more universal conditions for a wide range of substrates. Previous testing of various ligands had revealed 4,4'-dimethoxybipyridine (diMeObpy) as a potentially useful ligand. Unfortunately, the addition of diMeObpy decreased the yield even further, and time course data with other substrates revealed that the presence of bipyridine ligands facilitates product decomposition (Figure 2.4). The highest yield of 4-nitrophenylimidazole is 58%. 4-Methoxyphenylimidazole can be produced in 40% yield when 10 mol % of $NaNO_3$ is added to the reaction mixture, but the origin of this effect is not currently known.



a)



b)

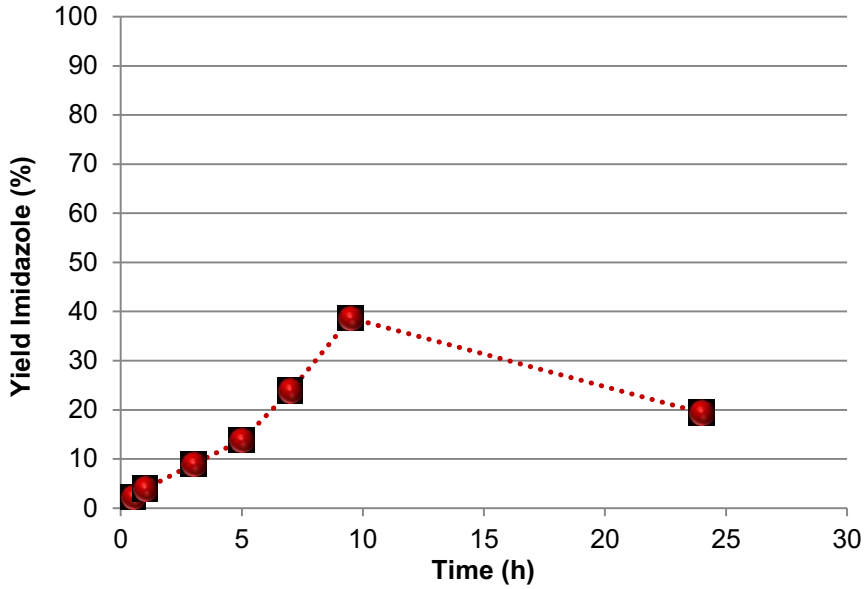
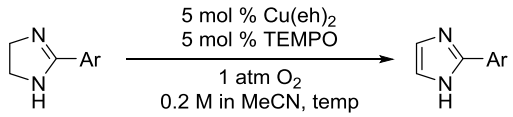


Figure 2.4. Time courses of the dehydrogenation of 4-trifluoromethylphenylimidazoline. a) without added diMeObpy; b) with added diMeObpy.

2.2.2 Applications of the Cu/TEMPO Catalyst System in the Aerobic Dehydrogenation 2-Arylsubstituted Imidazolines

Other substrates were then investigated to determine if other less electronically-extreme substrates could dehydrogenated using the previously optimized conditions. With 5 mol% $Cu(eh)_2$ and 5 mol % TEMPO in MeCN at 70 °C, the 4-cyanophenylimidazole product was formed in 59% yield. Lowering the reaction temperature to 50 °C afforded an increase in imidazole yield to 68% and an even further decrease in temperature to room temperature afforded the desried product in 79% yield. While room temperature provided the optimal conditions for the cyano-substituted imidazoline, 50 °C was determined to be the optimal temperature for almost all of the other substrates tested. During the course of optimizing mixtures of additives, it was determined that HNO_3 could also be employed to increase the yield of imidazole. Unfortunately, using HNO_3 as an additive lead to irreproducible results when the parent 2-phenylimidazoline was used. The results of additional substrate dehydrogenations are summarized in Table 2-2.



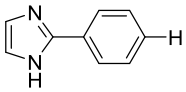
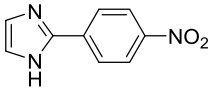
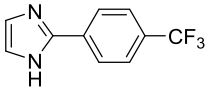
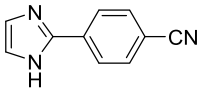
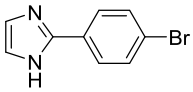
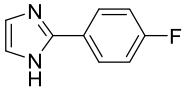
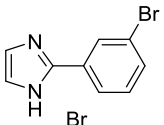
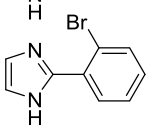
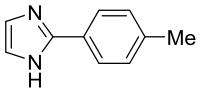
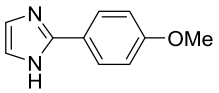
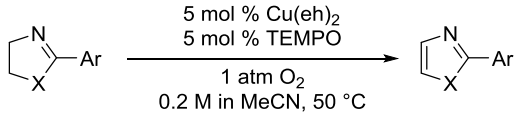
Entry	Product	Temp	Time	Yield[b]
1		50 °C	18 h	100 (100)
2		70 °C	20 h	58
3		50 °C	24 h	98 (98)
4		rt	24 h	87 (80)
5		70 °C	24 h	74
6		50 °C	4 h	72[c]
7		50 °C	4 h	65[c]
8		50 °C	4 h	35[c]
9		50 °C	24 h	61
10		50 °C	24 h	40[d]

Table 2.2. Cu-catalyzed aerobic dehydrogenation of 2-arylsubstituted imidazolines.[a]

[a] Reaction conditions: [substrate] = 0.2 M (0.1 mmol), [$Cu(eh)_2$] = 0.01 M (0.005 mmol), [TEMPO] = 0.01 M (0.005 mmol), 0.5 mL MeCN, 1 atm O_2. [b] Determined by ^{1}H NMR spectroscopy using phenyltrimethylsilane as an external standard. [c] With 10 mol % (0.01 mmol) HNO_3 added to reaction mixture. [d] With 10 mol % (0.01 mmol) $NaNO_3$ added to reaction

2.2.3 Limitations of the Cu/TEMPO Catalyst System

During the course of this study, the main limitation of this method was the inability to oxidize electron-rich substrates in high yields (Table 2-3). For example, 4-methoxyphenylimidazole could only be obtained in a maximum 40% yield. This lowered reactivity could be due to prohibitively strong coordination of the substrate to the catalyst, which is analogous to the lower reactivity seen for nearly all substrates when electron-rich bpy derivatives are added to the reaction mixture. The dual role of the imidazoline as both substrate and a potential ligand for copper may lead to the strong dependence on the substrate identity. This delicate interplay of substrate's coordinating ability and reactivity is also manifested in



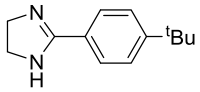
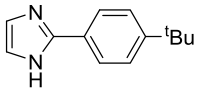
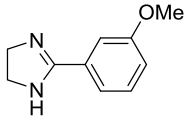
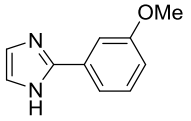
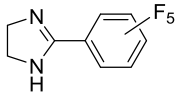
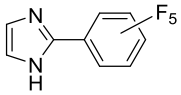
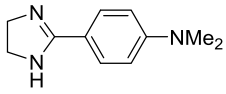
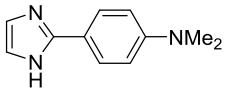
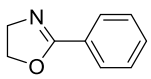
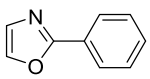
Entry	Substrate	Product	Yield[b]
1			no reaction
2			20
3			no reaction
4			6
5			no reaction

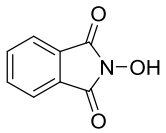
Table 2.3. Unsuccessful substrates for Cu/TEMPO-catalyzed aerobic dehydrogenation.[a]

[a] Reaction conditions: [substrate] = 0.2 M (0.1 mmol), [$Cu(eh)_2$] = 0.01 M (0.005 mmol), [TEMPO] = 0.01 M (0.005 mmol), 0.5 mL MeCN, 1 atm O_2. [b] Determined by ^{1}H NMR spectroscopy using phenyltrimethylsilane as an external standard.

extremely electron-withdrawing substrates, such that imidazolines such as 2,3,4,5,6-pentafluorophenylimidazoline also fails to react. 2-Phenyloxazoline was also not found to be a suitable substrate for dehydrogenation, which is most likely attributable to the decreased ability to undergo a single electron oxidation at oxygen due to its diminished coordination ability as an ether.

Given that the tested substrates also differ greatly in N–H acidity, the use of a strong base such as potassium *tert*-butoxide (KO*t*Bu) should facilitate the deprotonation, and hence coordination of substrate to the copper catalyst. However, addition of KO*t*Bu resulted in very poor yields (< 30%) for electron-rich, electron-poor, and electron-neutral substrates that were tested.

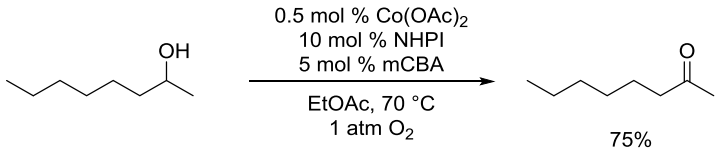
This catalyst system is also limited to imidazoline substrates that are not substituted on the backbone of the imidazole, i.e. at the 4- and 5-positions. In order to address this restriction, the literature was surveyed for existing alcohol oxidation methods that did not suffer from the same steric limitations as Cu/TEMPO systems. An ideal method would be capable of oxidizing a wide range of electronically distinct and sterically diverse substrates. Ishii has reported an aerobic Co/*N*-hydroxyphthalimide (NHPI **2-5**)- catalyst system capable of oxidizing a variety of



NHPI
2-5

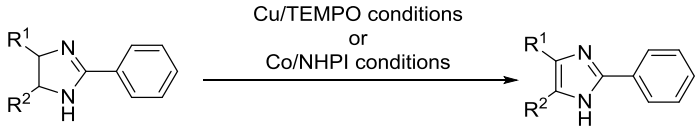
organic substrates, including alkanes and sulfoxides.[8,32-38] In 2000, Ishii reported that Co/NHPI could also be used for the oxidation of primary and secondary alcohols to the corresponding

aldehyde or ketones (eq. 2-4).[39] The ability of this catalyst system to oxidize aliphatic and sterically encumbered alcohols made this system an ideal starting point for the investigation of substituted imidazoline oxidation. An initial investigation into the Cu/TEMPO system with 2,4,5-substituted imidazolines revealed that this system was not



(2-4)

suitable for substituted imidazolines. It is well-established that TEMPO-mediated oxidation methods are often limited to less sterically encumbered substrates,[31] and such was the case for the oxidation of sterically encumbered imidazolines. Fortunately, the translation of Ishii's Co/NHPI system did not have such limitations. Using modified Ishii conditions, 2,4,5-



Entry	R^1, R^2	Yield with Cu/TEMPO[a]	Yield with Co/NHPI[b]
1	H, H	71	85
2	Me, H	15	50
3	Ph, Ph	2	29

Table 2.4. Comparison of Cu/TEMPO and Co/NHPI systems with 2,4- and 2,4,5-substituted imidazolines.

[a] Reaction conditions for Cu/TEMPO: substrate = 0.1 mmol, Cu(OTf) = 0.005 mmol, 5 mol %), [4-OH TEMPO] = 0.015 mmol, 15 mol %, bpy = 0.005 mmol, 5 mol %, NMI = 0.005 mmol, 5 mol %, 0.5 mL MeCN, 1 atm O_2. [b] Reaction conditions for Co/NHPI: substrate = 0.1 mmol, $Co(OAc)_2$ = 0.005 mmol, 5 mol %, NHPI = 0.01 mmol, 10 mol %, *m*-chlorobenzoic acid = 0.01 mmol, 10 mol %, 0.5 mL MeCN, 1 atm O_2. All yields were determined by ^{1}H NMR spectroscopy using phenyltrimethylsilane as an external standard.

triphenylimidazole could be obtained in 29% yield (vs. 2% with a Cu/TEMPO system, Table 2- While it is evident that steric hindrance is also a factor for Co/NHPI-catalyzed oxidations, this effect is much less pronounced than with the Cu/TEMPO system. Future work in the dehydrogenation of 4,5-substituted imidazolines should focus on further development of this method.

2.3 Conclusions

In summary, we have extended the use of the Cu/TEMPO system, a synthetically useful catalyst system for the aerobic oxidation of alcohols, to the oxidation of substituted imidazolines to imidazoles. Notable results include the use of $Cu(eh)_2$/TEMPO to dehydrogenate electron-poor aryl imidazolines in high yields (> 85%). This method is also tolerant of halogen- and coordinating group-containing substrates.

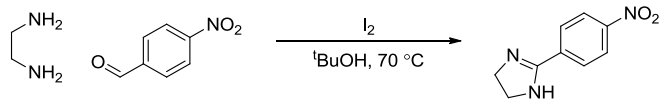
2.4 Experimental Protocols

2.4.1 General considerations

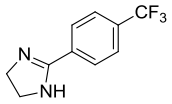
All commercially available compounds were purchased and used as received. Solvents were dried over alumina columns prior to use. ^{1}H and ^{13}C NMR spectra were recorded on Bruker or Varian 300 MHz spectrometers and chemical shifts are reported in parts per million relative to an internal standard (tetramethylsilane,0.00 ppm for ^{1}H NMR) or $CDCl_3$ (77.23 ppm for ^{13}C NMR). Flash column chromatography was performed using SiliaFlash® P60 (Silicycle, particle

size 40-63 μm, 230-400 mesh) or activated basic aluminum oxide (Brockmann I, standard grade, particle size 58Å, ~150 mesh) from Sigma Aldrich.

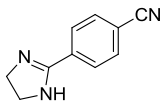
2.4.2 Representative procedure for the preparation of 2-substituted imidazolines



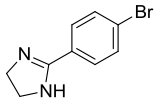
2-1: Ethylene diamine (11 mmol) was dissolved in tBuOH (100 mL) and the aldehyde (10 mmol) were added to a 250 mL round-bottomed flask at room temperature. The mixture was stirred under nitrogen for 30 minutes. I_2 (12.5 mmol) was then added and the solution was stirred at 70 °C for 3.5 hours. The reaction was cooled to room temperature and quenched with saturated aqueous $Na_2S_2O_3$ (30 mL) and diluted with $CHCl_3$ (50 mL). The resulting organic layer was washed with brine and dried with MgSO4, filtered, and evaporated. If necessary, the residue was purified by column chromatography using a mixture of hexane and ethyl acetate. Yielded 1.9 g of an orange solid (99%). ^{1}H NMR: (400 MHz, CD_3OD) δ 8.27 (d, J = 8.8 Hz, 2 H), 7.96 (d, J = 8.8 Hz, 2 H), 3.86 (s, 4 H).



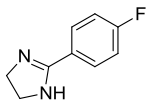
2-2: Prepared from ethylene diamine (11 mmol, 750 μL) and 4-trifluoromethylbenzaldehyde (10 mmol, 1.37 mL). Yielded 2.3 g of a pale yellow solid (100%). ^{1}H NMR: (400 MHz, CD_3OD) δ 8.06 – 7.88 (m, 2 H), 7.86 – 7.70 (m, 2 H), 4.91 (s, 1 H), 3.84 (s, 1 H), 3.42 – 3.21 (m, 1 H).



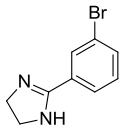
2-3: Prepared from ethylene diamine (11 mmol, 750 μL) and 4-cyanobenzaldehyde (10 mmol, 1.31 g). Yielded 1.6 g of a pale yellow solid (94%). ^{1}H NMR: (400 MHz, CD_3OD) δ 8.00 – 7.87 (m, 2 H), 7.87 – 7.72 (m, 2 H), 3.79 (s, 4 H).



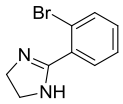
2-4: Prepared from ethylene diamine (11 mmol, 750 μL) and 4-bromobenzaldehyde (10 mmol, 1.85 g). Yielded 1.5 g of a pale yellow solid (66%). ^{1}H NMR: (400 MHz, CD_3OD) δ 7.65 (d, J = 8.5 Hz, 2 H), 7.54 (d, J = 8.5 Hz, 2 H), 3.80 (s, 4 H).



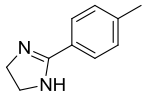
2-5: Prepared from ethylene diamine (11 mmol, 750 μL) and 4-fluorobenzaldehyde (10 mmol, 1.18 mL). Yielded 1.9 g of a pale brown solid (100%). %). ^{1}H NMR: (400 MHz, CD_3OD) δ 7.85 (dd, J = 8.9, 5.3 Hz, 2 H), 7.22 (dd, J = 8.9, 5.3 Hz, 2 H), 3.83 (s, 4 H).



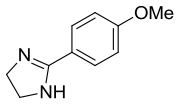
2-6: Prepared from ethylene diamine (11 mmol, 750 μL) and 3-bromobenzaldehyde (10 mmol, 1.17 mL). Yielded 2.2 g of a pale yellow solid (98%). ^{1}H NMR: (400 MHz, CD_3OD) δ 7.99 (t, J = 1.7 Hz, 1 H), 7.77 (dt, J = 7.8, 1.2 Hz, 1 H), 7.58 (ddd, J = 8.0, 1.9, 1.0 Hz, 1 H), 7.37 – 7.19 (m, 1 H), 5.67 (bs, 1 H), 3.82 (s, 4 H).



2-7: Prepared from ethylene diamine (11 mmol, 750 μL) and 2-bromobenzaldehyde (10 mmol, 1.17 mL). Yielded 2.2 g of a pale yellow solid (98%). ^{1}H NMR: (400 MHz, CD_3OD) δ 7.65 – 7.50 (m, 2 H), 7.39 – 7.23 (m, 2 H), 5.77 (bs, 1 H), 3.79 (s, 4 H).

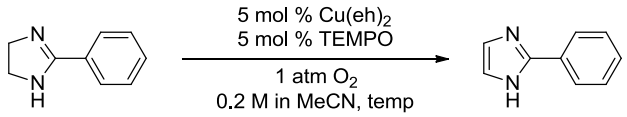


2-8: Prepared from ethylene diamine (11 mmol, 750 μL) and *p*-tolualdehyde (10 mmol, 1.18 mL). Yielded 1.9 g of a pale brown solid (100%). ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.88 – 7.58 (m, 2 H), 7.56 – 7.30 (m, 2 H), 5.29 (d, J = 3.9 Hz, 1 H), 4.25 – 4.01 (m, 1 H), 3.92 (dd, J = 11.8, 9.8 Hz, 1 H), 3.37 (dd, J = 11.8, 7.5 Hz, 1 H), 1.30 (d, J = 6.4 Hz, 3 H). ^{13}C NMR: (75 MHz, $CDCl_3$) δ 163.61, 130.98, 130.14, 128.60, 127.26, 57.75, 56.96, 22.02.

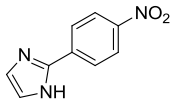


2-9: Prepared from ethylene diamine (11 mmol, 750 μL) and *p*-anisaldehyde (10 mmol, 1.22 mL). Yielded 1.7 g of a pale brown solid (95%). ^{1}H NMR: (400 MHz, CD_3OD) δ 7.83 (d, J = 9.1 Hz, 2 H), 7.12 (d, J = 9.0 Hz, 2 H), 4.01 (d, J = 1.1 Hz, 4 H), 3.90 (d, J = 1.1 Hz, 3 H).

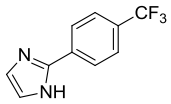
2.4.3 Representative procedure for dehydrogenation of 2-substituted imidazolines



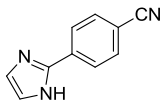
2-10: To a disposable 13 mm x 100 mm thick-walled culture tube was added 2-phenylimidazoline (0.1 mmol, 19 mg), Cu(eh)2 (0.005 mmol, 1.7 mg). A 400 μLsolution of TEMPO (4.4 mM, 0.8 mg) and an additional 400 μL of acetonitrile were added next. The reaction tube was then placed in a 48-well parallel reactor mounted on a Glas-Col large capacity mixer. The headspace was purged with O_2 for 3 min, and heated to 50 °C. The reaction was shaken at elevated temperature under 1 atm O_2 for 18 h, after which time it was stopped and filtered through a silica plug. The plug was washed with MeOH (4 mL), and concentrated in vacuuo. A 4.4 mM solution of trimethyl(phenyl)silane (PhTMS) in $CDCl_3$ (0.02 mmol, 200 μL) was added and the reaction was analyzed by ^{1}H NMR spectroscopy. Yields for each reaction were quantified by comparison of the product with PhTMS. Previously reported compounds were confirmed by comparison with literature spectral data.[7] Compounds were not isolated. ^{1}H NMR: (400 MHz, CD_3OD) δ 7.89-7.87 (m, 2 H), 7.40-7.35 (m, 2 H), 7.08(s, 2 H).



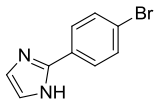
2-11: Prepared from 2-(4-nitrophenyl)imidazoline **2-1** (0.1 mmol, 20 mg). Calculated 98% NMR yield using PhTMS as internal standard. ^{1}H NMR: (400 MHz, CD_3OD) δ 8.34 (d, J = 6.3 Hz, 2 H), 8.07 (d, J = 6.3 Hz, 2 H), 8.03 (bs, 2 H).



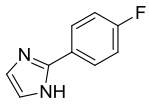
2-12: Prepared from 2-(4-triflouromethylphenyl)imidazoline **2-2** (0.1 mmol, 20 mg). Calculated 98% NMR yield using PhTMS as internal standard. ^{1}H NMR: (400 MHz, CD_3OD) δ 8.03 (d, *J* = 8.1 Hz, 2 H), 7.74 (*d*, J = 8.0 Hz, 2 H), 7.21 (s, 2 H). ^{13}C NMR: (101 MHz, CD_3OD) δ 135.01, 131.48, 131.06, 126.94, 126.91, 126.71, 124.22.



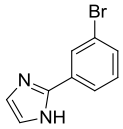
2-13: Prepared from 2-(4-cyanophenyl)imidazoline **2-3** (0.1 mmol, 20 mg). Calculated 87% NMR yield using PhTMS as internal standard. ^{1}H NMR: (400 MHz, CD_3OD) δ 8.01 (d, *J* = 8.3 Hz, 2 H), 7.80 (d, *J* = 8.3 Hz, 2 H), 7.23 (s, 2 H). ^{13}C NMR: (101 MHz, CD_3OD) 135.51, 133.93, 126.76, 119.48, 112.79, 54.80.



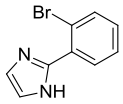
2-14: Prepared from 2-(4-bromophenyl)imidazoline **2-4** (0.1 mmol, 20 mg). Calculated 74% NMR yield using PhTMS as internal standard. ^{1}H NMR: (400 MHz, CD_3OD) δ 8.02 (d, *J* = 8.5 Hz, 2 H), 7.76 (dd, *J* = 25.2, 8.6 Hz, 2 H), 6.93 (s, 1 H),



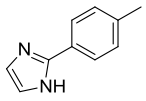
2-15: Prepared from 2-(4-fluorophenyl)imidazoline **2-5** (0.1 mmol, 20 mg). Calculated 72% NMR yield using PhTMS as internal standard. ^{1}H NMR: (400 MHz, CD_3OD) δ 7.99-7.94 (m, 2 H), 7.30-7.24 (m, 2 H), 7.00-7.03 (m, 2 H).



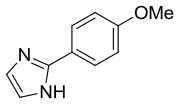
2-16: Prepared from 2-(3-bromophenyl)imidazoline **2-6** (0.1 mmol, 20 mg). Calculated 65% NMR yield using PhTMS as internal standard. ^{1}H NMR: (400 MHz, CD_3OD) δ 8.02-7.98 (d, J = 12.1 Hz, 1 H), 7.84-7.80 (s, 1 H), 7.46-7.29 (m, 2 H), 7.15-7.11 (bs, 2 H).



2-17: Prepared from 2-(2-bromophenyl)imidazoline **2-7** (0.1 mmol, 20 mg). Calculated 35% NMR yield using PhTMS as internal standard. ^{1}H NMR: (400 MHz, CD_3OD) δ 7.82-7.79 (m, 1 H), 7.69-7.65 (m, 1 H), 7.55-7.52 (m, 1 H), 7.35-7.30 (m, 1 H), 7.18-7.12 (bs, 2 H)



2-18: Prepared from 2-(*p*-toluyl)imidazoline **2-8** (0.1 mmol, 20 mg). Calculated 61% NMR yield using PhTMS as internal standard. ^{1}H NMR: (400 MHz, CD_3OD) δ 7.85-7.83 (d, J = 8 Hz, 2 H), 7.34-7.32 (d, J = 8 Hz, 2 H), 7.24 (bs, 1 H).



2-19: Prepared from 2-(4-methoxyphenyl)imidazoline **2-9** (0.1 mmol, 20 mg). Calculated 40% NMR yield using PhTMS as internal standard. ^{1}H NMR: (400 MHz, CD_3OD) δ 7.95-7.93 (d, J = 8 Hz, 2 H), 7.05-7.03 (d, J = 8 Hz, 2 H), 6.97 (bs, 1 H).

2.5 References

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Section II: Development, Implementation, and Evaluation of a Student-Generated ChemWiki and its Impact on Student Performance

Abstract

In large lecture courses where student-teacher interactions are minimal, learning tools that allow students to become engaged learners are crucial. For example, writing as a learning tool has been used as a powerful teaching technique for students to construct their own individual understanding. Online resources have also grown increasingly popular as media to engage a large number of students via graphic animations, video tutorials, and interactive tutorials that students can utilize at their own pace. Among these online resources, Wikipedia has become a dominant source of information for the casual learner as well as a gateway to additional information. While the main use of a wiki such as Wikipedia is information exchange, wikis provide an excellent platform for students to write about chemical concepts and utilize the plethora of graphic animations available on the internet. Another potential advantage of constructing student knowledge on a wiki platform is the inherent use of hypertext, or the explicit linking of one student's page to another, which may facilitate the building of bridges between interconnected concepts. Although wikis have been utilized successfully in smaller classrooms (30 students or less),[1-3] the effectiveness of constructing a class wiki in larger lecture courses (300 students or more) has not been determined. This study will describe the use of a student-generated general chemistry wiki in large lecture courses and its effect on student performance.

Chapter 3

Introduction

This chapter will provide an introduction and background for utilizing a student-generated chemistry wiki in large general chemistry courses. A theoretical framework based in constructivist epistemology will be presented. Previous examples and limitations of wiki usage in chemistry and non-chemistry environments will also be described.

3.1 Challenges of Teaching Chemistry in Large Lecture Courses

For the average undergraduate student, preparation for exams is a significant portion of the higher education process, and the ability to quickly and accurately comprehend concepts presented in lecture courses is perhaps the single most important skill learned as a student in a traditional lecture-style environment.[4] For students in large lecture courses, this can often be a daunting task as the interactions between the instructor and the students is often quite limited during class time. The traditional lecture course typically centers on the instructor reciting or demonstrating knowledge to be learned in a one-way discourse while students take notes. The primary mode of instruction in this context is transference, that is, the instructor transfers knowledge to students via monologue.[5] This mode of learning is essential in courses where there is a set curriculum and limited course time to present material. As a result, the burden of fully learning and comprehending material presented in lecture is the responsibility of the student outside of the classroom.

Instructors also influence student learning by the types of assignments they give their students.[4] The design of out-of-class assignments can be crucial in how well the students learn course material and is often a large factor in how students organize their study time. Many chemistry instructors rely on practice problems to teach students through repetition. This method is popular for a reason- many students appreciate the “practice makes perfect” approach and a

straightforward strategy for approaching new material. From an instructor's viewpoint, repetition of key concepts facilitates the recognition of patterns, a large part of chemistry education. While the practice problem method certainly has its utility in chemistry education, this approach can encourage terminal knowledge and rote memorization as students focus on how the material is presented by their instructor rather than constructing their own knowledge of chemistry.[6]

3.2 Theoretical Framework

To address the concern of lower-level learning, writing as a learning tool has been used as a popular and effective means for students to increase learning.[7a-c] According to Vygotsky, language is central to cognition. If a student is unable to articulate concepts, conceptual learning cannot be said to have truly occurred. Since language is the means by which knowledge is transferred and built, and therefore vital to the learning process, learning tools that utilize writing (e.g. wikis) could be incredibly useful to promote higher order learning. This notion is incredibly relevant to scientists and professionals in any field;[8] communicating technical principles to the uninitiated is an essential task for exhibiting content mastery as well as for persuasion. Writing can be a powerful vehicle for initial conceptual understanding as well as communication. Constructivism provides a theoretical framework for the collaborative writing approach used in this study.

Constructivist Learning Theory

The efficacy of writing in the learning process can be better understood through the constructivist learning approach. According to Applefield,[9] "Constructivism proposes that learner conceptions of knowledge are derived from a meaning-making search in which learners

engage in a process of constructing individual interpretations of their experiences." In stark contrast to objectivism, knowledge does not exist "out in the world"; knowledge can only be created by individuals and their own conceptual understanding of a phenomenon. Within the constructivist learning model, Moshman[10] distinguishes among three main categories: exogenous constructivism, endogenous constructivism, and dialectical (social) constructivism. Exogenous constructivism posits that the learner will construct internal knowledge from experiences with an external reality, i.e. experiences with the "real world" will shape the internal knowledge of an individual. Endogenous constructivism theorizes that existing internal cognitive structures or schemas must be modified by the individual to address cognitive disequilibrium. When experiences with the external environment cannot be neatly placed into the individual's pre-existing schema, an internal reorganization of the schema must take place before the knowledge can be incorporated and thus learned. This theory is highly reflective of Piaget's "accommodation and assimilation" theory of learning. Social interactions can also influence learning as articulation of one's thoughts can promote deeper learning.[11] Dialectical or social constructivism is highly impacted by the Vygotskian theory of learning. To Vygotsky, social interaction and experiences are necessary for knowledge building; it is only through discourse and the comparing and contrasting of ideas that a communal knowledge can be built. Social interactions help learners refine their own individual knowledge while simultaneously helping others find their own meaning and is the theoretical framework through which collaborative learning among groups of individuals takes place. While there are key differences in these approaches to the broad idea of constructivism, there are four tenets common to all constructivist theories. These shared characteristics and this study's effort to address them are listed in Table 3.1.

By operating from the constructivist framework that social interactions are crucial, this study aims to utilize asynchronous student-student interactions to increase meaningful learning among participants.[12] While the ratio of students to the instructor is often quite large in introductory lecture courses, the large size of lecture courses can also be used as an advantage. The large number of students results in a community in which large volumes of information can be built up simultaneously. The theory of knowledge building focuses on the idea that public knowledge is

Constructivist Tenet	Study Action
Learners construct their own learning	Participants are evaluated on individual performance in pre and posttests and completion of assignments
Dependence on student's existing understanding	Participants posttest performance is evaluated using pretest and standardized testing scores as covariates
Critical role of social interaction	Participants perform writing treatments in groups of 4
Necessity of authentic learning tasks for meaningful learning.	Participants asked to write summaries as well as propose original practice problems

Table 3.1. Summary of the tenets of constructivism and actions taken to address the tenets in the current study.

constructed collectively and is an inherently social process. While building knowledge, individuals can also simultaneously benefit through individual learning as they build knowledge with other learners. In this collaborative environment, four constructivist principles can be applied[13]:

1) Knowledge is built actively by individuals and communities
2) Language-based social interactions are central to the building of knowledge by individuals and communities

3) Cognition and language are functional and adaptive

4) The purpose of cognition and language is to bring coherency to an individual's world and a community's knowledge base.

To build a collective knowledge base of individual students of a large lecture course, a platform that is collaborative in nature is necessary. All learners must have access to read and edit their constructed public knowledge. Wikis provide an ideal means to achieve large-scale knowledge building. Wikis are a collection of websites in which text and images are freely added and edited by users. All of the content on a wiki can be viewed and edited by all users with access to the wiki, making it an ideal platform for both the building of cumulative information (page creation) as well as the refinement of ideas (editing).[14]

Using wikis as a platform of writing-to-learn has a distinctly different approach from generating a traditional text.[15] While traditional text is intended to be read in a linear fashion, the introduction of hypertext into wiki pages substantially alters the manner in which wiki pages can be read. Hypertext is text that includes hyperlinks, or links to other sources that are immediately accessible to the reader. The nature of hypertext allows the reader to freely navigate through a plethora of different topics as interest or needed clarification arises. While hypertexts can be read sequentially, they do provide opportunities for the reader to access other sources as needed. In doing so, readers of hypertexts can begin to construct narratives beyond the intended sequence of information.[16a-b] Likewise, writers of hypertext can also provide more than one linear narrative as the hyperlinks provide "nodes" at which multiple topics can be linked together through the use of multiple pages. From a constructivist approach, this type of writing-to-learn could potentially be quite beneficial for individual writers as cognitive dissonance may force individuals to

accommodate their new knowledge into pre-existing structures such as pre-written topic suggestions. On a communal level, the social process of writing (either traditional or hypertext) requires that individuals communicate their ideas and thought processes to one another, often refining ideas through discourse and debate.[16c] It is with this approach of endogenous and dialectical constructivism that the two treatment conditions (traditional and hypertext, or "wiki" writing) were chosen to study.

3.3 Literature Precedents for Wikis in Education

Within the last ten years, a growing interest in the potential benefits of using wikis as tools for learning science has taken place. The methods in which wikis can be used varies; while some have used wikis as purely platforms for information exchange, wikis have also been used as a means to improve scientific writing. Many fields have embraced the utility of wikis as vessels of large volumes of information, including the medical community,[17] the education community,[18] and the pharmaceutical industry.[19a-b] The largest chemistry-focused wiki is currently maintained by the University of California, Davis.[20] It is an open-access textbook that is built and maintained by students and faculty of UC Davis. The primary goal of this hypertext is "to develop and disseminate free, virtual, customizable textbooks that will substitute for current, commercial paper texts in multiple courses at post-secondary institutions."[21] Other institutions have constructed their own chemistry wikis as a means to convey educational materials[21], including ChemPrime, the basis for UW-Madison's online textbook.[23,24]

The chemical education community has only recently begun to embrace the use of wikis in the teaching of chemistry. Initial studies into the use of wikis in chemistry courses were primarily focused on the use of wikis in laboratory courses.[3] In response to criticism of group

work, Clougherty and Wells[1] reported using Seedwiki as a platform to increase participation among individual students for an end-of-semester group project in instrumental analysis. The researchers reported positive reviews from participants. Students generally enjoyed the process of using the wiki platform, as it facilitated inter- and intragroup participation. In 2010, McNeil *et al*.[2] reported using Wikipedia itself as a platform to improve scientific writing. In their study, graduate students were tasked with developing hypertext of self-proposed Wikipedia pages. Hypertext developed by groups of students underwent several rounds of revisions before they were approved for upload to Wikipedia. Within this study, participants were asked to report how various resources helped them meet course goals. After the completion of the Wikipedia pages, participants reported that using Wikipedia contributed substantially to meeting the course goals of communicating science to a general audience, identifying resources for building an argument, and working collaboratively. Prescott[25] and Pence[26] have also reported using wikis in general chemistry courses and environmental chemistry courses, respectively. The focus of wiki usage in these courses was writing-to-learn with assessment of the study focused on student perception of wiki usage.

3.4 Current Limitations of Wiki Studies

Although using wikis as a learning tool has become quite popular recently, the efficacy of wikis as a tool for learning chemistry has not been established, particularly with larger populations of students (> 100 students). Wikis find their greatest utility when constructed by a large number of contributors as the hypertext expands and is refined through multiple editing iterations that are simply not possible with smaller populations.[14] The ChemWiki at UC Davis provides the strongest example of reader-friendly hypertext, as it has had over 13.2 million visits

since 2002 with an estimated 974 hours of reading/writing occurring daily.[20] The streamlined and vast amount of information is possible through countless authors, providing evidence that wikis truly thrive when they are utilized by larger populations.

Evaluation and assessment of wikis in chemical education has been constricted to qualitative methods such as surveys and focus groups.[1-3] These methods are valuable in determining student perception and interest. As self-reported measures, these methods do not assess if the use of wikis increases student learning but are still useful for assessing student perception relative to previous studies. To the best of our knowledge, a quantitative evaluation of student performance based on wiki use has not been performed. To determine if wikis are meaningful tools for the learning of chemistry, the following research questions are proposed:

1) Does the use of wiki and non-wiki writing affect student perceptions of chemistry?

2) Do students who compose original hypertext about chemical concepts perform better on general chemistry exams than students who do not write about chemical concepts?

3) Do students who compose original hypertext about chemical concepts perform better on general chemistry exams than students who compose original, non-hypertext writing?

This study, as outlined in Chapter 4 and evaluated in Chapters 5 and 6, will present a quantitative evaluation of a student-generated chemistry wiki's effect on students' perception of chemistry (Chapter 5). Chapter 6 will describe the first quantitative evaluation of wiki usage in a large lecture course (> 300 students) and students' ability to learn chemistry compared to those not using wiki technology. (Chapter 6).

3.5 Summary

According to Vygotskian theory, language is essential to thought itself and the learning process. Scientific concepts are, at the most basic level, defined by verbal definitions, equations, and other representations that require a common language that is functional and adaptive. The use of learning tools that encourage the articulation of scientific concepts is therefore most likely to succeed in promoting learning when viewed through a social constructivist lens. Cakir[13] summarized this model impeccably: "Putting [scientific concepts] into words centers attention, clarifies thinking, provides a means of symbolizing thought and is an integral part of the process of concept formation…A concept is not fully developed until it is represented in words." Given the increasing interest in using wikis in the classroom, this sentiment is clearly shared by those in the education community who aim to increase student learning in a collaborative environment while using new technology.

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Chapter 4

Development and Implementation of

ChemWiki in General Chemistry Courses

The previous chapter detailed the theoretical framework that the ChemWiki is based upon. This chapter will describe the process of designing the ChemWiki experiment and the website itself. A detailed description of the assessments used to evaluate student performance will be presented. Considerations of the pilot study (study I), and how they affected future experiments, will also be addressed.

4.1 Development of the ChemWiki Structure: Pilot Study

This section will describe the process of developing the experimental design of this study. Considerations for equivalence of group assignments and the design of the pretest and posttest assessments will also be detailed.

4.1.1 Experimental Design

The direct goals of the pilot study (study I) were to determine a) if using a ChemWiki with 350 students was logistically feasible and b) if student usage of the ChemWiki would lead to higher performance on mid-term exams. In order to achieve these goals, it was critical to develop a systematic procedure for when and what subjects participants would write about. Descriptions of the terminology used in this thesis are outlined below:

- *Treatment group:* group assigned to write on their course's ChemWiki website on a concept that is evaluated on the posttest.
- *Comparison group:* group assigned to write on their course's ChemWiki website on a concept that is **not** evaluated on the posttest.
- *Concept:* a group of related subjects that a group is assigned (e.g. "intermolecular forces")

- *Topic:* a specific wiki page composed of various entries (e.g. “London forces”). Students were permitted to select any topic under their assigned concept.
- *Entry:* a short (< 500 words) summary or description of the selected topic.
- *Cycle:* an approximately 4 week period in which students are assigned to a treatment or comparison group and complete the assigned treatment. Cycle includes a mid-term exam in which the posttest is incorporated. Each cycle ends at the conclusion of the posttest and is repeated until the study is complete.
- *Study:* one complete semester in which four cycles of treatment are implemented.

4.1.2 Experimental Procedures

Each of the writing treatments was incorporated directly into the curriculum of the targeted course as a means to engage students with the writing treatments as fully as possible. Because participation did not require any additional time spent outside of the Chem 104 curriculum, a large sample size (n = 285) was obtained for study I. Students were informed during the consent form process that their decision to participate would have no impact on their grade or what assignments they needed to complete. The full text of the consent form instructions can be found in Appendix B.

During the course of study I, students were required to complete four assignments pertaining to writing on the ChemWiki. Each assignment consisted of writing a short entry (< 500 words) on a topic of the student’s choosing. These short summaries could consist of text, graphics such as tables or pictures, or original practice problems. Any resources had to be cited in American Chemical Society (ACS) format in order to receive credit. Each topic/wiki page

consisted of six total entries written by six different students. A full description and student guide to the ChemWiki assignments can be found in Appendix C.

This method of constructing wiki pages is inherently cooperative rather than collaborative in nature, that is, students are individually constructing their own entries and using their compiling entries to make an entire page rather than working on the page as team effort. However, this approach was necessary as one of the major goals of the pilot study was to determine if participants could learn how to use the ChemWiki. By writing individual entries, individual competence with the wiki was required and depending on other students to complete the wikitext editing was not possible. Students were also given an opportunity to edit other students' wiki pages after the posttest on the pertinent material was administered. These edits could be done in exchange for extra credit and should not affect the treatment effect as they were done after the posttest. A timeline of the ChemWiki assignments is detailed in Table 4.1.

Cycle	Assignment	Points *	Optional?	Deadline
1	Individual entry for "Organic Chemistry" and "Biochemistry"	5	No	Tuesday, February 19th at 12:00 P.M. (noon)
2	Individual entry for "Kinetics" and "Chemical Equilibrium"	5	No	Sunday, March 17th at 11:55 P.M.
2	Edits for "Organic Chemistry" and "Biochemistry"	0-5**	Yes	Sunday, March 17th at 11:55 P.M.
3	Individual entry for "Thermodynamics" and "Acids and Bases"	5	No	Tuesday, April 23rd at 11:55 P.M.
3	Edits for "Kinetics" and "Chemical Equilibrium"	0-5**	Yes	Sunday, April 28th at 11:55 P.M.
4	Individual entry for "Electrochemistry"	5	No	Thursday, May 9th at 11:55 P.M.
4	Edits for "Thermodynamics" and "Acids and Bases"	0-5**	Yes	Thursday, May 9th at 11:55 P.M.
	Total	20**		

Table 4.1. Summary of ChemWiki assignments for study I, spring 2013. *Out of 1000 points. **Students could earn up to 30 points if they earned the maximum extra credit points for edits.

In total, four cycles of experimentation were completed during study I. During each cycle, students were randomly assigned to one of six concepts. At the beginning of each cycle, students were assigned a topic and emailed details about their assignment. These instructions contained the information below:

- You have been assigned to the concept [insert concept] (located under [insert concept heading]) for your exam [number] mandatory contribution on the Chem 104 wiki (http://chem104wiki.chem.wisc.edu).
- You may contribute to any page under your assigned concept. Only one entry (Paragraph 1, Figure 2, etc.) is required.
- Before you begin contributing, you must read the main page and the other relevant pages
- If you have any questions, there is an FAQ page ("Main FAQ Page") that you are encouraged to post questions on.

Each cycle focused on different material; for example, in Chem 104, the first cycle comprised topics related to organic chemistry, whereas the second cycle comprised topics related to chemical kinetics and mechanisms. Rather than focus on one concept, this pilot study was designed to explore multiple concepts in order to determine which concepts were most impacted by the writing treatments. Fifteen multiple-choice questions (three per concept) were included on each mid-term exam at the conclusion of each cycle. These 15 multiple-choice questions were included specifically on the midterm exams to encourage students to answer to the best of their ability.

4.1.3 Design of Assessments

At the beginning of the pilot study, no pretest had yet been developed for Chem 104 material. The posttest was developed by Jaclyn Brown using questions similar in nature to practice questions found in *Chemistry: The Molecular Science* (4th Edition) by Moore, Stanitski, and Jurs,[1] which was the course textbook for Chem 104 during the spring 2013 semester. These 48 multiple-choice questions were assessed for conceptual relevance and accuracy by Professor John Moore, who concluded that they were valid questions for evaluating knowledge of Chem 104 concepts. These questions were included as part of each midterm exam (12 questions per midterm/posttest, see section 4.1.3)

In order to protect student confidentiality, a coversheet with questions about the students' wiki usage and their multiple choice answers was attached to each exam. The complete coversheet can be found in Appendix D. Students were instructed to fill in their answers to the multiple choice questions on a different attached sheet in the exam booklet, and these answers were graded by the teaching assistants of the course. After grading the multiple choice questions, the TAs then marked each incorrectly answered question with an "X" on the cover sheet. Once the coversheet was complete, it was removed from the exam. The coversheet included each student's 10-digit campus ID number as the identifier. A research team member (Jaclyn Brown) then manually matched each ID number to the list of research participants. If no matching ID number was found to the one listed on a coversheet (i.e. the coversheet did not belong to a participant), the coversheet was discarded and its data was not used in further analysis. Coversheets of participants were then individually coded as correct or incorrect based on coversheet information.

Because no pretest was implemented during this study, the design of the study I falls into the category of a posttest-only control-group design. A posttest-only control group design must satisfy the following requirements:

1. Random assignment of research participants to experimental and control groups
2. Treatment is administered to experimental group and no treatment or alternative treatment is administered to the control group
3. Posttest is administered to both groups.

There are a few limitations present in the posttest-only control-group design. First, there may be inherent differences between the experimental and control groups. If no pretest is used, it is not possible to determine if the groups are equivalent. However, it is more likely with large sample sizes ($n > 30$) that random assignment will prevent such inequalities. This study employed groups of $n > 40$, and differences between groups are expected to be minimal, although such a claim cannot be assured in the absence of a pretest (see section 4.3.4). Also, in the absence of a pretest, it is not possible to analyze if covariance with a variable such as pretest score is present. It is possible that participants at different levels are affected by the writing treatment differently. As a result, study I did not incorporate covariate analysis. Finally, if a high degree of participant drop out occurs, it is not possible to determine if any treatment effect on the remaining participants is due to inherent characteristics of the participants who remained in the study. This last limitation resulted in switching to a pretest/posttest design for study II and III (see section 4.3.4).

4.1.3 Results of Study I

Quantitative Results

As part of the treatment, participants were randomly assigned to one of six concepts (e.g. intermolecular forces) and required to write an entry on that concept. All participants participated in writing during each of the four treatments, but their concept assignment determined if they were considered as part of the experimental group (writing about a concept that is related to the targeted question content) or the control group (writing about a concept that is unrelated to the targeted question content). On each posttest, each of the 12-15 questions was coded according to their content (e.g. intermolecular forces, organic reactions, etc.), and one group was assigned to write about each concept. If a participant wrote about a concept unrelated to the question's content, that student was considered a member of the control group. The group number indicated in Table 4.2 reflects the order in which the material was presented, i.e. participants in group 1 performed their writing treatment on material that was taught earliest in the treatment cycle.

This methodology has a few limitations. First, all participants are participating in writing treatments. This approach was necessary due to all participants being enrolled in the same lecture course and requiring the same number of assignments; participants in the experimental group could not be given a different number of assignments from participants in the control group. Unfortunately, this design makes it unclear if writing in general or writing about specific content has a stronger effect, if any. These effects could become convoluted when the control group is participating in a similar alternative treatment. Since the design used in the pilot study is not able to deconstruct these different effects, an additional non-wiki writing treatment and true control group were used for studies II and III. Secondly, the absence of a pretest limits the assumption that all of the groups are equal. Finally, the number of questions used to determine the mean

score of each group (1-3 questions per group) is quite small and should be expanded in order to claim internal consistency of concept. These limitations and subsequent changes in experimental design are discussed further in section 4.3.

The results of this posttest-only control group design are presented in Table 4.2. Each group ("treatment") was compared to the rest of the class ("control"). For example, a t-test statistic of -0.2466 was calculated for treatment 1 when group 1 was compared to groups 2-6. The sample sizes of each treatment group and control group vary significantly since the treatment group corresponds to roughly $1/6^{th}$ of the participants while the control group consists of the remaining $5/6^{th}$ of the participants. As a result of the difference in sample sizes, equal variances of each of the treatment and control groups are unlikely to occur. Welch's approximation[2] can be used to calculate an effective degrees of freedom that occurs with unequal sample variances Welch's test was therefore used to compare the sample means of the treatment and control groups for each writing treatment.

Group	Treatment 1	Treatment 2	Treatment 3	Treatment 4*
1	-0.2466 (0.8054)	1.7004 (0.09083)	**-11.3329 (<0.0001)**	**-4.5733 (<0.0001)**
2	-2.0505 (0.041)	**-7.5899 (<0.0001)**	**-4.4709 (<0.0001)**	
3	**-4.3946 (< 0.0001)**	**-10.62 (<0.0001)**	-1.6028 (0.11)	**-8.5951 (<0.0001)**
4	**3.4161 (<0.0001)**	0.0039 (0.9969)	0.8035 (0.4427)	
5	**-8.3604 (<0.0001)**	**-2.8381 (0.0051)**	**2.305 (0.002)**	**3.38321 (0.00016)**
6	**3.4768 (0.00059)**	**4.382 (< 0.0001)**	**4.3493 (<0.0001)**	

Table 4.2. T-test statistics for H_o: the difference in means between the treatment and control group is 0. P-values are in parentheses. *Due to a decreased amount of material during treatment 4, only groups 2, 3, and 5 were assigned to write wiki pages.

Feedback from Participants

The reception of the ChemWiki assignments by the participants was generally negative. Much of the feedback was centered on the difficulty in formatting the wikitext or inserting images and tables:

> *"Formatting can be tricky for someone who isn't experienced with computer-entry type assignments. It can be frustrating when you are trying to work efficiently."* –Participant 17

> *"It was not helpful and was a pain for me because I am not good with computers. I found myself wasting hours trying to get a few points from this wiki instead of constructively studying and doing practice problems".* –Participant 75

Many participants suggested incorporating a tutorial or some sort of documentation in order to alleviate issues of confusion on how to edit the ChemWiki.

> *"Perhaps have a video tutorial on how to use the wiki or sessions to learn how to use the wiki, but it was very hard to learn how to use."* –Participant 1

> *"It would be beneficial to have better or more detailed instructions on how to format and edit the wiki and the technical aspects involved".* –Participant 142

On the post-study survey, participants were asked how often they read the Chem 104 wiki. Very few students read the ChemWiki on a regular basis. (Figure 4.1) However, the majority of those who did read the Chem Wiki found it to be at least somewhat useful. (Figure 4.2)

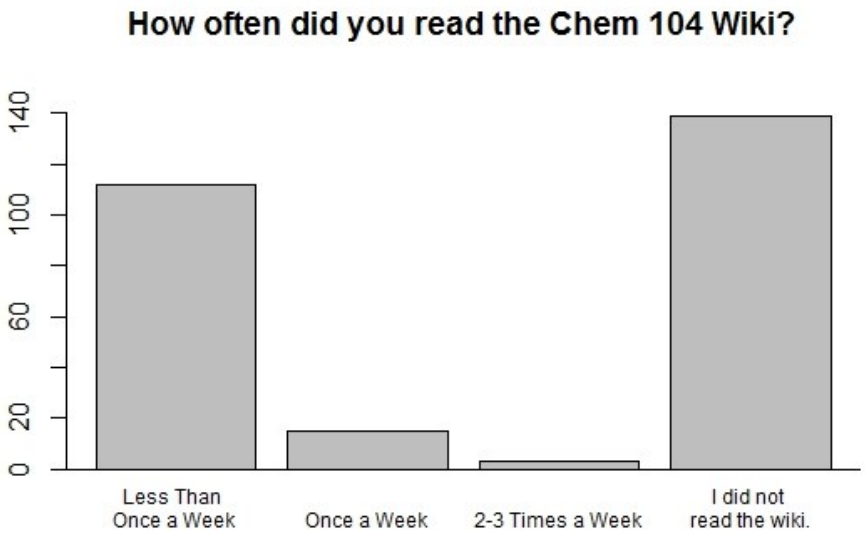

Figure 4.1. Participant responses to the question "How Often Did You Read the Chem 104 Wiki?" on post-study survey.

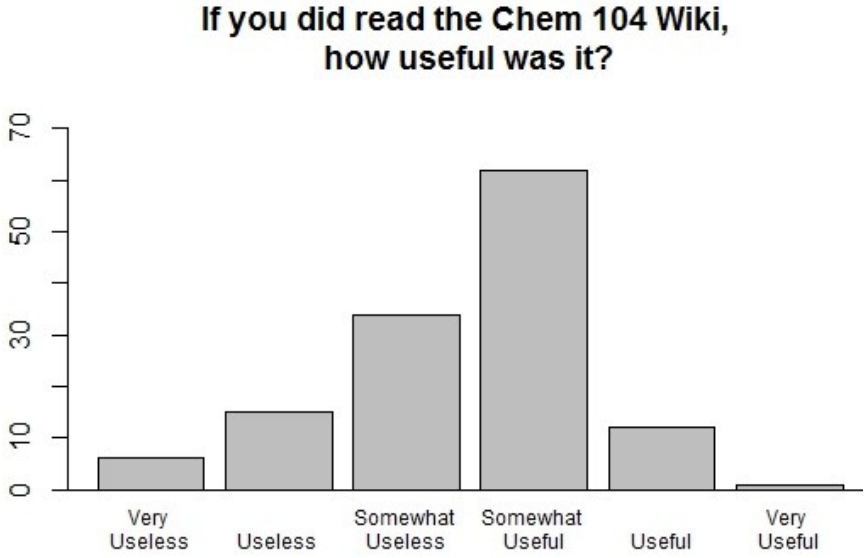

Figure 4.2. Participant responses to the question "If you did read the Chem 104 Wiki, how useful was it?" on post-study survey.

The lack of use of the ChemWiki as a studying resource stemmed from the participants' mistrust of the content on the ChemWiki. Many participants felt that because the ChemWiki was written by students and not monitored by chemistry "experts" such as the course instructors and teaching assistants, the content was not reliable and should not be used for studying purposes.

> *"Sometimes I have noticed information on the wiki that is not quite correct, so I think it would be beneficial to have someone monitoring it who is knowledgeable about chemistry."*
> –Participant 102

> *"I would recommend having a TA or anyone else knowledgeable monitor the pages so that the information is relevant and students can trust the pages more."* –Participant 131

> *"I was very uncomfortable using it as a resource because I felt little confidence in the legitimacy of the entries, so I was not sure how to use it effectively. It's possible I would have felt differently if the wiki had been monitored more by T.A.'s."* –Participant 193

Although many participants did not enjoy contributing to the wiki as individuals, they did acknowledge that editing other students' entries helped them think about the material more deeply, and even suggested that editing inaccurate entries would be useful for studying:

> *"I believe allowing students to edit the wiki pages of other persons would be highly useful. The most valuable part of any wiki is that it may be *peer* edited (or professionally edited)."*
> –Participant 216

Discussion

The effects of the writing treatments are mixed. Most of the negative treatment effects where the experimental group had a lower mean score than the control group occur within groups 1-3, or groups that performed writing treatments that were taught earlier in the treatment cycle while groups 4-6, in general, had a higher mean score than the control group. Since most of the activity on the ChemWiki occurred within one week of the assignment deadline, the material on which groups 4-6 were writing about was being presented most closely to the time frame of maximum student activity on the ChemWiki. Because of the combination of positive and

negative treatment effects exhibited in study I, it is not possible to state definitively whether these treatment effects are a result of the specific material that is being presented or a temporal effect of when the material is being presented and then written about. In order to analyze these differences, an adapted experimental design was used for studies II and III (see section 4.3).

Overall, the majority of the feedback involved the participants' difficulty with using the ChemWiki. Consequently, many changes to improve usability were incorporated in subsequent experiments, and these changes are detailed in section 4.3. The overwhelming amount of feedback from participants suggesting the use of a tutorial resulted in incorporation of both a video tutorial and written manual on how to use the ChemWiki in study II and study III (see section 4.3.5) as well as an introductory assignment that tested their proficiency in utilizing wikitext (see section 4.3.6).

4.2 Development of the ChemWiki Websites

A platform that was easy to navigate and edit was essential for the ChemWiki websites. The recent surge of wikis in chemistry courses has led to the implementation of various wiki platforms such as SeedWiki,[3] MindTouch,[4,5] and Wikipedia[6,7] itself, which is powered by MediaWiki.[8] MediaWiki is a free open-source wiki platform software written in the PHP language that was designed specifically to power Wikipedia. MediaWiki was chosen as the preferred platform due to its popularity as the most widely used wiki platform for public pages. For collaborative writing, Tonkin[9] also recommends that the wiki platform should have the ability to 1) lock pages from editing and 2) adapt multiple versions of the same page in the case of simultaneous edits. The MediaWiki software is capable of both suggestions. The ChemWiki websites were set up by Alan Silver and Paul McGuire of the UW-Chemistry Department

CompHelp Services. All three ChemWikis were launched at least one week prior to the semester of study. Each of the ChemWikis was embedded with a Google Analytics code so that activity on the ChemWiki could be tracked throughout the semester (see section 5.3).

The ChemWiki sites were also blocked from editing by the public since a valid username and password were required to edit the ChemWiki. At the beginning of the semester, students were instructed to sign up for a username using their NetID by the end of the first class week. Students were also warned that if they did not sign up for a username, they would not be able to edit the ChemWiki and would therefore lose the points associated with the ChemWiki assignments. Teaching assistants, who were given administrative privileges on their respective ChemWiki via the "bureaucrat" designation, gave editing rights to their own students after the signup date elapsed. Username creation was permanently closed after the third week of the semester due to the high amount of spam usernames being created by third parties. However, usernames could be created by an administrator (Jaclyn Brown) past the three week time point if necessary.

All ChemWikis were filled with pre-selected concepts and topic pages for the students to complete. The strict nature of selected topics was necessary to prevent redundant or irrelevant topics from being created. These topics, along with the students' concept assignments, were available on the main page of each ChemWiki. Additional information such as assignment deadlines (Fig. 4.3), helpful pages, a brief overview of how to edit a wiki page, and ChemWiki writing restrictions (Fig. 4.4) were also included. Screenshots of sample pages of each of the three ChemWikis can be found in Appendix C.

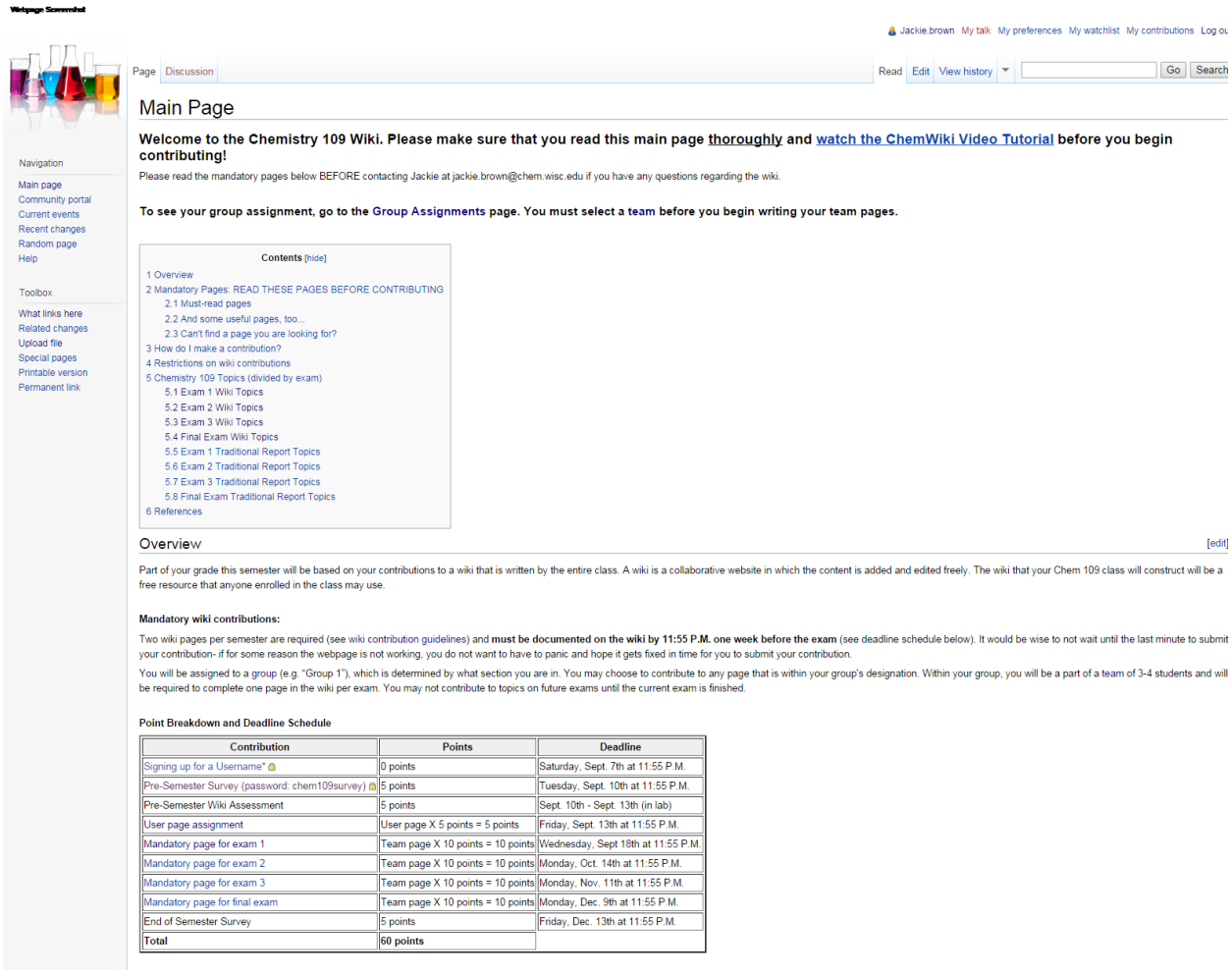

Figure 4.3. Main page of the ChemWiki for study II (Chem 109, Fall 2013).

Mandatory Pages: READ THESE PAGES BEFORE CONTRIBUTING [edit]

Before you get started, you **MUST** watch the ChemWiki Video Tutorial and read the following pages:

Must-read pages [edit]

Avoiding plagiarism
References
Wiki contribution guidelines
Adding images to the wiki
Useful templates for wiki editing
Useful shortcuts for wikitext
ChemWiki Video Tutorial
Traditional report guidelines
FAQs

And some useful pages, too... [edit]

ChemWiki Video Tutorial
Complete Student Guide to the ChemWiki
Group Assignments
What is a team?
User page assignment

Can't find a page you are looking for? [edit]

A complete list of all the pages that exist on the wiki can be found here.

- Note: This list only includes pages that have text in them. The exam topics can be found at the bottom of the main page.

How do I make a contribution? [edit]

Before you begin contributing, you must watch the ChemWiki Video Tutorial. Your first assignment is to edit your user page, and you will learn the necessary skills to edit the wiki by watching this video.

For each exam, you need to select one page on the wiki to fill out as a team. This page must be under your assigned group heading. Please do not edit the other team's page- remember, a digital log is created for all edits made on the wiki. To start contributing, click on the edit tab on the page you wish to write on.

Saving your wikitext:

1) Select "This is a minor edit" and click "Save page" (see figure below).

2) When you are completely done writing your entry, click "Save page" without selecting "This is a minor edit".

If you are only changing something small (grammar, spacing, changing font, etc.) make sure to indicate that it is a minor edit so that your TA can easily assess your major contributions. Please keep your TAs happy!

1) For information on how to **format your text** in the wiki, go here.

2) For information on how to **add images** to the wiki, go to the adding images to the wiki page or Wikipedia's help page on adding images.

3) For information on how to **add tables** to the wiki, go here.

4) For a quick reference for **symbols**, go here.

5) For information on how to cite your sources, go to the references page or Wikipedia's help page on citing sources.

Restrictions on wiki contributions [edit]

Please **do not edit the content (i.e. change other students' contributions) for current exam material**. Once the exam has passed, then the content may be freely edited.

This wiki will be monitored frequently for abuse. **Any spam, vandalism, profanity, or vulgar content will be immediately removed and your account will be blocked.** Keep in mind that a digital record is made for every contribution on this wiki. If you see inappropriate content, please notify Jackie immediately at jackie.brown@chem.wisc.edu.

Plagiarism will not be permitted on this website. Please see UW-Madison's information for students on plagiarism. The Writing Center is also a good resource for how to avoid plagiarism and cite your sources. If you ever have any questions on phrasing or how to appropriately cite sources, it is best to **ask your TA or Prof. Moore before you turn anything in**, either here on the wiki or on other class assignments. Plagiarism is taken very seriously here at UW, and you should not take it lightly, either.

This wiki is for **chemistry content only**. While adding chemistry "trivia" such as historical perspectives, fun facts, etc. are encouraged, we ask that you do not litter the wiki with extraneous pages or links to non-chemistry related items.

Chemistry 109 Topics (divided by exam) [edit]

Exam 1 Wiki Topics [edit]
Exam 2 Wiki Topics [edit]
Exam 3 Wiki Topics [edit]
Final Exam Wiki Topics [edit]
Exam 1 Traditional Report Topics [edit]
Exam 2 Traditional Report Topics [edit]
Exam 3 Traditional Report Topics [edit]
Final Exam Traditional Report Topics [edit]

References [edit]

Figure 4.4. Additional information on the main page of the ChemWiki for study II (Chem 109, Fall 2013).

4.3 Experimental Design of Pilot Study and Subsequent Modifications

After the pilot study (study I), many issues were addressed by adapting the writing treatment procedures as well as the experimental design. Additional materials, including a video tutorial and introductory assignment, were developed and used for studies II and III.

4.3.1 Design of Study I ChemWiki Treatments

The setup of the writing assignments for study I (the pilot study) was intrinsically different from the setup of studies II and III. As one of the main goals of the pilot study was to assess if students could satisfactorily use the ChemWiki platform, individual assignments were used rather than group assignments. Each student was assigned to a concept (e.g. "Organic Chemistry-Intermolecular Forces", see Fig. 4.5) and allowed to select a topic (e.g. "Ionic Bonding") and entry (e.g. "Paragraph 1"). Students were designated to fill out one entry per assignment; four entries were assigned over the semester.

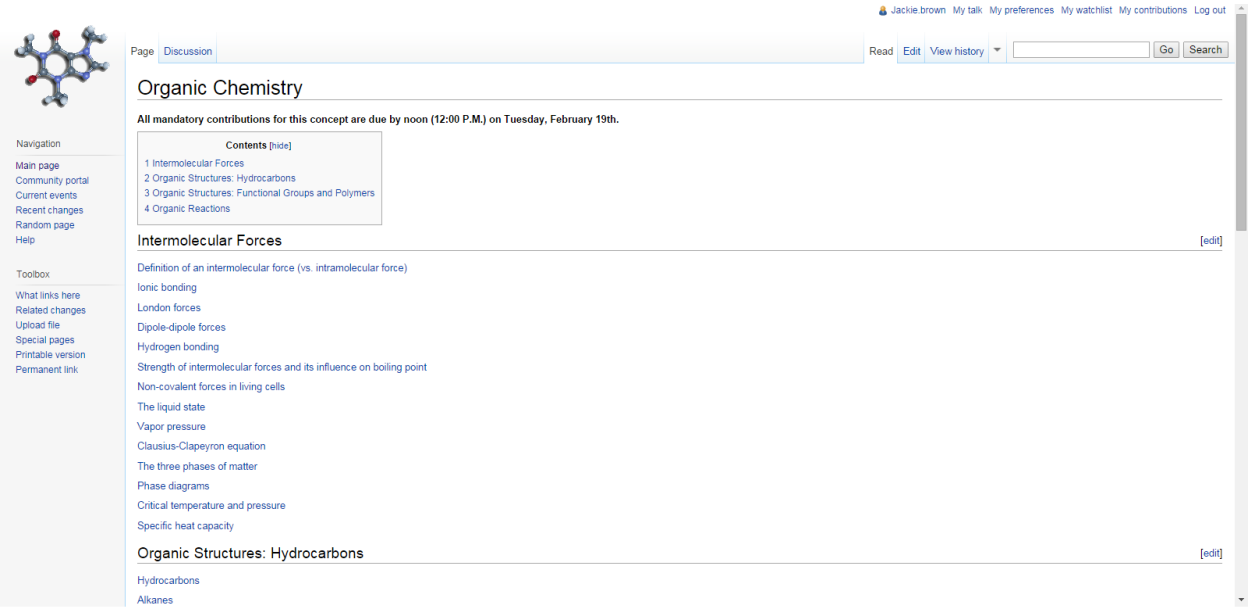

Figure 4.5. Concept (Organic Chemistry) and topic page for study I (Chem 104, Spring 2013).

Once a topic was selected, students could choose to make a contribution by creating one of three types of entries: 1) a textual paragraph, 2) a figure, table, or scheme, or 3) an original practice problem.

A paragraph was defined as "A chemical definition or description of the concept…This description should be at least one paragraph long (4-5 sentences) and should sufficiently illustrate the concept at hand to a fellow student who is learning the material for the first time."[10] A figure was described as "A graphic or table that helps illustrate the concept". Students who chose to write an original practice problem were instructed to create "An example problem where the solution is worked out or a concept is illustrated. You may also create your own "exam"-type questions here for concepts that are more conceptual (rather than solution-based) in nature. Make sure that you include an answer and an explanation of how that answer was formulated." Examples of each of the types of entries were found on the "Wiki Contribution Guidelines" page.

Regardless of the type of entry chosen, each contribution had to fulfill the same requirements in order to receive full credit:

1) At least 2 internal links to other pre-existing relevant pages in the ChemWiki.

2) External references (listed at the bottom of the page under "References") to where the original information came from.

3) Clear, concise text or figures that help peers understand the concept at hand.

In study I, each contribution was worth 5 points. Teaching assistants were instructed to assign 0 points (missing entry), 3 points (incomplete entry), or 5 points (complete entry) for each assignment. Examples of participant entries can be found in Appendix C.

In order to encourage students to evaluate and edit their peers' entries, extra credit edits were permitted. Up to 5 points (1 point per substantial edit) were allowed per exam period, up to 15 extra credit points total. These edits had to be substantial edits to the content (adding content, correcting incorrect content, useful formatting changes) and had to be documented on the edited page's Talk page (see section 4.3.3) in order to receive one point. Feedback from the teaching assistants indicated that the grading of the original contribution and edits typically required 1-1.5 hours per exam period.

4.3.2 Lessons of Study I and Modifications to Experimental Design

At the onset of this study, the logistical factors were a large focus of the experimental design. Since only one lecture was participating in the intensive pilot study (spring 2013), issues of treatment equity immediately emerged. The Institutional Review Board (IRB), which is responsible for ethical oversight of education and social/behavioral research, does not permit research in which different students receive different educational treatments within the same lecture due to issues of curriculum inequality. This issue was circumvented through the adoption of rotating treatment groups where assignment to the control group (writing wiki pages on topics not on the posttest) varied during the course of the experiment (Figure 4.6). Groups that functioned as the control group (groups 3-6) wrote on topics that were tested on other portions of the midterm exams in order to prevent groups 1 and 2 from having a testing advantage (or disadvantage) on the multiple choice questions.

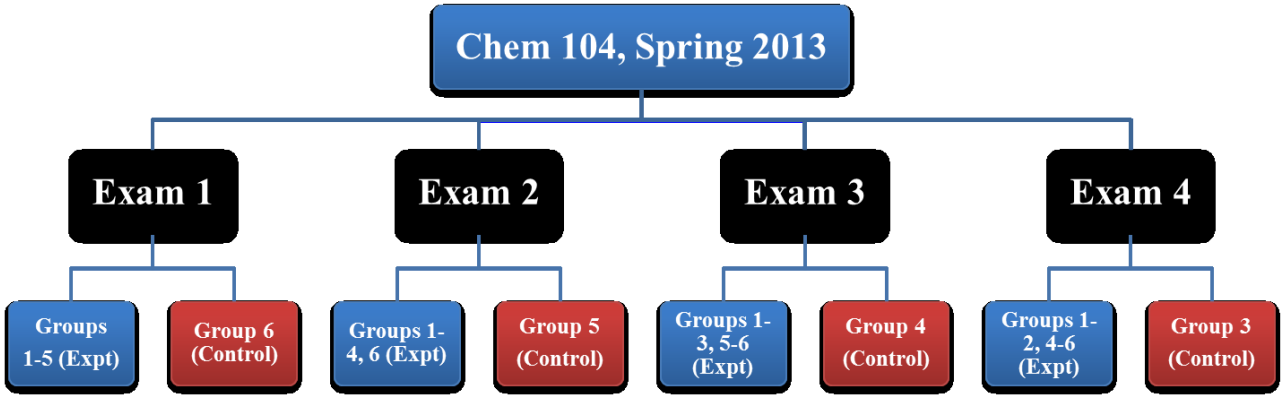

Figure 4.6. Rotating group design for study I (Chem 104, Spring 2013). Groups in blue functioned as the experimental group. Groups in red functioned as the control group.

As discussed in section 4.1.3, this experimental setup has a major limitation in that the control group performed a wiki page treatment simultaneously with those participants in the experimental group. With this type of setup, it is unknown if any (lack of) difference in posttesting is a result of a) wiki writing, b) writing in general, or c) wiki writing on a targeted concept. In order to deconstruct these effects, a few changes were incorporated into study II and study III:

1) A true control group that does not perform writing of any sort was included

2) A separate traditional writing (i.e. non-wiki) group was included

In order to incorporate a true control group, more than one lecture section must participate due to ethical constraints. Different lecture sections are inherently different in their curriculum and treatment of students, and it is therefore permissible for different assignments to be dispensed for different lectures. However, within a lecture section, which may assign grades based on the performance of the class as a whole, it would be unethical to have an uneven number or dissimilar assignments for a portion of the class. For studies II and III, two lecture sections were used, with one functioning as the experimental group and one as the control

group. Students in the control group did not participate in any writing assignments in the lecture portion of the course. Study II was undertaken with two lecture sections of Chem 109, and study III was performed with two lecture sections of Chem 104. A description of the various chemistry courses at UW-Madison can be found in section 5.1.

Within the experimental group, two different writing treatments were assigned. Students assigned to the "wiki writing" groups wrote a wiki page with 3 other students on topics that were targeted on the posttest (coded as TW) or topics that were not targeted on the posttest (UW). Students assigned to the "traditional writing" group wrote a group report on topics that were targeted on the posttest (TR) or topics that were not targeted on the posttest (UR). During the course of Chem 109, four total cycles of experimentation were performed. A cycle consists of a) wiki page treatment or traditional writing treatment and b) posttest evaluation (see section 4.1.1). For the first two cycles, students were assigned to the same treatment type. At mid-semester (between the second and third treatment), the treatment groups were switched so that students in the wiki writing group were now assigned to write traditional reports and vice versa. This switch was necessary so that each student received exactly two wiki page treatments and two traditional report treatments during the semester. An outline of assignments for the treatment and control groups is seen in Table 4.3. At the conclusion of study II, it was determined that having four assignments throughout the semester was too burdensome for the students, and the number of assignments was reduced from four to two assignments, one wiki page and one traditional report (Figure 4.8).

Participants in study I also voiced concern that the amount of time they spent completing the wiki page assignments was not commensurate with the amount of credit assigned to the

assignment. It was decided to increase amount of credit each assignment was worth in studies II and III (see section 4.3.3).

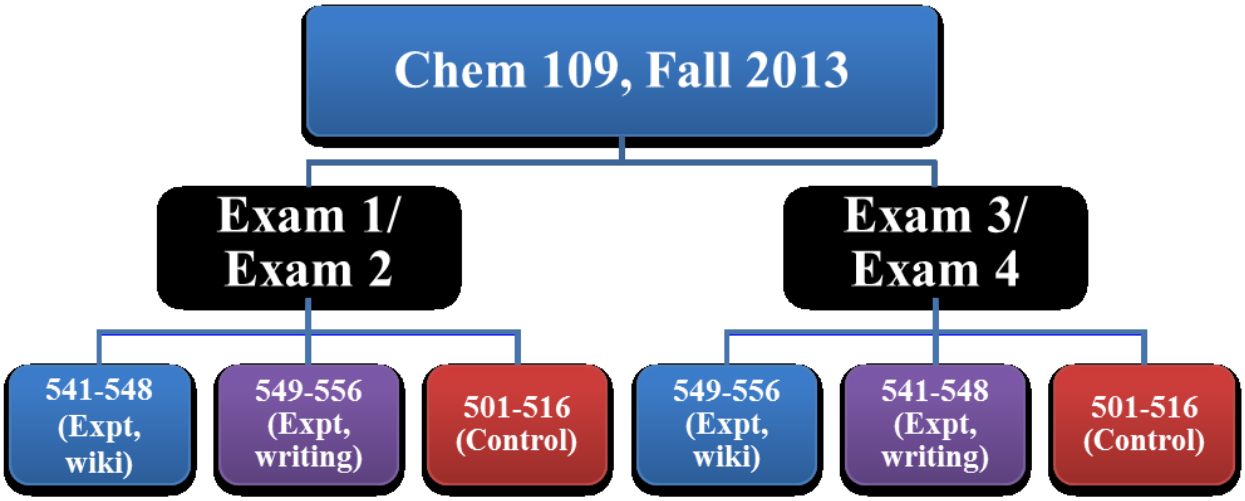

Figure 4.7. Rotating group design for study II (Chem 109, Fall 2013).

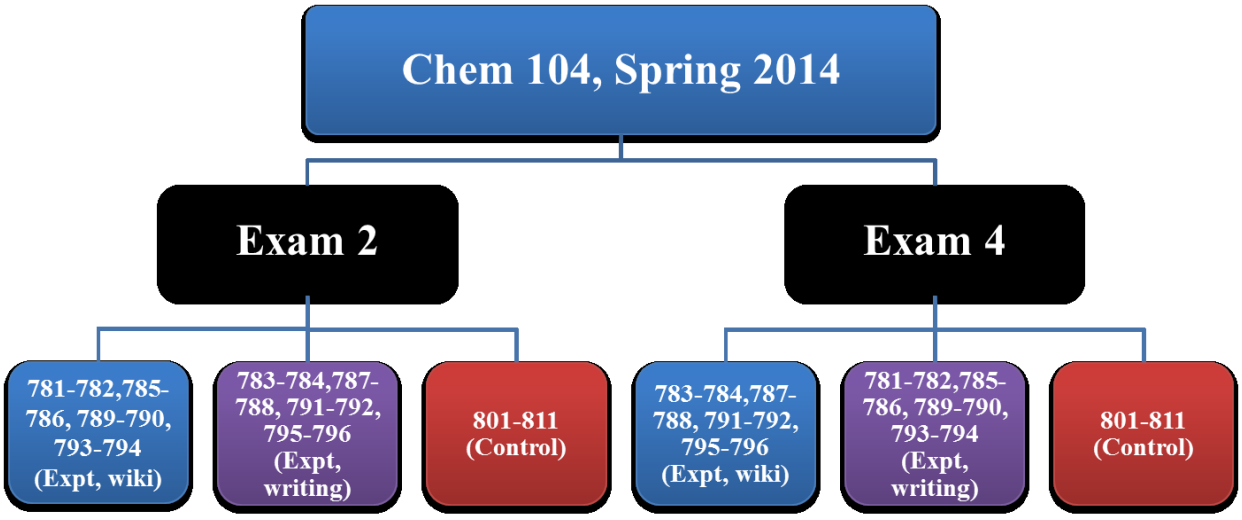

Figure 4.8. Rotating group design for study III (Chem 104, Spring 2014).

4.3.3 Design of Study II and Study III Writing Treatments

The pilot study established that it was possible for students to construct a ChemWiki on a large scale. However, many participants commented that the pages that were constructed were not cohesive and thus had limited utility for studying purposes. Based on this response, it was decided that the students should construct their wiki pages and traditional reports as pre-determined groups to avoid redundant entries. Additionally, collaborative writing[11,12] has been successfully utilized to improve academic performance. Students were instructed to work collaboratively to complete their writing assignments, which had to include the same types of entries as in study I (text, figures, and practice problems). Each group page or report was required to have the items below in order to receive credit:

1) Clear, concise text that thoroughly explains the topic at hand.
2) At least 4 embedded figures (with source citations if applicable)
3) At least 4 original practice problems, including answer keys to each problem.
4) External references to where the original information came from.
5) *Wiki pages only:* At least 10 internal links to other pre-made relevant pages in the ChemWiki.

Before beginning each assignment, students were asked to form a team with three other students (four students per team). These teams remained constant throughout the semester and were used to construct two wiki pages and two traditional reports (study II) or one wiki page and one traditional report (study III). A full set of instructions to the students can be found in the Student Guide to the ChemWiki (Appendix C).

Grading the Writing Assignments

All writing assignments were graded by the teaching assistants of each course. In response to participant feedback in study I, the amount of credit given for each wiki and writing assignment was increased. A breakdown of the points assigned for each assignment involved in this study is outlined in Table 4.3.

Assignment	Credit Assigned in Study II (%)*	Credit Assigned in Study III (%)*
Pre-Semester Survey	5 points (0.5%)	4 points (0.5%)
Pre-Semester Wiki Assessment	5 points (0.5%)	4 points (0.5%)
User page assignment	5 points (0.5%)	15 points (2%)
Wiki page or report for exam 1	10 points (1%)	N/A
Wiki page or report for exam 2	10 points (1%)	15 points (2%)
Wiki page or report for exam 3	10 points (1%)	N/A
Wiki page or report for final exam	10 points (1%)	15 points (2%)
End of Semester Survey	5 points (0.5%)	4 points (0.5%)
Total	**60 points (6%)**	**57 points (7%)**

Table 4.3. Point breakdown for study II and study III. *Percentage is based on maximum number of points in each course. The maximum credit available in study II (Chem 109) is 1000 points. The maximum credit available in study III (Chem 104) is 829 points.

Teaching assistants were instructed to grade the wiki pages and traditional reports based on a rubric similar to the rubric used at UW-Madison to grade lab reports. Wiki pages and traditional reports were evaluated based on:

- General Intro Content (5%)
- Body Paragraph Content (20%)
- Figures (15%)
- Practice Problems (15%)
- References (20%)
- Accuracy (15%)
- Format/Grammar/Spelling (10%)

Grades were input into a pre-designed Microsoft Excel spreadsheet. The UW-Madison Chemistry Department has developed a system (Teaching Assistant Grade Report E-mailer, or TAGRE) for TAs to email individualized grades for student lab reports. The excel spreadsheet used to grade the wiki pages and reports is TAGRE-compatible and was used to email students their grade breakdowns. A copy of the spreadsheet used to grade the wiki pages and reports is found in Appendix C.

Since many participants in study I voiced their concern with the accuracy of the wiki pages, teaching assistants posted feedback on the wiki pages via the "Talk" or pages, also known as Discussion pages (Figure 4.9). This feature is intentionally included for collaborative sites such as Wikipedia to facilitate discussion of improvement on each page. Talk pages are easily accessed by clicking a tab next at the top of each wiki page. Feedback for the traditional reports was written on the report itself by the teaching assistants.

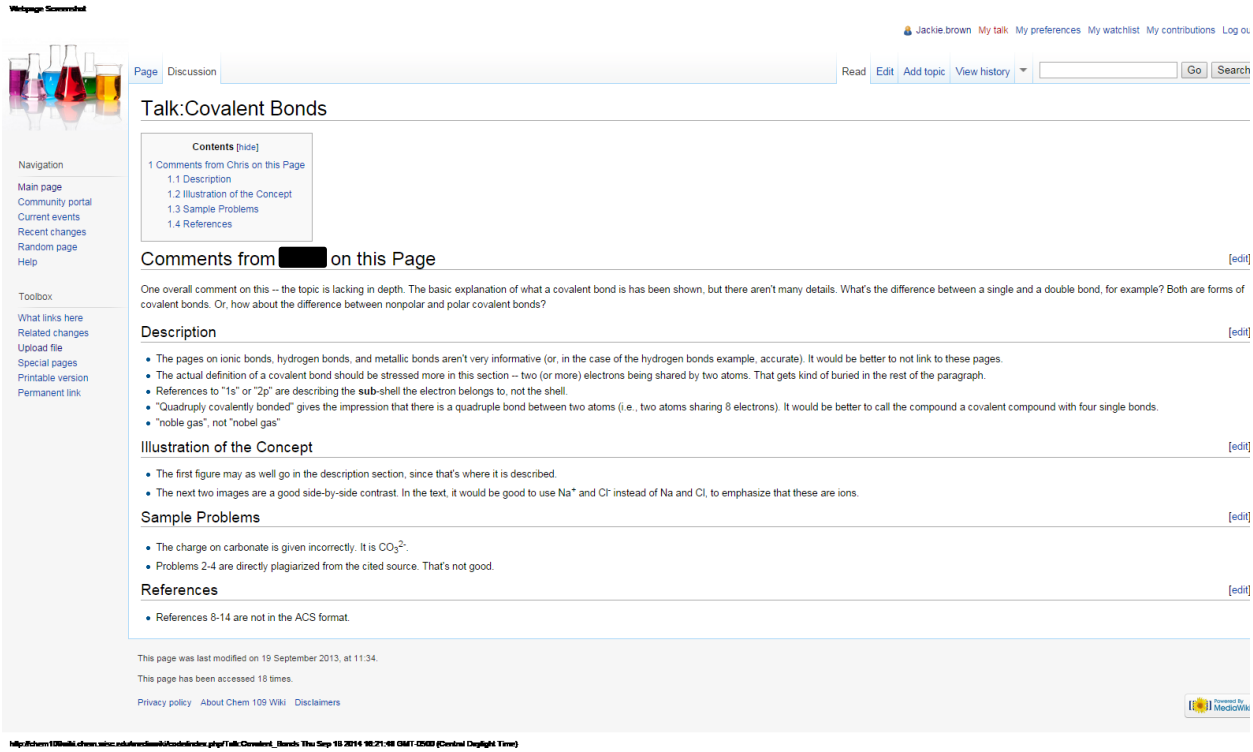

Figure 4.9. Example of teaching assistant feedback on Talk page.

In order to encourage students to evaluate their own writing and make corrections to their wiki pages or reports, students were given the opportunity to earn back up to 75% of the credit lost during the initial grading. For example, if a student initially earned 16 out of 20 points, they could earn up to 3 points back if they utilized the feedback from their TA to correct their page or report. Teaching assistants were instructed to grade more strictly on the initial grading to encourage students to critically evaluate their TA's suggestions and feedback.

4.3.4 Pretest/Posttest Implementation

In order to establish that all experimental and control groups were equivalent, the implementation of a pretest was necessary. The pretests utilized for study II and study III tested the concepts of organic chemistry, kinetics, chemical equilibrium, thermodynamics, and acids and bases. Since the curriculum varies slightly between Chem 109 (study II) and Chem 104 (study III), the pretests for each study contained only content that was relevant for each respective course. The full pretests can be found in Appendix D. By using a pretest/posttest experimental design, it is possible to use learning gains as a metric for student performance in each study. Learning gains are a simple measure of the difference between pre and posttest score.

4.3.5 Development of Student Guide and Video Tutorial on the ChemWiki

Based on feedback from the pilot study, it was clear that the students needed more direction on how to complete the wiki assignments. Although all of the necessary information was posted on the ChemWiki itself, a separate document was created with all information pertaining to the ChemWiki included. This document, "The Student Guide to the ChemWiki" was posted on either Moodle (Chem 109) or Learn@UW (Chem 104), the course management websites for study II and study III, respectively. The full text of the student guides can be found in Appendix C.

In addition to the Student Guide, a video tutorial was also developed to explain how to use the ChemWiki. Due to the large size of both study II and study III, a video tutorial that could be watched at the user's convenience was deemed to be a more suitable method for demonstrating how to use the ChemWiki as opposed to written instruction. The video tutorial was developed during the summer of 2013 by Jaclyn Brown using the Active Presenter program.[13] The goal of the video tutorial was to introduce students to the ChemWiki as well as give them more detailed instructions on how to complete their first assignment, the User Page Assignment (see section 4.3.6). The video tutorial was approximately 21 minutes long and consisted of six sections (lengths of each section are in parentheses):

1) Introduction (00:44)
2) How to sign up for a username (00:56)
3) Editing Your Preferences (01:52)
4) Navigating the Main Page (05:19)
5) How to Add Text (01:17)
6) Editing Your Userpage/First Assignment (11:51)

Each section consisted of a screencast narrated by a student researcher, Jaclyn Brown. The screencast was composed primarily of real-time screenshots of the ChemWiki being used by the student researcher with voice-over explanations of the various ChemWiki pages. This video tutorial was published as an unlisted video on YouTube[14] and could be accessed by anyone with the video's web address. The full video can be seen at the link below:

http://youtu.be/IvsEj20N8H0

4.3.6 Implementation of an Introductory Assignment

Many participants in study I also suggested that some sort of assignment that introduced students to using the ChemWiki would be beneficial. In order to meet this goal, an assignment that trained students in the basic functions of wikitext on the ChemWiki was incorporated into the curriculum. In this assignment, students were instructed to edit their personal user page. User pages are similar to "Talk" pages in that they are used to communicate information about potential edits and discussion of wiki pages.[15] Since each username has a user page linked directly to it, the user page was an easily accessible individual page for all students in the course, making it ideal for grading individual assignments. The user page assignment was worth 4 or 5 points (study II and III, respectively).

Students were instructed to edit their user page to include answers to "ice-breaker"-type questions, allowing students to focus on the learning how to use the ChemWiki as well as getting to know their classmates. These directions for the user page assignment were included on the ChemWiki, Moodle (study II) or Learn@UW (study III), and the Student Guide to the ChemWiki. Specific learning goals of the user page assignment included learning how to format

text, insert graphics, insert references, and link to other pages within the ChemWiki. A sample user page (Figure 4.10) was also distributed to students.

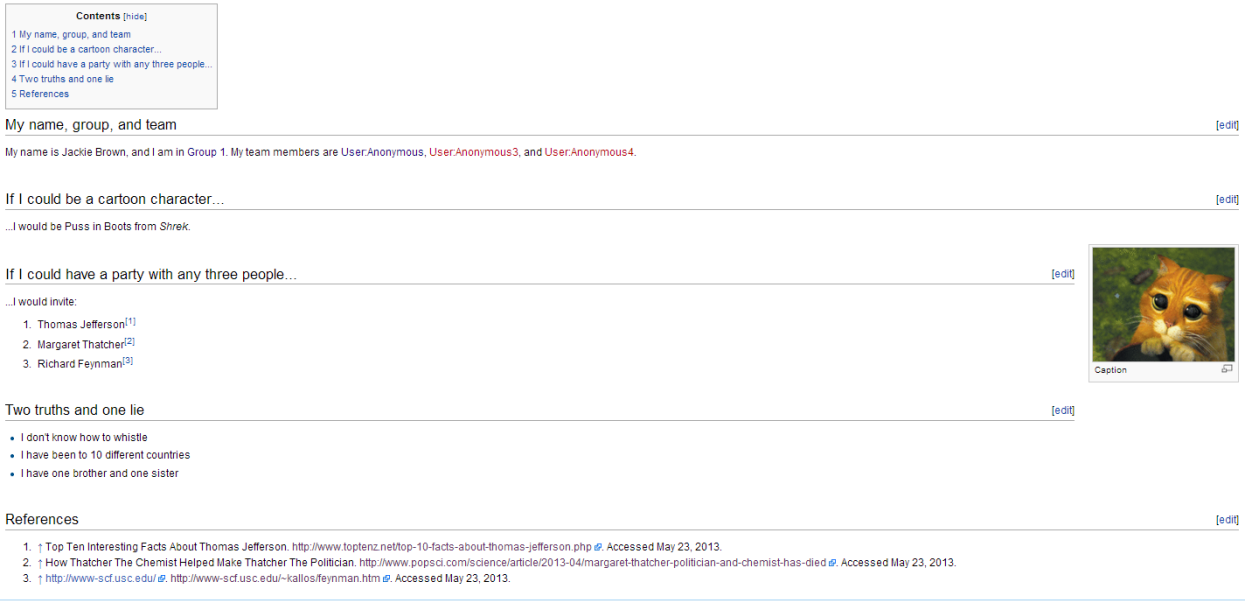

Figure 4.10. Example of a completed user page.

Overall, the user page assignment was viewed as a helpful and beneficial to the students for learning how to use the ChemWiki:

> *"I like the group structure of the pages, and the user page was a GREAT way to introduce how to use the Wiki pages. It was a little frustrating at first, just because it was something new, but once I got the hang of it, it was pretty wonderful."* –Participant 518

4.4 Summary

This chapter detailed the logistical aspects of implementing the ChemWiki in general chemistry courses at UW-Madison. A pilot study was performed using a posttest-only control group design. When this design was deemed insufficient for assessing student performance, major structural changes were implemented for studies II and III. A pretest/posttest design was incorporated to establish equivalency between experimental and control groups. Also, a rotating group design in which a traditional writing assignment (i.e. a "report") was included was

integrated into the research design to analyze differences between writing effects on various platforms. Finally, additional instructional materials such as a student guide and video tutorial were introduced to clarify student issues with the ChemWiki website. These concerns by students in the pilot study were further improved by the use of the introductory user page assignment. Overall, many issues were addressed following the pilot study, and these changes contributed substantially to the results presented in chapters 5 and 6.

4.5 References

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Chapter 5

Evaluation of Student Attitudes, Motivations, and Experiences with Writing Treatments

The previous chapter detailed the design and implementation of a student-written chemistry wiki. After completion of the pilot study (study I), numerous changes to the study design were incorporated to improve the inferential power for study II and study III. This chapter will address the first research question presented in Chapter 3:

- Does the use of wiki and non-wiki writing affect student perceptions of chemistry?
- Do students' chemistry self-concepts change over the course of general chemistry?
- How does student engagement with the wiki compare to student performance?

To answer these questions, two surveys designed to assess the qualitative aspects of the second-generation wiki design are described. Additionally, an overview of participants' perception of the chemistry wiki and its utility will be described (sections 5.4 and 5.6). Participants' interactions with the chemistry wiki were also tracked via usage logs, and the patterns of wiki usage will also be summarized in sections 5.5-5.6.

5.1 Description of General Chemistry Courses

The University of Wisconsin-Madison enrolls 2,500 students in general chemistry each semester. The general chemistry courses that UW-Madison offers are typically comprised of students with distinct academic paths. The descriptions below are provided by the UW-Madison Chemistry Department:[1]

- **103 General Chemistry I**

Course description: Introduction. Stoichiometry and the mole concept, the behavior of gases, liquids and solids, thermochemistry, electronic structure of atoms and chemical bonding, descriptive chemistry of selected elements and compounds, intermolecular forces. For students

taking one year or more of college chemistry; serves as a prereq for Chem 104; lecture, lab and discussion.

Pre-Reqs: Suitable algebra placement test score or completion of Math 112, Math 114, Math 171 or equivalent. One year HS chemistry recommended. Open to first year students. Enrollment not permitted for students who have completed Chem 109 or 115.

- **104 General Chemistry II**

Course description: Principles and application of chemical equilibrium, coordination chemistry, oxidation-reduction and electrochemistry, kinetics, nuclear chemistry, introduction to organic chemistry. Lecture, lab, and discussion.

Pre-Reqs: Chem 103; suitable algebra placement test score or completion of Math 112, Math 114, Math 171 or equivalent. Open to 1st year students. Enrollment not permitted for students who have completed Chem 109 or 115.

- **108 Chemistry in Our World**

Course description: A one-semester introductory course that covers selected topics in inorganic and organic chemistry. Emphasis is on relevance to biological, environmental and social issues. Chem 108 is not intended for students who expect to take additional chemistry courses and it does not satisfy any prerequisites for further chemistry courses.

Pre-Reqs: Open only to those taking only one semester of chemistry. No HS chemistry required. 1 year HS chemistry is permitted. Open to first year students. Enrollment not permitted for students who have completed Chem 104, 109 or 115.

- **109 Advanced General Chemistry**

Course description: A modern introduction to chemical principles that draws on current research themes. For students with good chemistry and math background preparation who desire a one-

semester coverage of general chemistry. Recommended for students intending majors in chemistry or allied fields. Lecture, lab, and discussion.

Pre-Reqs: At least 1 year HS chem; placement into Math 221 or higher or equivalent math proficiency. Open to 1st year students. Enrollment not permitted for those who have completed Chem 104 or 115.

- **115 Chemical Principles I**

Course description: For specially well qualified students majoring in chemistry or chemical engineering. Lecture, lab, and quiz.

Pre-Reqs: Adv placement or adv HS chem, cr or con reg in Math 221 or cons inst. Open to Fr.

A large sample size was desirable for the quantitative aspect of this study. Chem 103, 104 and 109 usually enroll at least 300 students per lecture, which made these courses particularly attractive for a large-scale study. Chem 103 is the first semester of a two-semester sequence and is followed by Chem 104 once completed. Chem 109 is an accelerated general chemistry class that gives an overview of material normally covered in Chem 103 and more in-depth coverage of topics covered in Chem 104. Chem 109 is only offered in the fall semesters. The Chem 103/104 sequence has its largest enrollment of Chem 103 in the fall and Chem 104 in the spring.[2] Enrollment in the "off-sequence" courses is usually no more than 30% of the "on-sequence" enrollment. In order to perform a study each semester with the appropriate enrollment, it was necessary to use Chem 109 during the fall semester. Since Chem 109 covers the curriculum of Chem 104 at approximately the same depth, Chem 104 and Chem 109 were chosen as the targeted courses. It should be noted that while the curriculum of Chem 104 and Chem 109 are quite similar, the student populations enrolled in each course vary significantly. Differences between the two course populations are detailed further in section 5.4.

5.2 Survey Design and Procedure

It is well-known that academic motivation[3-5] and self-perception[6] can have a substantial impact on student performance. Chem 109, as an accelerated general chemistry sequence that has stricter enrollment criteria such as higher math proficiency and at least one year of high school chemistry, typically enrolls a group of more academically talented students than Chem 104. These differences may or may not contribute to how each group of students responds to the writing treatments of this study, and a descriptive overview of each lecture's motivations and self-concept was necessary. The items used to measure academic self-concept and chemistry self-concept are described further in section 5.2.1.

5.2.1 Design of Pre- and Post-Study Surveys

The post-study survey for the experimental group was considerably longer than the pre-study survey due to added questions about the students' experiences with the writing treatments. The post-study survey consisted of approximately 50 items for the experimental group and approximately 25 items for the control group. All surveys in their complete form can be found in Appendix F.

Pre-Study Survey

Each pre-study survey consisted of four types of questions. Each block of questions asked students to describe their:

1) Academic and chemistry self-concept

2) Use of various educational resources

3) Use of online resources, particularly wikis

4) Demographic information

Self-concept can have a profound impact on student performance[3] and should be taken into account when comparing seemingly similar groups of students. In 2007, Bauer *et al*.[8] developed the Chemical Self-Concept Inventory (CSCI) as a means to measure different aspects of "attitude" (namely, self-concept) in a valid and reliable fashion. According to Bauer, attitude can be broken down into seven categories (Table 5.1):

Term Related to "Attitude"	Definition
Attitude	A learned predisposition to respond favorably or unfavorably toward an attitude object
Beliefs	Personal knowledge or understandings that are antecedents of attitudes and subjective norms; they establish behavioral intentions
Interests	Personal or situational preferences for particular activities
Values	Enduring beliefs regarding what should be desired, what is important, and what standards of conduct are acceptable, which influence or guide behavior
Self-Concept	Evaluation an individual makes and customarily maintains with respect to himself or herself in general or specific areas of knowledge
Self-Efficacy	Self-perception of an ability to do something very specific
Self-Esteem	One's level of satisfaction with one's self-concept

Table 5.1. Definitions of Bauer's categories of "attitude".

For our study, self-concept is the most relevant construct and is addressed in the first block of questions. Self-concept is an individual's assessment of his or her own ability in a specific area such as chemistry or academics and has been identified as a robust mental construct.[9] Self-concept is especially relevant in expectancy models of motivation and conceptual change.[10] A higher self-concept can aid in forming manageable expectations for learning, and learners are more likely to persist in difficult learning tasks if they feel there is a reasonable likelihood they will succeed. The ability to persist through learning tasks (such as learning how to use wikitext to write in the ChemWiki) is especially relevant for our study, since there is somewhat of a learning curve associated with learning how to successfully use the ChemWiki. The second block of questions asked students about their use of various educational

resources. This section was necessary to assess students' studying habits. We were interested in investigating whether these studying habits changed from the beginning of the semester towards the end of the semester. Therefore, this block of questions was included on both the pre- and post-study survey. We also wanted to know if the participants had any experience with writing in wiki platforms. The third block of questions focuses on students' usage of learning resources. In order to understand how students will incorporate the writing treatments into their existing study habits, an examination of which resources students use to study is necessary. Since writing about chemical concepts is not traditionally incorporated into the curriculum of the lecture portions of Chem 109 and Chem 104, most students use a variety of online and non-web-based materials to help them learn chemistry. The final block consisted of demographic questions (major, lecture enrolled in) and was used primarily to assign credit to students who completed the survey. An item breakdown of the pre-study survey is shown in Table 5.2.

Topic	Items
Chemistry Self-Concept	1-4, 9
Academic Self-Concept	5-8
Learning Resources	10-12
Online Learning Resources	13-22
"Have you ever edited a wiki? If you have not edited a wiki, why?"	23-24
"Why are you taking general chemistry?"	25
"What is your major?"	26
Identification	27-29

Table 5.2. Outline of pre-study survey questions.

Post-Study Surveys

The post-study surveys for the experimental and control groups varied for each study. The experimental group survey was approximately twice as long as the control group survey due

to added questions addressing the writing treatments. The survey evolved from study I to study III, and an in-depth breakdown of each survey is outlined in Table 5.3.

Although the format and content of the post-study survey for each study changed from semester to semester, there were three question blocks that remained consistent across all semesters for both the experimental and control groups: academic self-concept, chemistry self-concept, and learning resources. Since the academic self-concept items were not internally consistent (page 117), they were not considered reliable and will not be discussed further. The results of the chemistry self-concept items and students' use of various educational resources will be detailed in section 5.4 and discussed in section 5.6. For the experimental groups, all students were surveyed on their experience with wiki writing and traditional writing, if applicable. Survey data on writing experiences will also be detailed further in sections 5.4 and 5.6.

Topic	Study I Items	Study II Items (E)	Study II Items (C)	Study III Items (E)	Study III Items (C)
Topics edited by students	1-3	N/A	N/A	N/A	N/A
Chemistry Self-Concept	4.1-4.4, 4.8, 4.9	1.1-1.4, 1.8, 1.9	1.1-1.4, 1.8, 1.9	1.1-1.4, 1.8, 1.9	1.1-1.4, 1.8, 1.9
Academic Self-Concept	4.5-4.7	1.5-1.7	1.5-1.7	1.5-1.7	1.5-1.7
"Make contributions to the wiki?"	5	N/A	N/A	N/A	N/A
Experience with wikis	6-10	2-4, 6-8	N/A	2-4, 6, 7, 10-12	N/A
Experience with traditional writing	N/A	2, 3, 5	N/A	2, 3, 5, 8, 9	N/A
Learning Resources	11.1-11.3	9.1-9.3	2.1-2.3	13.1-13.3	2.1-2.3
Online Learning Resources	11.4-11.9, 12	9.4-9.9, 10	2.4-2.9, 3	13.4-13.9, 14	2.4-2.9, 3
Demographics	N/A	N/A	N/A	15, 16	4, 5
Previous Academic Experience	N/A	N/A	N/A	17-19	6-8
Identification	13-15	11-13	4-6	20-21	9-10

Table 5.3. Outline of post-study surveys. E = experimental group, C = control group.

The first block of questions was included in both the pre- and post-study survey to evaluate how this mental self-concept influences student performance. A group of items was selected from the chemistry self-concept and academic self-concept constructs of the CSCI. The original CSCI consists of 40 items, which was too lengthy for our purpose, and a reduced 5 item block of questions was used.

As discussed in section 5.1, the student populations of Chem 104 and Chem 109 can vary significantly. Chem 109 students tend to be more academically motivated as there is a higher math standard that must be met in order for a student to enroll in Chem 109. Since Chem 109 is a one-semester class covering two semesters of general chemistry, Chem 109 also typically attracts students seeking to finish their chemistry courses quickly. The condensed curriculum can be particularly attractive to students majoring in certain disciplines that have a heavy emphasis on major-based courses, e.g. engineering. A breakdown of each study's student majors is presented in Figure 5.1 on page 127.

For coding purposes, the major areas of study were classified using the categories below. If a participant listed more than one major, the first major listed was used as that participant's major.

- *Natural Sciences:* biology, ecology, geology, food science, dairy science, animal science, environmental science, forestry science, horticulture, agronomy, zoology
- *Health Sciences:* nursing, pharmacology, toxicology, kinesiology, dietetics, pre-pharmacy, pre-medicine, pre-optometry
- *Physical Sciences:* mathematics, physics, chemistry, biochemistry, computer sciences

- *Engineering:* biomedical, chemical, civil, computer, electrical, geological, industrial, mechanical, nuclear and systems engineering
- *Liberal Arts:* anthropology, art history, economics, foreign languages, history, political science, psychology, sociology
- *Business:* accounting, finance, international studies
- *Education:* secondary education

5.2.2 Survey Procedure

The large number of participants in this study requires a streamlined and easily distributable survey. Qualtrics,[7] a web-based survey service, was utilized to administer both online surveys that students could complete at any time prior to the deadlines. All students, regardless of their participation in the research study, were required to complete both surveys as part of their grade (course syllabi are included in Appendix E). Only survey data from students who signed a consent form (Appendix B) were included in this study.

Students were guaranteed via their signed consent form that their responses would remain confidential from their course instructor and teaching assistant until final grades were submitted to the registrar. Students were required to submit either their NetID or campus ID number on each survey in order to get credit for each survey. This identifiable information was collected by study team member Jaclyn Brown and sent to Rachel Bain, Instructional Technology Specialist. Every NetID or campus ID number was then given the requisite credit for completing each survey. Principal investigator John Moore, who was one of the instructors for Chem 109 during the fall 2013 semester, had access to non-identifiable survey data after course grades were

submitted to the registrar. No other member of the teaching staff had access to the survey data as per IRB protocol (Appendix B).

The pre-study survey was made available on the first class day of the semester and was closed at 11:59 P.M. on the second Friday of the semester, giving the students approximately 10 days to complete the 29-item pre-study survey. The post-study survey was made available approximately one week before the last class day of the semester and was closed at 11:59 P.M. of the last class day. This survey consisted of approximately 50 items for the experimental group and approximately 25 items for the control group (25 items pertaining to the writing treatments were omitted for the control group). Both surveys were password-protected so that only students enrolled in the appropriate Chem 104 and Chem 109 classes could access the survey. Each instructor sent an email to their students with the appropriate link to their class survey. The survey link was also included on Learn@UW during the spring 2014 semester of Chem 104. An email reminder was also sent by each instructor 2-3 days prior to the deadline reminding students to take the survey.

Once the deadline for each survey had passed, Jaclyn Brown downloaded the complete survey data and matched participant ID numbers. Data from unmatched participant ID numbers were discarded, and the remaining survey data were analyzed (section 5.4).

Some of the items were no longer used after study I. Items asking students to report which concepts they wrote about were omitted from the post-surveys in study II and study III due to inaccurate reporting by the students in study I. Many of the students did not remember which topics they wrote about at the end of the semester, and manual verification of each student's topic was necessary. Jaclyn Brown verified that each student wrote about his assigned topic by visually inspecting each course's ChemWiki. Teaching assistants also reported if a

student completed a different treatment than he was assigned, and his placement in a treatment group was modified as necessary.

Additional items specific to the study III post-study survey only comprised demographic questions. When it became clear that academic factors such as standardized math scores were having a significant impact on student performance (see section 6.3.2), the impact of other academic factors such as Chem 103 grade and cumulative college GPA were considered. It should be noted that these variables are self-reported,[12] and their effects should be considered carefully as such.

5.3 Data Tracking

A major advantage of using digital media such as wikis is the ability to monitor how and when users are interfacing with the website via digital logs. Third party analysis toolkits such as Google Analytics[18] are especially robust in collecting web statistics and trafficking logs. Google Analytics is a free service offered by Google that was designed specifically for marketers concerned with increasing traffic and engagement with a specific website. However, the collection of trafficking logs from Google Analytics is instructive for education researchers wanting to assess how students use online educational resources such as the ChemWiki. To use Google Analytics, a simple code must be inserted into the website's source code. Alan Silver and Paul McGuire of the chemistry department CompHelp Services inserted this code into the ChemWiki for study I, II, and III.

In order to evaluate the web statistics reported by Google Analytics, a few definitions of the Google Analytics terminology are prudent:[19]

- *Bounce Rate:* the percentage of single-page visits (i.e. visits in which the person left the site from the entrance page without interacting with the page).

- *Pageview*: a single view of a page on the site. If a user clicks reload after reaching the page, this is counted as an additional pageview. If a user navigates to a different page and then returns to the original page, a second pageview is recorded as well.
- *Page Depth*: the number of pages viewed during a session. Repeated views of a single page are counted.
- *Session:* a group of interactions that take place on the website within a given time frame. A single session can contain multiple page views. A session will terminate after 30 minutes if no further activity is recorded (e.g. a user leaves the browser open with no additional clicks).
- *Unique Pageviews*: number of pageviews generated by a user during the same session.

For studies I and II, a total of five assignments (an introductory assignment and four wiki pages) were to be completed on the ChemWiki, while study III incorporated three ChemWiki assignments (introductory assignment and two wiki pages). It is therefore expected that the week prior to each assignment's deadline would experience the highest traffic on the ChemWiki. Graphs of the average number of sessions for each study are detailed in section 5.5. At the time of this study, it was not possible to track individual users and determine if any overlap between treatment groups was occurring. However, student feedback during the pilot study indicated that unless the students were specifically assigned to a wiki assignment at the time, they did not visit the ChemWiki in a significant amount. It is therefore assumed that the data discussed below is due only to activity by students in the treatment group. Results of data tracking are discussed further in section 5.6.

5.4 Survey Results

Chemistry Self-Concept

Even though the CSCI as a whole was found to be reliable for academic self-concept (α = 0.77) and chemistry self-concept (α = 0.9) in Bauer's study, it cannot be assumed that the subset of questions that we used are also internally consistent and thus reliable. An α value greater than 0.7 is considered strongly reliable.[11] Under our conditions, the chemistry self-concept subset was found to be reliable (α = 0.7) for all three studies, but the academic self-concept subset was not reliable for any study ($\alpha \leq 0.6$). The decreased internal consistency between subsets is not surprising, as the number of questions in the original subsets (10) is much larger than the number of questions in our subset (4). Due to the lack of reliability for the academic self-concept subset, further analysis on chemistry self-concept items only was performed.

In order to assess the chemistry self-concept (CSC) of participants, five questions about students' attitude towards chemistry were included on both the pre- and post-study survey to determine if self-concept had changed regarding chemistry over the course of the semester. Questions were based on a 6-point Likert scale ranging from "Strongly Disagree" to "Strongly Agree". A summary of the mean and standard deviation for participant responses about chemistry self-concept is also summarized in Table 5.4. Summaries of CSC items are also shown in Figure 5.1 (Chem 104, Spring 2013), Figure 5.2 (Chem 109, Fall 2013), and Figure 5.3 (Chem 104, Spring 2014).

Item (Number)	Study I: Chem 104, Spring 2013 (n = 278)	Study II: Chem 109, Fall 2013		Study III: Chem 104, Spring 2014	
		E* (n = 259)	C* (n = 303)	E* (n = 229)	C* (n = 152)
I find chemistry concepts interesting and challenging. (1.1)	4.63 (0.88)	5.12 (0.79)	4.99 (0.83)	4.65 (0.74)	4.64 (1.0)
I have trouble understanding anything based on chemistry. (1.2)	2.73 (1.13)	2.22 (0.97)	2.18 (0.91)	2.82 (1.22)	2.73 (1.19)
Chemistry intimidates me. (1.3)	3.57 (1.36)	2.85 (1.27)	2.87 (1.33)	3.54 (1.36)	3.52 (1.25)
I participate confidently in discussions with school friends about chemical topics. (1.4)	3.68 (1.2)	4.21 (1.12)	4.22 (1.06)	3.7 (1.08)	3.76 (1.18)
I can communicate chemistry effectively. (1.9)	4.02 (0.98)	4.3 (0.84)	4.39 (0.87)	4.13 (0.88)	4.09 (1.04)

Table 5.4. Summary of pre-semester chemistry self-concept item means with standard deviations shown in parentheses. 1 = Strongly Disagree, 2 = Disagree, 3 = Somewhat Disagree, 4 = Somewhat Agree, 5 = Agree, 6 = Strongly Agree. * E = experimental group, C = control group.

In general, the Chem 104 participants exhibited lower chemistry self-concept than Chem 109 participants. Positively worded items 1.1, 1.4, and 1.9 all showed lower means for Chem 104 participants when compared to Chem 109 participants. Conversely, the mean responses for Chem 104 participants for negatively worded items were higher than for Chem 109 participants. Pairwise differences were tested using Welch's t-test, a two-sample t-test that does not assume equal variances between the two samples.[13] No statistically significant differences were found at the $\alpha = 0.05$ level.

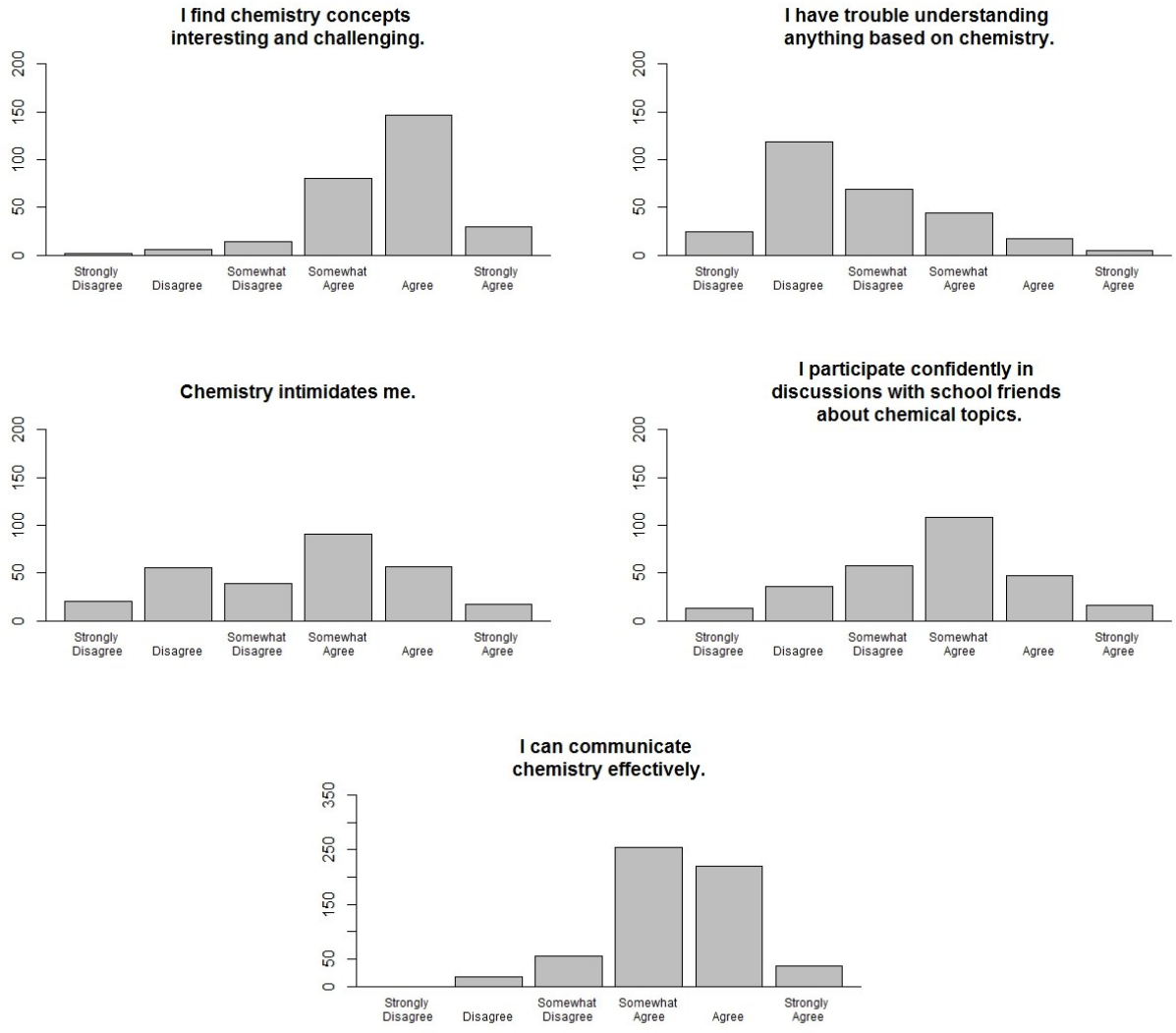

Figure 5.1. CSC responses for study I: Chem 104, Spring 2013.

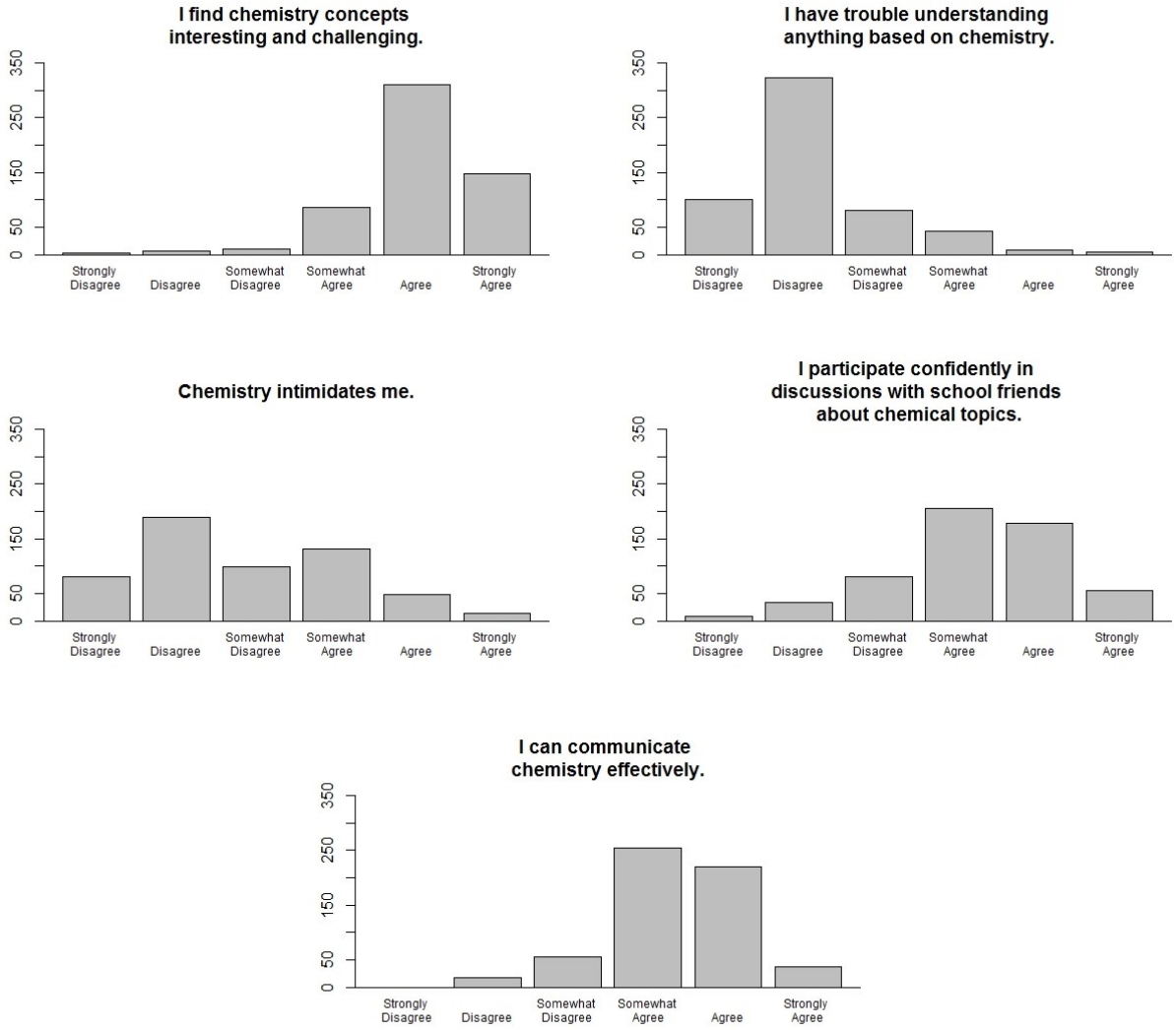

Figure 5.2. CSC responses for study II: Chem 109, Fall 2013.

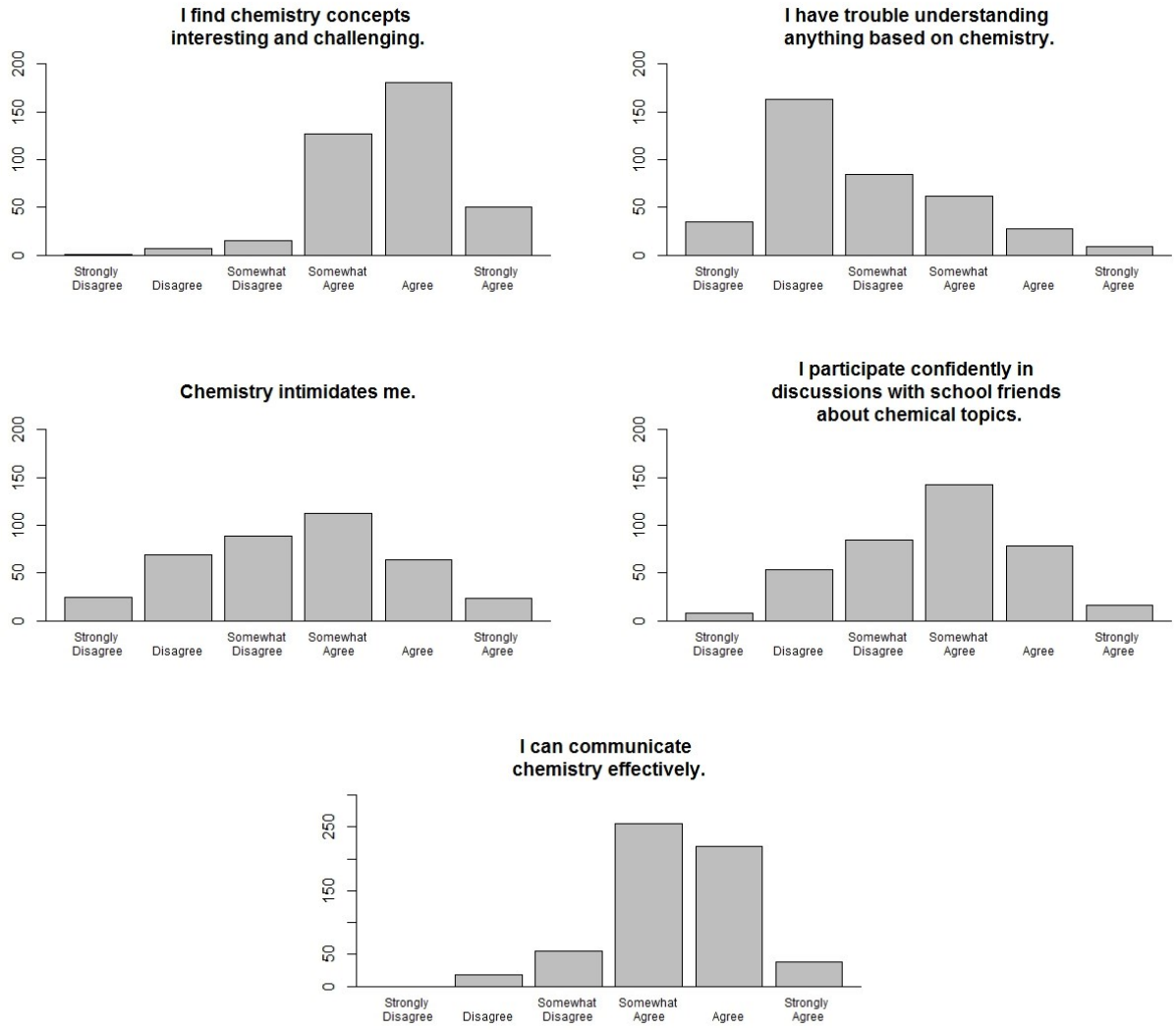

Figure 5.3. CSC responses for study III: Chem 104, Spring 2014.

At the end of the semester, participants were asked the same chemistry self-concept questions that were given in the pre-semester survey. Comparison of the chemistry self-concept items on the pre-semester survey and the post-semester survey are summarized in Table 5.5. A Bonferroni correction of $\alpha = 0.01$ was applied to evaluate the 5 testing items. Bonferroni

corrections are used when multiple hypothesis tests are being performed to minimize Type I error.[16]

Item	Study I: Chem 104, Spring 2013 (n* = 264)	Study II: Chem 109, Fall 2013		Study III: Chem 104, Spring 2014	
		E (n = 207)	C (n = 237)	E (n = 217)	C (n = 148)
1) I find chemistry concepts interesting and challenging.	2.52 (0.012)	**7.20 (<0.0001)**	**6.31 (<0.0001)**	-1.160 (0.247)	0.1884 (0.8508)
2) I have trouble understanding anything based on chemistry.	-1.645 (0.1011)	**-4.53 (<0.0001)**	**-6.64 (<0.0001)**	0.00 (1.00)	-0.585 (0.5571)
3) Chemistry intimidates me.	0.427 (0.6698)	**-2.89 (0.004)**	**-2.81 (0.005)**	1.314 (0.19)	2.34 (0.02012)
4) I participate confidently in discussions with school friends about chemical topics.	**-2.7481 (0.0064)**	2.52 (0.012)	**3.178 (0.0017)**	**-2.688 (0.0078)**	-2.1744 (0.0313)
5) I can communicate chemistry effectively.	-2.586 (0.0103)	1.0045 (0.316)	**3.08 (0.0023)**	-0.987 (0.3248)	-0.3395 (0.7347)

Table 5.5. Summary of paired t-test statistics of chemistry self-concept items before and after study. P-values are in parentheses. Statistically significant ($\alpha = 0.01$) results are in bold.* Sample size decreased (Table 5.4) due to experimental mortality.

Resources

Analysis of post-study survey responses concerning educational resources revealed many stark changes on participants' attitudes and resource usage between the beginning and end of the semester. Significance testing was used to determine if statistically significant differences between pre-survey answers and post-survey answers were present. A two-sided t-test in which equal variances are not assumed (Welch's test) was performed using a family-wise alpha level of 0.05.A summary of the mean and standard deviation for participant responses concerning educational resources is summarized in Tables 5.6 and 5.7

Resource (Number)	Study I: Chem 104, Spring 2013 (n = 278)	Study II: Chem 109, Fall 2013		Study III: Chem 104, Spring 2014	
		E (n = 259)	C (n = 303)	E (n = 229)	C (n = 152)
Lecture notes that I've taken (2.1)	3.33 (0.74)	3.29 (0.71)	3.34 (0.73)	3.23 (0.78)	3.34 (0.74)
TA lecture notes (2.2)	2.61 (0.95)	2.83 (0.82)	2.77 (0.91)	2.5 (0.93)	2.56 (0.96)
Course textbook (2.3)	3.16 (0.85)	3.41 (0.74)	3.17 (0.91)	2.99 (0.93)	2.92 (0.8)
Chem 104 or Chem 109 class website (2.4)	2.83 (0.84)	2.26 (0.87)	2.09 (0.99)	2.51 (1.02)	2.43 (0.93)
Online textbook (available only to students in Chem 109) (2.5)	N/A	2.82 (0.76)	2.8 (0.87)	N/A	N/A
Course websites from other institutions (2.6)	1.79 (0.8)	2.03 (0.86)	1.97 (0.84)	1.99 (0.87)	1.82 (0.82)
Wikipedia (2.7)	1.87 (0.8)	2.22 (0.88)	2.01 (0.81)	1.76 (0.73)	1.71 (0.75)
Search engine (Google, Yahoo!, Bing, etc.) (2.8)	2.71 (0.82)	2.76 (0.83)	2.71 (0.82)	2.59 (0.87)	2.52 (0.84)
Other websites (2.9)	1.46 (0.84)	1.54 (0.84)	1.47 (0.82)	1.48 (0.84)	1.44 (0.91)
Other resources (2.10)	1.52 (0.9)	1.57 (0.89)	1.45 (0.73)	1.45 (0.81)	1.51 (1.0)

Table 5.6. Summary of responses to "How often do you use [resource] to help you study?" items on pre-study survey. Means are shown with standard deviations shown in parentheses. 1 = Never, 2 = Occasionally, 3 = Often, 4 = Very Often.

Resource (Number)	Study I: Chem 104, Spring 2013 (n = 278)	Study II: Chem 109, Fall 2013		Study III: Chem 104, Spring 2014	
		E (n =259)	C (n = 303)	E (n = 229)	C (n = 152)
How often do you use the internet to help you learn chemistry?	3.37 (1.14)	3.42 (1.11)	3.28 (1.07)	3.07 (1.11)	3.05 (1.15)
How often do you use Wikipedia to help you learn chemistry?	1.8 (1.1)	2.19 (1.14)	1.83 (1.04)	1.63 (0.91)	1.51 (0.85)
How often do you use Wikipedia to help you learn about other subjects (i.e. not for studying purposes)?	2.48 (1.31)	2.8 (1.3)	2.64 (1.3)	2.33 (1.22)	2.21 (1.25)

Table 5.7. Summary of responses to "Please indicate how many times a week you use the following resources." items on pre-study survey. Means are shown with standard deviations shown in parentheses. 1 = Less than Once a Week, 2 = Once a Week, 3 = 2-3 Times a Week, 4 = 3-4 Times a Week, 5 = Daily.

Behavior in resource usage (Table 5.8) also exhibited many statistically significant changes between pre- and post-testing. A Bonferroni correction of $\alpha = 0.006$ was applied to evaluate the 9 resources. Only changes in which a single group (experimental or control) showed statistically significant change will be discussed here. In study I, the Chem 104 course website (Learn@UW) showed a statistically significant drop in usage at the end of the semester, while the course textbook showed an increase in usage. Studies II and III incorporated control groups, and a few noteworthy observations are present. Both studies saw increased usage of TA lecture notes, other course websites, and other (non-academic institution) websites and a decrease in Chem 104 or Chem 109 class website and search engine usage. It should also be noted that the control groups of study II and study III exhibited higher usage of their course textbook at the end of the semester.

Participants were also asked how they used internet resources such as Wikipedia to study both chemistry and non-chemistry related topics (Table 5.9). A Bonferroni correction of $\alpha = 0.0125$ was applied to evaluate these three items. No compelling interstudy trends were observed.

Resource (Item)	Study I: Chem 104, Spring 2013	Study II: Chem 109, Fall 2013		Study III: Chem 104, Spring 2014	
	(n* = 264)	E (n = 207)	C (n = 237)	E (n = 217)	C (n = 148)
Lecture notes that I've taken (1)	0.346 (0.729)	**2.1964 (0.029)**	1.14 (0.254)	-0.949 (0.344)	-0.755 (0.4516)
TA lecture notes (2)	-2.671 (0.008)	**3.28 (0.0012)**	**6.47 (<0.0001)**	**4.229 (<0.0001)**	2.556 (0.0116)
Course textbook (3)	**3.705 (0.0002)**	2.3611 (0.01915)	**5.35 (<0.0001)**	1.856 (0.0647)	**6.003 (<0.0001)**
Chem 104 (Learn@UW) or Chem 109 (Moodle) class website (4)	0.666 (0.506)	**-5.5067 (<0.0001)**	**-7.39 (<0.0001)**	**-10.79 (<0.0001)**	**-14.305 (<0.0001)**
Course websites from other institutions (4)	**-4.853 (<0.0001)**	**5.106 (<0.0001)**	**7.006 (<0.0001)**	**5.994 (<0.0001)**	**3.7108 (<0.0001)**
Wikipedia (5)	0.7792 (0.437)	**-3.92 (0.00012)**	-1.76 (0.0795)	**3.584 (<0.0001)**	2.765 (0.0064)
Search engine (Google, Yahoo!, Bing, etc.) (6)	-0.0665 (0.947)	**-9.431 (<0.0001)**	**-12.018 (<0.0001)**	**-12.09 (<0.0001)**	**-11.341 (<0.0001)**
Other websites (7)	1.407 (0.161)	**13.27 (<0.0001)**	**19.84 (<0.0001)**	**14.4 (<0.0001)**	**15.14 (<0.0001)**
Other resources (8)	0.8142 (0.416)	2.307 (0.022)	1.718 (0.087)	0.8922 (0.3733)	1.92 (0.057)

Table 5.8. Summary of paired t-test statistics of resources before and after study. P-values are in parentheses. Statistically significant ($\alpha = 0.05$) results are in bold.

Resource (Item)	Study I: Chem 104, Spring 2013 (n* = 264)	Study II: Chem 109, Fall 2013 E (n = 207)	Study II: Chem 109, Fall 2013 C (n = 237)	Study III: Chem 104, Spring 2014 E (n = 217)	Study III: Chem 104, Spring 2014 C (n = 148)
How often do you use the internet to help you learn chemistry? (1)	0.1083 (0.914)	**-4.64 (<0.0001)**	**-3.917 (<0.0001)**	0.1219 (0.9031)	0.826 (0.4102)
How often do you use Wikipedia to help you learn chemistry? (2)	0.407 (0.684)	**-3.16 (0.0018)**	**-3.910 (0.00012)**	-0.2091 (0.8346)	1.167 (0.245)
How often do you use Wikipedia to help you learn about other subjects (i.e. not for studying purposes)? (3)	0.470 (0.639)	-0.7944 (0.4279)	0.772 (0.4407)	2.514 (0.0127)	**3.715 (<0.0001)**

Table 5.9. Summary of paired t-test statistics of internet usage items before and after study. P-values are in parentheses. Statistically significant ($\alpha = 0.05$) results are in bold.

Demographic Information

A few key differences between students in Chem 104 and Chem 109 exist. Over half of the participants enrolled in Chem 109 were majoring in engineering (Figure 5.4). While engineering was also a large proportion of participants in Chem 104 (37% and 42%), there are nearly 10% more engineering students enrolled in Chem 109. This discrepancy in engineering students in Chem 104 is mostly made up in an increase of students in the natural sciences. There are approximately 10% more natural science majors in Chem 104 than Chem 109. Chem 104 also contained the question "Why are you taking Chem [109 or 104]?" are shown in Figure 5.5. Participants were allowed to select all options that applied.

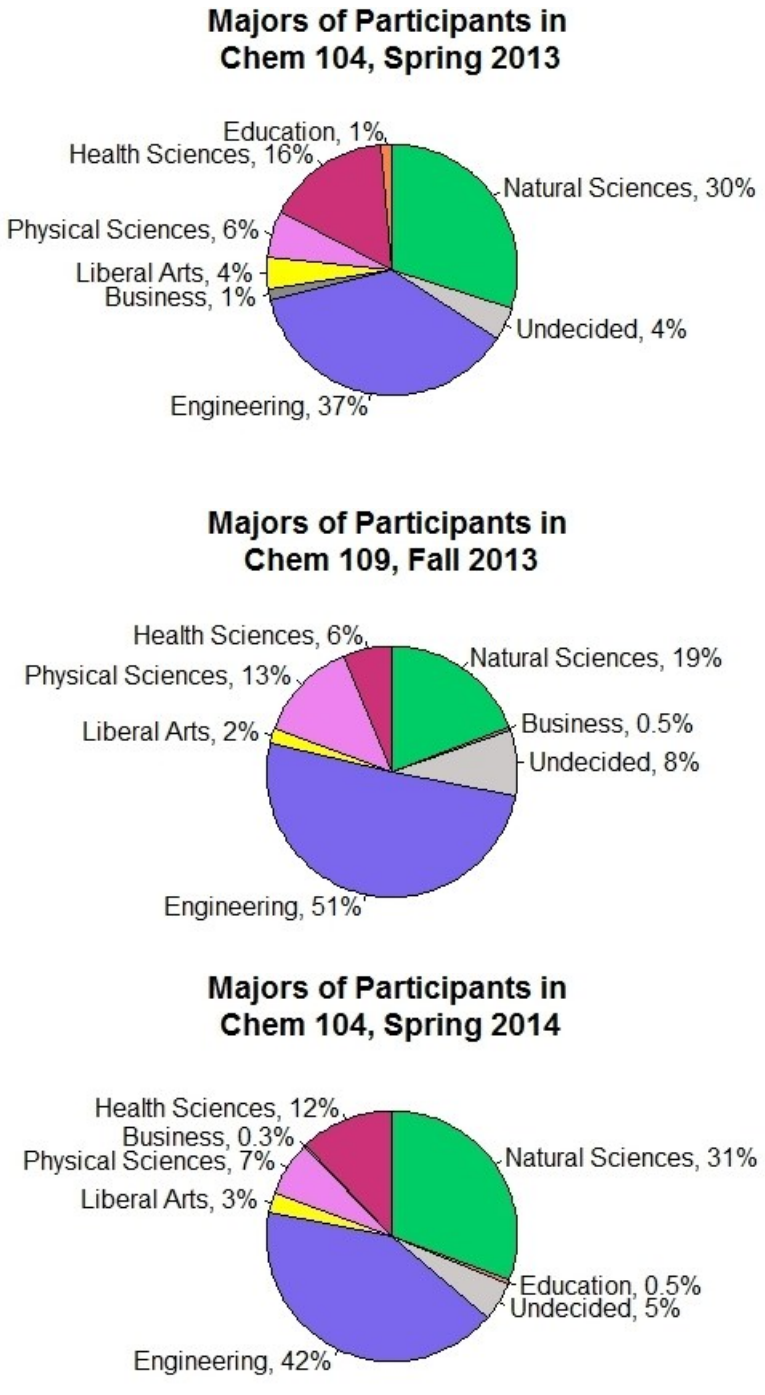

Figure 5.4. Breakdown of student majors by study.

While nearly all participants were taking general chemistry as a degree requirement, a clear difference between Chem 109 and Chem 104 participants is visible. Many of the Chem 109 participants reported having a "personal interest" in general chemistry.

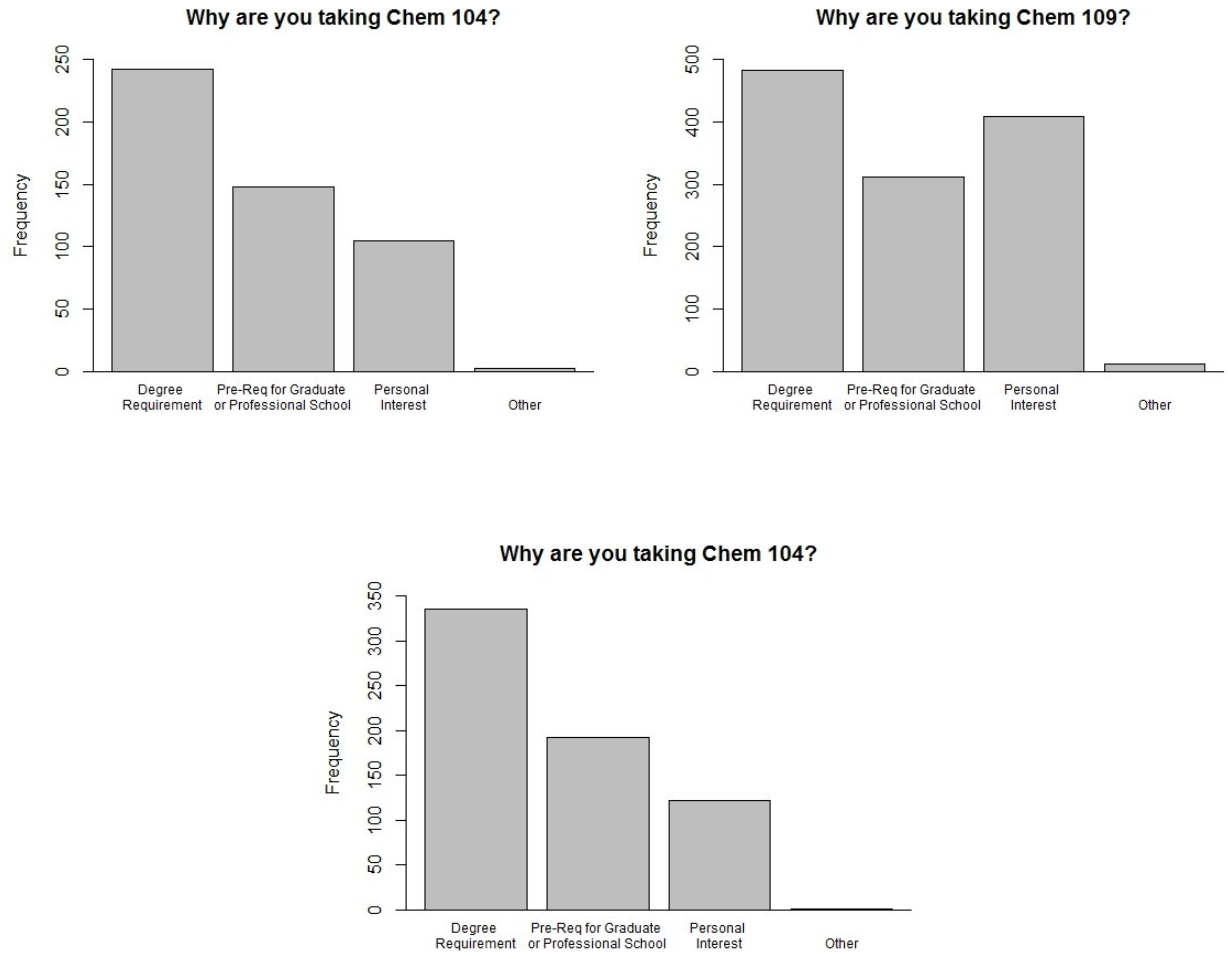

Figure 5.5. Participant motivations for taking Chem 104 or Chem 109. L-R: Study I responses, study II responses, study III responses.

Reception of Writing Treatments

Prior to administering the writing treatments, the participants were asked if they had previously written in a wiki platform before the semester of study. In study I, 7% of the participants had written in a wiki before. In study II, a substantially higher percentage (16%) had experience with wikis. Only 9% of study III participants had experience writing in a wiki.

Overall, very few participants (no more than one-fifth of each study) had experience with using a wiki platform. The platform requires the use of "wikitext", a simplified version of hypertext markup language (HTML).[17] It was expected that the students would struggle with using wikitext, and various resources such as a student guide and a video tutorial were developed (see section 4.3) to abet these difficulties. Participant responses to the wiki platform were generally negative, although the participants in study II (Chem 109) appeared to enjoy the ChemWiki more so than the Chem 104 participants (Table 5.10).

Item	Study I: Chem 104, Spring 2013 (n* = 264)	Study II: Chem 109, Fall 2013 (n = 207)	Study III: Chem 104, Spring 2014 (n = 217)
"Writing original contributions in the Chem Wiki helped me learn chemical concepts." (1)	3 (1.37)	3.29 (1.49)	2.62 (1.43)
"Writing traditional reports (hard copy reports) helped me learn chemical concepts." (2)	N/A	3.97 (1.37)	3.45 (1.51)
"Reading the Chem [104 or 109] wiki helped me learn chemical concepts." (3)	2.53 (1.31)	2.82 (1.39)	2.37 (1.3)
"I enjoyed contributing to the Chem Wiki." (4)	2.12 (1.22)	2.68 (1.51)	2.19 (1.32)
"I am proud of the contributions that I made to the Chem [104 or 109] wiki." (5)	3.71 (1.29)	3.71 (1.47)	3.45 (1.57)
"I trust the content on the Chem Wiki." (6)	3.24 (1.23)	3.68 (1.27)	3.47 (1.38)
"I feel more comfortable working with digital media (e.g. downloading files, navigating web pages) than before the beginning of this semester." (7)	3.76 (1.31)	4 (1.35)	3.25 (1.46)
"Writing entries on the Chem [104 or 109] wiki was straightforward and user-friendly." (8)	3.19 (1.39)	3.35 (1.39)	3.44 (1.45)

Table 5.10. Summary of items assessing student experience with writing treatments. Means of each item are shown (standard deviations in parentheses). 1 = Strongly Disagree, 2 = Disagree, 3 = Somewhat Disagree, 4 = Somewhat Agree, 5 = Agree, 6 = Strongly Agree.

Participants in study II and study III were also asked which writing treatment (wiki or traditional report) they thought was more helpful for learning chemical concepts (Table 5.11). In general, most students preferred writing traditional reports because they thought that the assignment was easier.

Study, Course	Number of participants who preferred wiki (%)	Number of participants who preferred traditional report (%)	Total (%)
II, Chem 109	79 (38%)	128 (62%)	207 (100%)
III, Chem 104	60 (28%)	157 (72%)	217 (100%)

Table 5.11. Responses to the post-study survey question "Which assignment was more helpful for learning chemical concepts?"

Participants were also asked to expand on their assignment preference. Overall, most of the comments favoring the traditional report focused on the ease with which traditional reports could be written. Many participants commented that the wiki formatting was troublesome and difficult to navigate. However, participants who preferred the wiki page assignment commented that the increased amount of time spent formatting the wiki pages actually helped them learn the material at hand because they spent significantly more time completing the assignment and thus focusing on the material they were writing about. Participants also noted that the ChemWiki provided more flexibility in terms of presenting the material to their peers in new and interesting ways. Many participants also commented on the visibility of their wiki pages, i.e. they were able to learn from other students' contributions and get feedback on their own contributions from students who read their pages. Representative student feedback is listed in Table 5.12.

Although there were varying opinions on the utility of the traditional reports and the wiki pages, both assignments were found to aid in student performance. The quantitative measure of increased student performance is discussed further in Chapter 6.

Comments in favor of wiki pages	Comments in favor of traditional reports
It was an abstract way that forced me to think more. –Participant 324 *Other groups' wiki pages are accessible by everyone to study from. Internal and external links also help with studying a great deal.* –Participant 439 *Easier to collaborate on and hold group members accountable.* – Participant 325 *I feel like it took a longer time to edit than the traditional report and so by spending more time on the page, I read it more and became more acquainted with the material.* –Participant 339 *As students we have to write traditional reports for almost every other class we're in, so by being able to write about things in a new way made it more interesting, fun, and engaging than a traditional report. By enjoying the work I was doing, and being able to be kind of creative with it (and tell my friends and family I was "learning HTML code") made me feel as though the webpages were worth the time and effort I put into them.* –Participant 518 *I thought that the Chem 109 Wiki was more helpful for learning chemical concepts because it offered opportunities to explain our own research, as well as review and correct, if necessary, the research of our peers. This was helpful because when reading Wiki contributions it forced me to validate the content, which ensured that I knew and understood it. Also, the wiki helped to make connections between different chemical concepts because it required a certain amount of internal links.* –Participant 305	*It promoted more effective communication of chemical concepts.* –Participant 300 *You can focus on the material more fully when writing a traditional report, while on Chem Wiki half your brain power is invested in attempting to display the information correctly.* –Participant 321 *It allowed me to work with my partners in person and not over the internet.* –Participant 316 *Less time was worrying about formatting and linking. Word is familiar to us.* –Participant 317 *I feel that using the chem wiki took more time for students because a majority of the time was spent trying to format the wiki properly. I think it would be a better use of time if students just wrote the tradtional reports because they are more straightforward and that way students can focus on the content of their report rather than spending time learning the formating.* –Participant 461 *When we divided up the work for our wiki, some people were just responsible for pictures or practice problems, so they didn't get to go over actual material. When we did the traditional reports, we each wrote a page, so everyone was able to review/learn some actual material.* –Participant 326

Table 5.12. Student feedback on wiki pages and traditional reports.

5.5 Data Tracking Results

In all three studies, the expected spikes of activities did indeed occur within the week of each assignment's deadline (Figure 5.6). Fortunately, the activity on the ChemWiki was not exclusive to the assignments; each study also showed a relative increase in activity at the beginning of the semester as students sought to become acquainted with the website. It is also noteworthy that for study III, there were small surges of activity after each peak of usage. Students in the Chem 104, Spring 2014 semester were encouraged to correct their pages and incorporate feedback from their teaching assistant in exchange for partial credit. While very few students took advantage of this policy (< 10%), the noticeable increase of activity on the ChemWiki in study III is most likely due to students who chose to edit their pages.

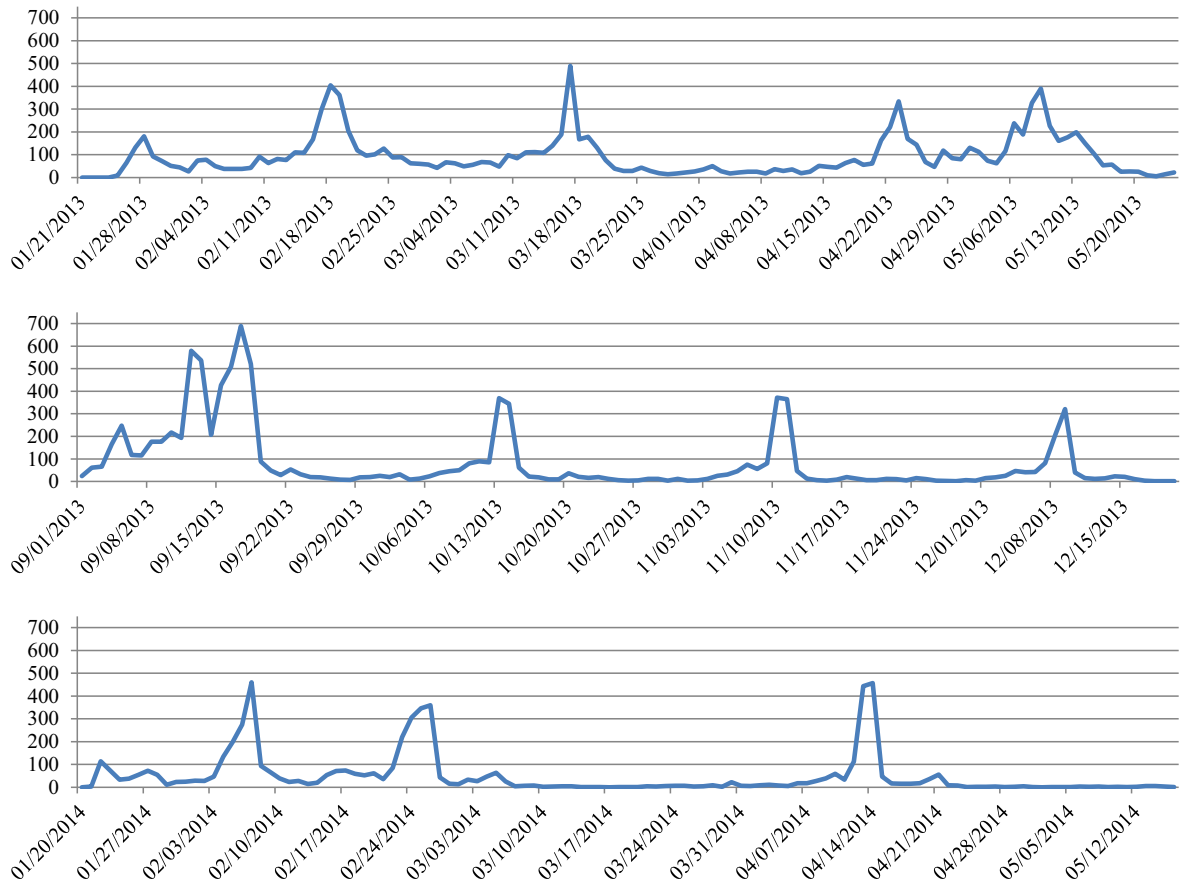

Figure 5.6. Number of sessions recorded for each ChemWiki over each 16-week semester. From top to bottom: Chem 104, Spring 2013 (Study I), Chem 109, Spring Fall (Study II), Chem 104, Spring 2014 (Study III)

During the course of study II, it appeared that a temporal effect was taking place between the first and second writing treatments (see section 6.3.3). An overview of various web statistics of the two writing treatment time frames revealed a few disparities between the first and second writing treatments (Figure 5.7). First, the number of unique pageviews during the first treatment was significantly greater (130% more) than during the second treatment. However, the average

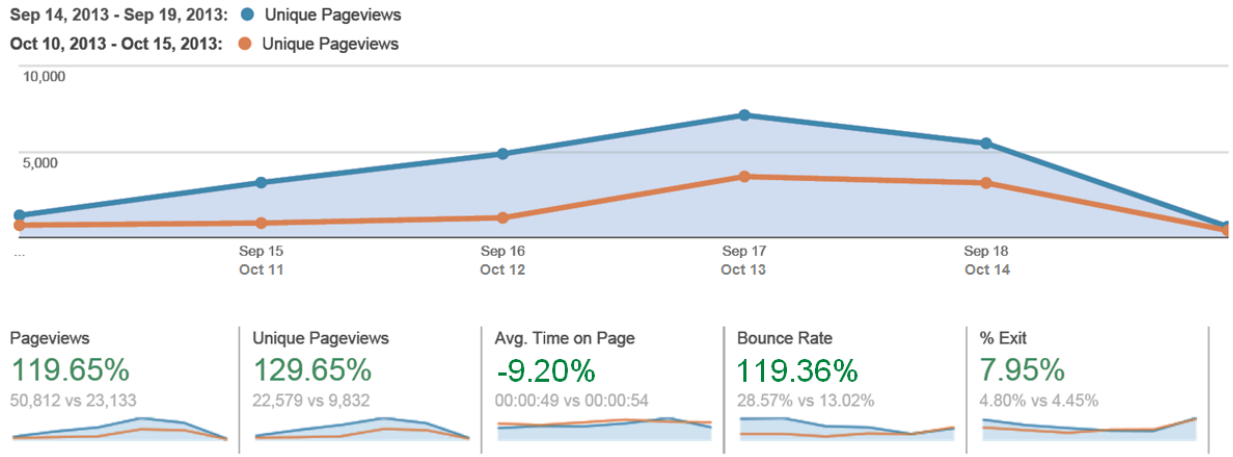

Figure 5.7. Web statistics acquired during writing treatment 1 (September 14-19, 2013, blue) and writing treatment 2 (October 10-15, 2013, orange) for Chem 109, Fall 2013 (study II).

time spent on each page increased during the second treatment. Finally, a large decrease in the bounce rate was observed; only 13% of users entered the ChemWiki website without further interaction with the wiki. At mid-semester, the treatment groups were switched so that students who were previously assigned to the wiki writing treatment (treatment 1 and 2) were then given the traditional report treatment (treatment 3 and 4). Conversely, students who wrote a traditional report for treatment 1 and 2 were assigned to write in the ChemWiki for treatments 3 and 4. The effects seen during treatments 1 and 2 have substantially decreased (Figure 5.8).

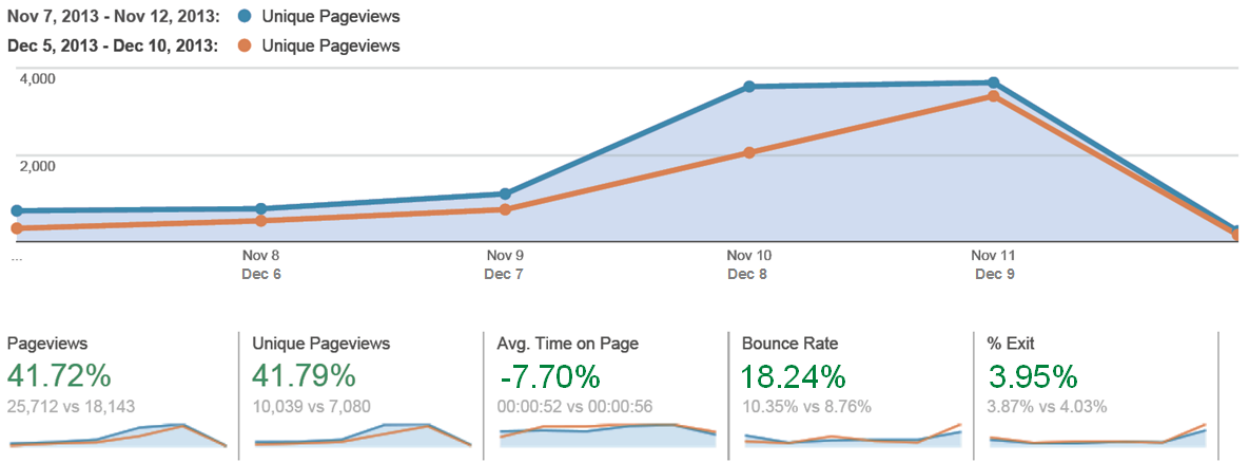

Figure 5.8. Web statistics acquired during writing treatment 3 (November 7-12, 2013, blue) and writing treatment 4 (December 5-10, 2013, orange) for Chem 109, Fall 2013 (study II).

As in the first cycle of experimentation, the bounce rate decreases over time. Also, the number of pageviews decreased from treatment 3 to treatment 4, indicating that students are visiting fewer pages during the course of the second iteration of the treatment. The average time on page also increased over time (52 seconds to 56 seconds. Page depth is another useful metric for determining engagement as it measures the number of pages per session for each unique visitor as opposed to total pageviews (Figure 5.9). Although the total number of sessions decreases from treatment 1 to treatment 2, the proportion of users interacting with a high page depth (> 12 pages/session) rather than a low page depth (< 5 pages/session) is significantly higher than for treatment 1; the number of low page depth sessions is approximately the same as the number of high page depth sessions. A similar trend is seen for treatments 3 and 4. While the total number of sessions decreases from treatment 3 to 4, the number of high page depth sessions compared to low page depth sessions increases between treatment 3 and 4.

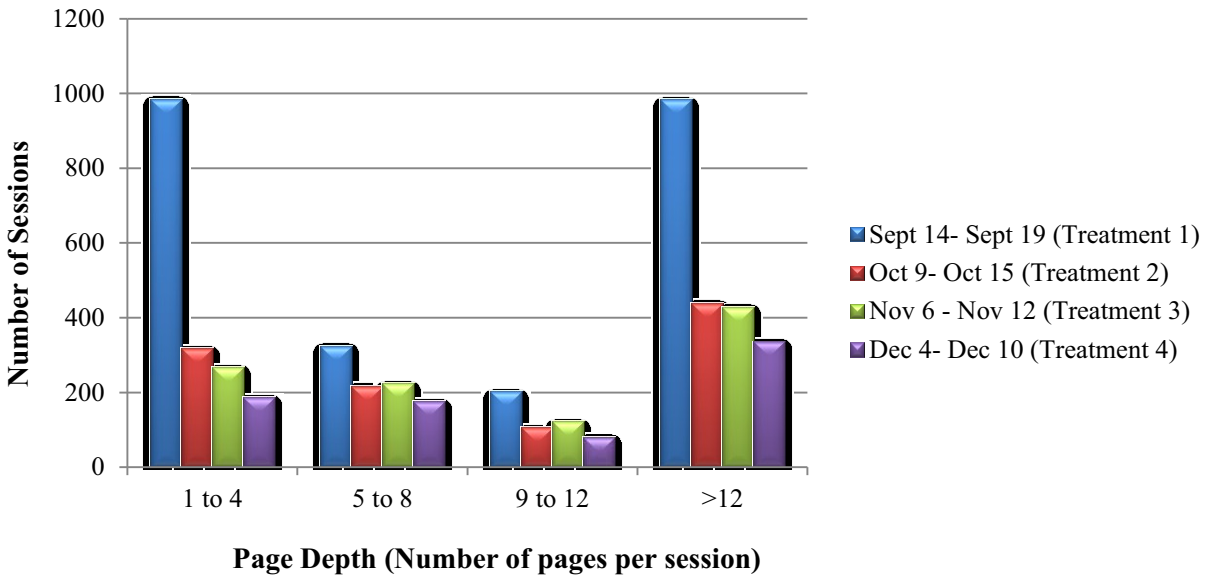

Figure 5.9. Page depths of each treatment for Chem 109, fall 2013 (study II).

5.6 Discussion of Findings

Chemistry Self-Concept

Comparison of the chemistry self-concept items on the pre-semester survey and the post-semester survey yielded a few surprising results (results are summarized in Table 5.5). A Bonferroni correction of $\alpha = 0.01$ was applied to evaluate the 5 testing items. Bonferroni corrections are used when multiple hypothesis tests are being performed to minimize Type I error.[16] Participants in both study I and study III showed a statistically significant decrease in confidence in participating in chemistry discussions with classmates (item 4). This decrease may be due in part to a treatment effect. It cannot be said with certainty that this decrease is due to a treatment effect for study I since no control group was incorporated; however, the same trend is observed in study III (in which the control group exhibited no decrease in confidence), lending evidence that the writing treatments may actually be lowering participant confidence in

chemistry-related discussions. It is possible that for participants in Chem 104 (study I and III), who began the study with lower chemistry self-concept than Chem 109 participants (study II), the process of constructing a group-written assignment actually led to negative interactions between group members. Similarly, having their writing evaluated critically by an instructor may have also led to decreased confidence. Participants in the experimental group did not exhibit a statistically significant change in confidence in participating in discussion. However, the control group of study II did show improved confidence (items 4 and 5). For participants in Chem 109, it appears that less feedback results in higher self-concept, specifically confidence. In general, study II showed the most drastic pre-/post-testing differences in self-concept (items 1-3). Since the directionality of each of these differences is the same in both the experimental and control group, changes in self-concept cannot be attributed to a treatment (or lack of treatment) effect.

Resources

Overall, participants in all studies reported using their own lecture notes as their primary resource and their course textbook as their second most-used resource (Table 5.6). This result is not surprising, as students typically view material that is approved by their specific instructor as "superior" or as having the "correct" answer. Participant responses to online resources (items 2.4-2.9) were generally low. Despite the numerous amounts of educational resources on the internet,[14] participants exhibited a low usage of these types of resources (Table 5.6). This bias appears to stem from an uncertainty of the accuracy of online resources (Wikipedia in particular) that have not been approved by the instructor teaching the observed course.[15] In terms of online resource usage, students in Chem 104 and Chem 109 varied significantly at the beginning of the semester (Table 5.7). In all three studies, the mean amount of time that participants used the internet to study chemistry was 2-3 times a week. Each group also averaged less Wikipedia use

(once a week) to study both chemistry and non-related chemistry subjects. Participants also generally used Wikipedia more to learn about non-chemistry related subjects (mean = 2.22 to 2.8) than chemistry (mean = 1.53 to 2.19).

Only a few statistically significant changes from pre- to posttest were observed. Although both Chem 109 and Chem 104 participants rely heavily on their course textbook, Chem 109 participants increased their course textbook usage while decreasing their usage of online resources like Wikipedia. Chem 104 participants also tended to increase their textbook usage over the course of the semester (Table 5.8). Also, the control group of study III reported higher usage of Wikipedia to learn about non-chemistry related topics. It is notable that participants in study II reported decreased usage of internet resources (items 1 and 2) to study chemistry. It is possible that this decrease in usage of internet resources from Chem 109 participants is due to more critical evaluation of resource accuracy. However, in direct contrast to Chem 109 participants (study II), Chem 104 participants (study III) actually reported a statistically significant increase in usage of Wikipedia over the semester. The decrease in Wikipedia use for the experimental groups of study II may be a result of the participants' enhanced awareness of the limitations of wikis. However, this effect is clearly not present for Chem 104 participants (study III). These discrepancies between Chem 109 and Chem 104 students indicate that there is no concrete trend for general chemistry students at this time in regards to the effect of writing on Wikipedia usage.

Since the control groups were not given assignments in which they were required to use various resources to write about chemical concepts, it is not unsurprising that their resource usage would increase for the recommended class resource, i.e. the course textbook.

Reception of Writing Treatments

Student perception of the effectiveness of the wiki writing treatment was not strongly positive or negative (Table 5.10, items 1-3). This trend may be due to partcipants' distrust of the ChemWiki content (item 6) or their lack of enjoyment contributing to the wiki (items 4 and 8). It was expected that the students would struggle with adjusting to using wikitext, and various resources such as a student guide and a video tutorial were developed (see section 4.3) to abet these difficulties. However, participants still favored the traditional report over the wiki page assignment in both studies II and III (Table 5.11). The somewhat negative reception of the wiki writing treatment mirrors these difficulties with formatting (Table 5.12).

Data Tracking Analysis

During the course of study II, it appeared that a temporal effect was taking place between the first and second writing treatments as no treatment effect was observed in the first treatment but was present after the second treatment (see section 6.3.3). An overview of various web statistics of the two writing treatment time frames revealed a few disparities between the first and second writing treatments (Figure 5.7). First, the number of unique pageviews during the first treatment was significantly greater than during the second treatment. This trend is almost expected, as the students are gaining familiarity with the ChemWiki. However, the average time spent on each page increased during the second treatment, indicating a higher average engagement of the user for each page. Finally, a large decrease in the bounce rate further supports greater user engagement with the website. Together, these statistics indicate that although users are visiting fewer total pages, they are spending more time on each page. The increase in student performance on items concerning material related to the second treatment

suggests that higher engagement, rather than number of pageviews, may be contributing to greater learning.

At mid-semester, the treatment groups were switched so that students who were previously assigned to the wiki writing treatment (treatment 1 and 2) were then given the traditional report treatment (treatment 3 and 4). Conversely, students who wrote a traditional report for treatment 1 and 2 were assigned to write in the ChemWiki for treatments 3 and 4. The treatment history of these two distinct groups makes a direct comparison between the two groups unfeasible. However, similar trends to the first group of students were found during the second cycle of experimentation, although the effects seen during treatments 1 and 2 have substantially decreased (Figure 5.8).

As in the first cycle of experimentation, the bounce rate decreases over time. Also, the number of pageviews decreased from treatment 3 to treatment 4, indicating that students are visiting fewer pages during the course of the second iteration of the treatment. This trend may suggest that they are either a) spending more time per page or b) spending less total time on the ChemWiki. The increased average time on page indicates a higher level of engagement during the second treatment. In addition, an increased number of sessions with high page depth was observed for treatment 2 compared to treatment 1. This increase over time indicates that the visits students make to the ChemWiki in the second treatment are more engaged than in the previous cycle. A similar trend is seen for treatments 3 and 4. While the total number of sessions decreases from treatment 3 to 4, the number of high page depth sessions compared to low page depth sessions increases between treatment 3 and 4, again indicating higher engagement.

Based on these web statistics, it appears that in order for a significant treatment effect to be observable, a high level of engagement (low bounce rate, high average time on page, and high

page depth) may be a contributing factor to higher student performance for students who write on a wiki platform. Unfortunately, there is no practical means to measure level of engagement for traditional writing at this time. Since traditional writing also appears to increase student performance, these behaviors of increased engagement would be expected to also be linked to increased student performance.

5.7 Summary

This chapter focused the development and implementation of a pre- and post-study survey that was informative in measuring participants' self-concept, motivation, and attitude towards chemistry. The types of educational resources (digital and non-digital) participants generally utilize, and how these habits change over the course of a semester of general chemistry, was also described. In general, participant feedback on the wiki and writing treatments was negative due to the amount of time spent on each treatment. However, it appears that it is the increased engagement required of these assignments that actually influences student performance. The next chapter will detail the effect of the described treatments on student exam performance.

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Chapter 6

Quantitative Design and Analysis

of Student Performance in General Chemistry

The previous chapter detailed the implementation and qualitative aspects of a chemistry wiki in large lecture courses of general chemistry. In this chapter, a quantitative analysis of the efficacy of the chemistry wiki on student posttest scores will be described.

In order to meet the needs of students in large lecture courses, new learning tools that aid students in a critical analysis of course content should be a focal point of development for educational researchers. Given the limited interaction between instructors and students in large (N > 350) lecture courses, effective learning tools can be crucial in supplementing lecture-based classes. However, any new tool should be thoroughly analyzed for efficacy; if the tool is ineffective (or worse, detrimental), its use in the classroom may not be suitable for the goals of the course. This chapter will quantitatively evaluate the two types of writing on chemistry content mastery: 1) writing in which hypertext is utilized on a wiki platform and 2) writing without hypertext in a traditional, hard-copy report format.

6.1 Methods

During the course of this study, a pretest and posttest were used to evaluate student performance of the experimental and control groups. The instruments described below were developed prior to the beginning of study II (Chem 109, fall 2013).

6.1.1 Experimental Design

For studies II and III, two lecture sections were used, with one functioning as the experimental group and one as the control group. Study II was undertaken with two lecture sections of Chem 109, and study III was performed with two lecture sections of Chem 104. Both experimental and control groups took the same pretests and posttests. However, students

in the control group did not participate in any writing assignments in the lecture portion of the course.

Within the experimental group, two different writing treatments were assigned. Students assigned to the "wiki writing" groups wrote a wiki page with 3 other students on topics that were targeted on the posttest (coded as TW) or topics that were not targeted on the posttest (UW). Students assigned to the "traditional writing" group wrote a group report on topics that were targeted on the posttest (TR) or topics that were not targeted on the posttest (UR). During the course of Chem 109, four total cycles of experimentation were performed. A cycle consists of a) wiki page treatment or traditional writing treatment and b) posttest evaluation (see section 4.1.1). For the first two cycles, students were assigned to the same treatment type. At mid-semester (between the second and third treatment), the treatment groups were switched so that students in the wiki writing group were now assigned to write traditional reports and vice versa. This switch was necessary so that each student received exactly two wiki page treatments and two traditional report treatments during the semester. At the conclusion of study II, it was determined that having four assignments throughout the semester was too burdensome for the students, and the number of assignments was reduced from four to two assignments, one wiki page and one traditional report (Figures 6.1-6.2).

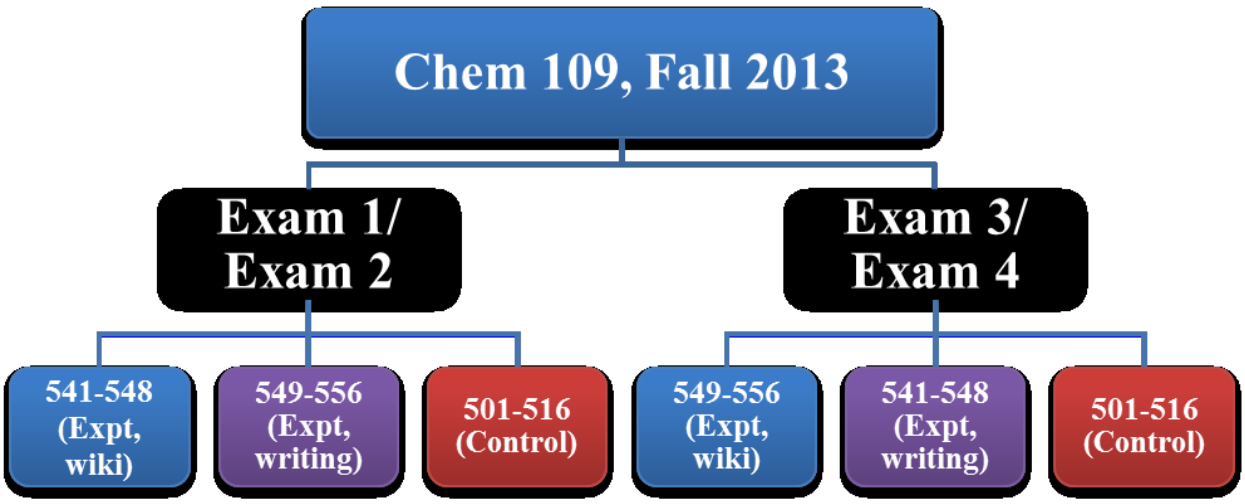

Figure 6.1. Rotating group design for study II (Chem 109, Fall 2013).

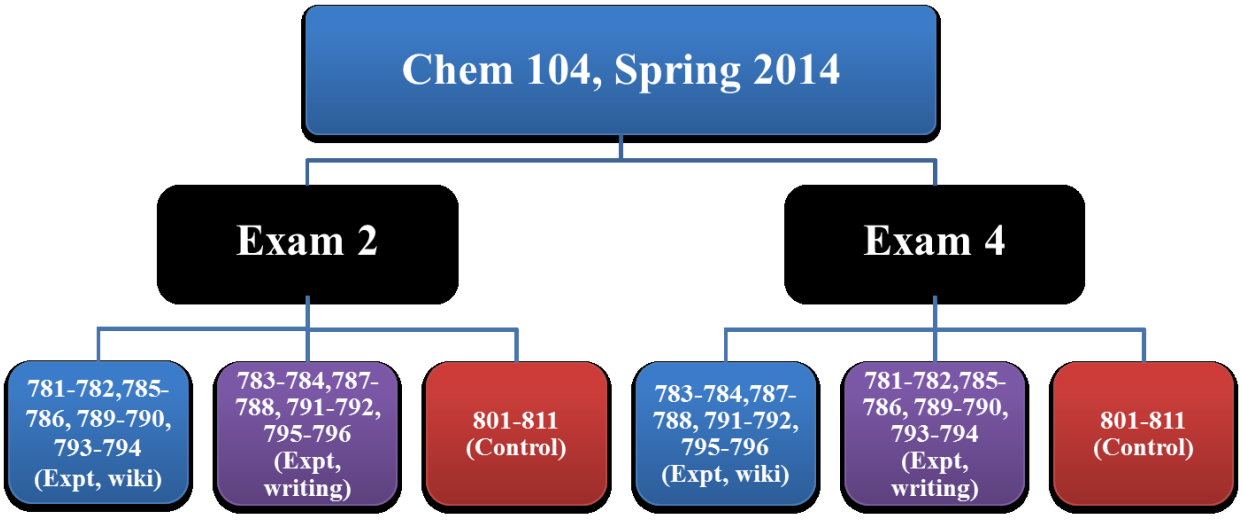

Figure 6.2. Rotating group design for study III (Chem 104, Spring 2014).

6.1.2 Designing an Instrument for Evaluation

Chemistry 109, an accelerated general chemistry course, covers all of the topics of a traditional two-semester sequence of general chemistry (Table 6.1). At the time that this study was being designed, only a few tools had been reported for assessing general chemistry posttest

scores.[1-4] Unfortunately, these assessments were either too lengthy or were not similar enough to the curriculum taught at UW-Madison. Therefore, a tool to assess the posttest scores of Chem 109 and Chem 104 topics needed to be developed. Two different studies of two general chemistry courses will be detailed in this chapter. Study II was performed with Chem 109, an accelerated one-semester general chemistry course. Study III was performed with Chem 104, the second semester of the standard two-semester general chemistry sequence taught at UW-Madison.

Exam 1	Exam 2	Exam 3	Exam 4
Atoms, Elements, and Chemical Reactions	**Molecular Structure and Bonding**	**Chemical Kinetics**	**Acids and Bases**
Atomic Structure	**Organic Molecules**	**Mechanisms and Catalysis**	**Acid-Base Reactions**
Periodic Trends	Organic Reactions	Thermodynamics	Buffers and Titrations
Ionic and Covalent Compounds	Biopolymers and Biomolecules	Chemical Equilibrium	Electrochemistry

Table 6.1. Overview of Chem 109 curriculum. Topics are divided by exam. Topics that were tested during this study are in bold.

At the beginning of this study (Chem 109, study II), the effect of writing about various topics was unknown. The curriculum of Chem 109 is quite diverse, and the effect of writing about learning concepts more algorithmic in nature (e.g. titration calculations) may vary significantly from the effects seen when writing on more conceptually-based curriculum (e.g. movement of electrons in organic chemistry mechanisms). We therefore elected to design four different posttests, one for each exam. It should be noted that because each of these instruments

assesses different chemistry concepts, student performance should be analyzed on a posttest by posttest basis.

Each posttest question (6 questions per posttest) was written in a similar style to questions found in *Chemistry: The Molecular Science* by Moore, Stanitski, and Jurs.[5] This textbook is used by both the experimental and control lecture. In addition, each question was individually proof-read and examined for conceptual relevance by the two instructors of the course, Prof. John Moore and Dr. Oana Martin, who concluded that they were valid questions for the assessment of general chemistry content knowledge. The validity and reliability of these instruments are discussed further in section 6.2.

During the course of study II, it was discovered that the time commitment of four writing assignments during the semester was burdensome for students. Therefore, the number of writing assignments was reduced to two per semester in study III (Chem 104). Although the majority of the questions used in study II were reused on the instruments used in study III, there were slight variations in course curriculum between Chem 109 and Chem 104, which required the development of new testing items. Therefore, with the exception of questions that were used for both Chem 109 and Chem 104, it is not appropriate to make direct comparisons between study II and study III (see section 5.1). The curriculum assessed for Chem 104 can be found in Table 6.2.

Exam 2	Exam 4
Organic Chemistry	Thermodynamics
Chemical Kinetics	**Acids and Bases**

Table 6.2. Overview of abbreviated Chem 104 curriculum.
Topics are divided by exam.
Topics that were tested for posttest scores are in bold.

Each posttest included 6 questions on the targeted concepts. Questions were further divided into conceptual (C) or algorithmic (A) types of questions.[6] Once the questions for the posttests were finalized, all 24 questions were assembled into a 24-question pretest. The administration of the pre- and posttests are discussed further in sections 6.1.4 and 6.1.5, respectively.

6.1.3 Solicitation of Participation

In order to participate in this research study, a potential participant was required to be enrolled in either lecture 1 or lecture 2 of Chem 109 during the fall 2013 semester. Lectures 1 and 2 were selected for study II due to each instructor's familiarity with the Chem 109 curriculum. The two instructors of these lectures (John Moore and Oana Martin) had taught Chem 109 concurrently in previous semesters and present the material in an identical sequence to each of their respective lectures. For study III, lectures 5 and 6 of Chem 104 (spring 2014) were chosen as the experimental and control lectures, respectively. Both lectures were taught by Dr. Linda Zelewski, who presented identical lectures to both lecture 5 and 6.

During the first class day (Fig. 6.3), a study team member (Jaclyn Brown) verbally read an IRB-approved recruitment prompt to each of the targeted lectures. The students of each of these lectures were informed that their participation in the research aspect of the study (i.e. release of personal information) was voluntary, but the assignments required during the course of the semester would be required regardless of whether or not they released their data to the study team. Consent forms were collected by Jaclyn Brown during either the discussion or laboratory period during the second week of classes. The approved IRB protocol, recruitment prompt, and

consent form are included in Appendix B. The participation rate of study II was 91%, while the participation rate of study III was around 69%.

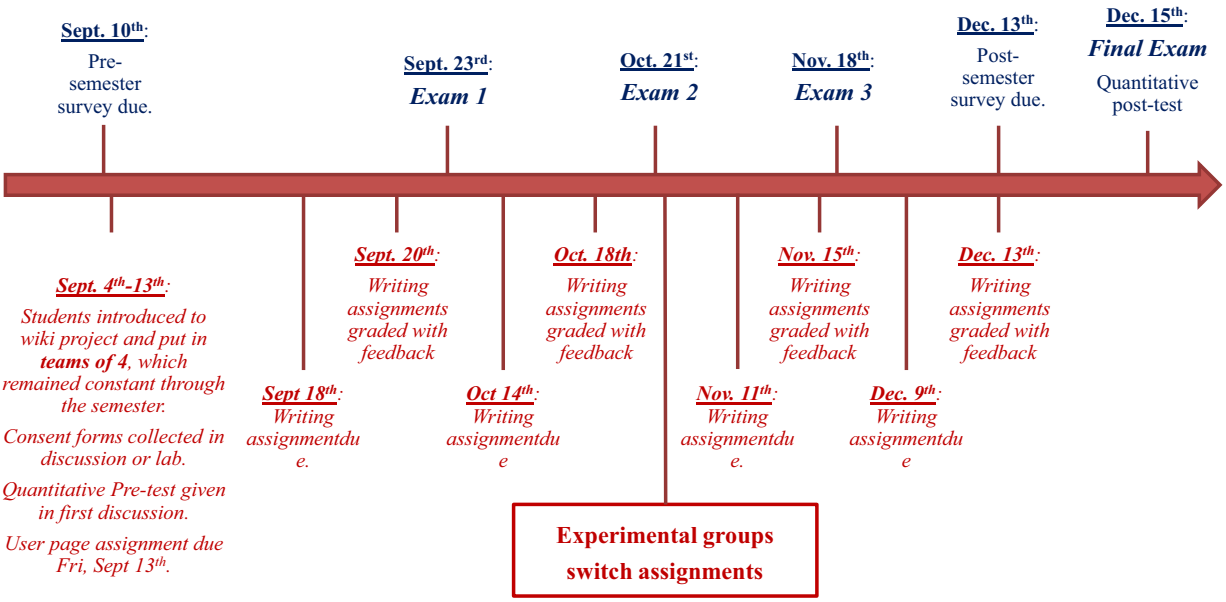

Figure 6.3. Timeline of study II (Chem 109).

6.1.4 Administration of Pretest

The pretest for study II was administered during the first laboratory period of Chem 109 (September 9th-13th, 2013). While it was preferred to administer the pretest in a setting more similar to exam testing (i.e. discussion), the instructors preferred to perform the pretest during the laboratory period since Chem 109 discussion only meets once a week. The pretest for study III was administered during the first discussion in the second week of the semester.

Pretests were administered by the teaching assistants of their respective discussions. Students were given 40 minutes to answer the 24 multiple choice question pretest. TAs were

given verbal and written instructions on how to administer the pretest (full proctoring instructions are found in Appendix D). TAs were instructed to tell their students the following items:

- [The students] need to turn in [their] scantron sheet AND the assessment.
- The material on this assessment is on concepts that [the students] will learn during Chem [104 or 109]; [a student] may not know the answers to all of the questions, and that's OK- just fill out the entire assessment to the best of [his] ability.
- [The students] will get full credit if [he] answers all 24 questions; [a student] will receive partial credit if [he] leaves questions blank. If [a student] does not know how to answer a question, [tell them to] give it [his] best guess.

The questions on the pretest were either identical or very derivative of questions on the posttest. To prevent pretests from being shared or "leaked" to other sections, the pretests were numbered and each TA was instructed to sign out and sign in each pretest that was distributed to a student. All pretests were returned and accounted for after all pretests had been administered. The pretests were compiled by Jaclyn Brown and sent to Testing and Evaluation Services on the UW-Madison campus. The scantron results were sent to Rachel Bain, Instructional Technology Specialist, who removed personally identifiable information (i.e. first and last name). These edited results were then sent to Jaclyn Brown for analysis.

6.1.5 Administration of Posttest

Each posttest was administered as part of the midterm exams. Since each posttest only consisted of 6 multiple choice questions, the posttest was easily incorporated into the beginning of each 80-minute (Chem 109) or 50-minute (Chem 104) exam. The students' answers were

again collected on scantron sheets and turned in to their instructor, who sent the scantron sheets to Testing and Evaluation Services. The scantron results were then emailed to Rachel Bain, who removed personally identifiable information (i.e. first and last name). These edited results were then sent to Jaclyn Brown for analysis. For study II, four posttests were administered over the course of the semester (exams 1, 2, 3, and the final exam). For study III, two posttests were administered during the semester (exam 2 and exam 4).

6.2 Validity and Reliability

The quality of an instrument of assessment is typically evaluated based on two factors: validity and reliability.[7,8] Validity evaluates whether or not the instrument is actually measuring what it is intended to measure (section 6.2.1).[9] Reliability measures the ability of groups of items to test for the same construct.[10] Reliability of the test items is discussed further in section 6.2.2.

6.2.1 Validity of the Instrument

To ensure that the questions on the pre- and posttests were valid measures of the content of Chem 109 and Chem 104, instructors familiar with the general chemistry curriculum were consulted and asked to evaluate if the questions were a) understandable with a clear, correct answer, b) factually correct, and c) representative of the content of the general chemistry curriculum (see Tables 6.1 and 6.2). Changes to the wording of some questions were incorporated into the final pre- and posttests. For each study, the pretest was used as a means to assess equivalency between the treatment and control groups, while the posttest was used as the metric for student performance (see section 6.2.2). When designing an instrument, it is prudent to examine common threats to internal validity. Internal validity evaluates whether any observed

differences between groups is a result of the treatment itself.[9] The common threats to internal validity (and their implications in this study) are discussed below.

Selection Bias: In our study, it was not possible to completely randomly assign students to each of the treatment groups due to the discussion sections being intact groups.[11] However, the selection of each section to a particular treatment (wiki writing group or traditional writing group) was random. Standardized math scores and pretest scores were also examined by analysis of variance (ANOVA) to determine if significant differences between each treatment group and the control group were present (section 6.3.1).

Experimenter Bias: Experimental integrity during collection of data is critical for valid inferential results. In order to eliminate experimenter bias, the same teaching assistants administered both the pre- and posttest for each study. No member of the study team had access to or collected any of the raw data; only after the scantron sheets were scored and identifiable information removed was the study team able to analyze participant data.

Instrumentation: Another aspect required for internal validity is the use of an appropriate and accurate instrument. The instrument, or in our study, the pre- and posttest, should be able to accurately measure the response variable in a reliable manner. The pretest and posttest were administered using a scantron sheet that participants used to bubble in their responses. These responses were recorded and tabulated by the UW-Madison's Testing and Evaluation Services to minimize errors in recording. The teaching assistants were also instructed to check that all 24 questions were answered on the scantron sheet after the pretest to avoid missing data. Data from the final exam was prepared by the Examinations Institute of the American Chemical Society and administered in an analogous manner.

Testing: If administration of the first round of testing results in participants responding differently in subsequent testing, then the testing itself may be the primary cause of differences in the response variable rather than the treatment itself. For this study, the questions of the pre- and posttests needed to be similar in content without being identifiable by the participants. To prevent participants from recognizing questions from the pretest, the pretest was administered for a strict time interval (40 minutes) and all pretests were collected immediately following administration. Questions were also modified slightly so that a simple memorization of the question's answer would not be useful for the posttest. At least four weeks elapsed between the administration of the pretest and the posttest.

History: During the course of an experiment, it is possible for intervening events to contribute to changes in the response variable. Both of our studies spanned an entire academic semester (12 weeks). Since the participants were obviously not isolated at this time, it is possible that personal events could contribute to the observed changes in individual responses. This limitation on internal validity is most pertinent to posttests that are administered later in the semester as more time has passed. In addition, the participants in these experiments were able to communicate with one another and might influence other participants' perception or approach to each of the writing assignments. However, any differences in history should occur on an individual basis rather than on a group basis. Since all participants experienced the same curriculum over the same time period (the fall 2013 semester for study II or the spring 2014 semester for study III), it is unlikely that the intact groups would experience a different history from one another.

Maturation: If a participant changes over the course of an experiment due explicitly to the passage of time, then maturation may pose a significant threat to internal validity. The length

of our experiment (12 weeks) may result in fatigue from the students, particularly towards the end of the semester. A control group was used for comparison in order to account for natural fatigue over the semester. Any maturation that occurs with the treatment groups would simultaneously occur with the control group, limiting any maturation effects on the treatment effect.

Selection-Maturation Interactions: When differences between subjects change over time, a selection-maturation interaction occurs. This type of interaction is problematic when there are major differences between subjects and the passage of time is experimentally problematic. Although the sample was not randomly selected, no significant differences between the treatment groups and the control groups were found, and a selection-maturation interaction is not expected to occur.

Regression to the Mean: Regression to the mean is a statistical phenomenon that can occur when many extreme values are present within a data set.[12] Participants who score extremely high or extremely low on the pretest tend to score closer to the sample mean when tested again. This effect is particularly relevant when the sample is asymmetrical or skewed. Inspection of the quantile-quantile (Q-Q) plots confirmed that all pretest and posttest scores were normally distributed. It is not expected that regression to the mean will be a significant effect in this study.

Experimental Mortality: A high attrition rate during the course of an experiment may result in non-representative results if the participants who finish the study have characteristics that make them more likely to endure the study (e.g. academic talent or higher motivation). During the course of study II, 33 participants (out of 344) discontinued Chem 109, a 6% attrition rate. In the fall 2013 semester, the overall attrition rate for students in Chem 109 was 10% for the

experimental lecture and 15% for the control lecture. In Study III, 5 out of 374 participants discontinued Chem 104, resulting in a 1% attrition rate. In the spring 2014 semester, the experimental lecture attrition rate was 15% while the attrition rate for the control lecture was 13%. All of the attrition rates of the participants (versus all enrollees) are significantly less than the overall attrition rates. The attrition rate of participants in our study can therefore be attributed to natural disenrollment rather than a response to the treatments themselves. However, it is also possible that the low attrition rate of participants in our study indicates that students who chose to participate in the study were overall more academically motivated.

Overall, the largest threats to internal validity in our study are selection bias and selection-maturation interactions since it was not possible to randomly assign participants to the treatment or control groups.

Another consideration is the quasi-experimental nature of this study. When designing a experimental study, random assignment is the "gold standard". Ideally, participants for the study sample would be selected randomly from the population of interest and randomly assigned to a treatment or control group.[13] However, in educational research, it is often not feasible to perform research studies with completely randomized samples. In most cases, pre-existing constructs (e.g. school district, classroom, discussion section, etc.) prevent random selection of participants. It would be impractical for some students in a classroom to be using a different instruction method than their peers, and it would be unethical if the treatment is beneficial or harmful. The presence of intact groups in educational research has resulted in the prevalent use of quasi-experimental designs.[14] A quasi-experiment differs from a true experiment in that it lacks random assignment of the sample. Random assignment minimizes differences between groups, since a participant has an equal likelihood of being assigned to the treatment group as the

control. However, in cases in which random selection of the sample is not achievable (e.g. educational research), careful inferences about the population can still be made. In order to make a meaningful comparison between treatment and comparison groups, differences in background characteristics must be minimal or accounted for (section 6.3.1).

6.2.2 Reliability of the Instrument

The reliability of an instrument is essential for reaching valid conclusions that can be inferred to a broader population. If the instrument is not reliable, then any differences (or lack of differences) between the treatment group and control group can be attributed simply to measurement error.[15] Cronbach's alpha (α)[16,17] is commonly used to test the claim whether there is a correlation between test items within a common construct, i.e. internal consistency. In this study, two types of questions were asked on the pre- and posttests; algorithmic (coded as "A") or conceptual (coded as "C"). Distinguishing between these two types of questions allows for differences to be detected between mathematically-based concepts and abstract concepts. Each item/question within the algorithmic or conceptual construct should correlate well ($\alpha > 0.7$) with other items in the construct in order to make the claim that the instrument is reliably measuring test scores on algorithmic and conceptual questions.

For each posttest, the items were designed to be either algorithmic- or conceptual-based questions. In order for each question group to be considered reliable, they must measure the same property (algorithmic vs. conceptual) to be internally consistant with one another (Cronbach's alpha ≥ 0.7). The internal consistancy of raw learning gains (posttest score minus pretest score) for each question group was investigated. When Cronbach's alpha was calculated using the raw learning gain formula, the learning gains did not have acceptable reliability ($\alpha <$

0.5). Using gain scores as a measure of learning has many known difficulties, specifically with low reliability when the pretest and posttest scores have a high degree of correlation.

The lack of internal consistency between conceptual and algorithmic questions may be attributed to a few causes. First, due to space and time constraints of incorporating the posttest into timed midterm exams, a relatively small number of questions (2-3 per algorithmic/conceptual construct per exam) was included. Reliability measures such as Cronbach's alpha are notorious for underestimating reliability when a small number of test items is used.[18] At the onset of this study, the ability to measure student responses accurately in a true testing environment (i.e. during a midterm exam) was more desirable than having a large number of testing items. The testing items were also designed to encompass general topics (e.g. algorithmic questions about chemical kinetics) because it was undesirable to measure a narrowly defined skill that could not be extrapolated to more general learning gains. As a result, the failed internal reliability of these constructs is not totally unexpected. Unfortunately, it does render an analysis based on conceptual and algorithmic questions inconclusive.

Since the pre- and posttests failed the test of internal consistency between algorithmic- and conceptually-based content, a straightforward and conclusive comparison between the two types of questions is not possible. The rest of this analysis will compare participant responses for all questions in the final exam regardless of their algorithmic or conceptual nature. The final exam consisted of questions selected directly from a second term ACS exam prepared by the Examinations Institute of the Chemical Education Division of the American Chemical Society.[19] The validity of these questions are established by the ACS Examinations Institute and were found to be reliable in this study with a Cronbach's alpha = 0.84.

In terms of interstudy reliability (Chem 109 vs. Chem 104), no reliability could be established quantitatively. The curriculum of Chem 109 and Chem 104 and the manner in which concepts were presented between the Chem 109 and Chem 104 instructors was sufficiently different that it would be ill-advised to make a comparison between the two studies. An individual analysis of study II and study III is more appropriate.

6.3 Analysis of Student Performance Using a Control Group

In order to determine if differences between the experimental group and control group exist, an analysis of each group's existing chemistry knowledge must be evaluated using a pretest. Once the groups are tested for equivalency, i.e. each group has an equivalent level of pre-existing chemistry knowledge, the effect of the writing treatments can be determined based on the analysis of posttest results. This section will detail the statistical analysis used to evaluate both pretest and posttest scores. Although initial data formatting was performed using Microsoft Excel, all statistical analyses were performed using RStudio (Version 0.98.953).

6.3.1 Using Analysis of Variance (ANOVA) to Find Differences in Background Characteristics

A number of methods can be used to determine if differences exist between two groups. When comparing two or more groups in which a quantitative outcome variable is being measured (e.g. pretest score), an analysis of variance (ANOVA) can be used to determine if the means of the different groups are different.[20] If there is a difference between the means of the different groups, ANOVA measures the extent to which these differences are due to variation within a single group versus variation between the different groups. The between-group

$$F = \frac{between-group\ variance}{within-group\ variance} = \frac{\sum_i n_i(\bar{Y}_i-\bar{Y})^2/(K-1)}{\sum_{ij}(Y_{ij}-\bar{Y}_i)^2/(N-K)} \quad (1)$$

n_i = number of observations in the *i*th group, $\bar{Y}$ = overall mean, $\bar{Y}_i$ = mean of group *I*,
Y_{ij} = the j^{th} observation in group *i*, K = number of groups,
N = total number of observations.

variability is divided by the within-group variability to yield the test statistic, F. If the variation between groups is relatively large compared to the variation within groups, the result is a large F value (eq 1).

If minimal background differences between the treatment and comparison groups are established, an analysis of the difference in posttest scores will be useful from an inferential perspective. For each study, an ANOVA was performed on pretest scores to determine if any pre-existing knowledge about the future chemistry concepts was present in a statistically significant amount. The results of these ANOVAs are presented in Table 6.3. Testing at an α level of 0.05 was used in an omnibus test (F-test) for differences between groups. If a difference between groups was detected, then a t-test between the regression coefficient of the control group and each treatment group was performed using a Bonferroni-corrected alpha level of 0.0125.[21]

Study	Content	F	p	Higher pretest score relative to control group *	Lower pretest score relative to control group *
Chem 109 (Study II)	**Exam 1**	**2.553**	**0.0381**	**Non-targeted writing (NR)**	None
	Exam 2	0.465	0.7612	None	None
	Exam 3	0.5115	0.7273	None	None
	Exam 4	0.63	0.6413	None	None
Chem 104 (Study III)	Exam 2	1.304	0.268	None	None
	Exam 4	1.432	0.227	None	None

Table 6.3. Analysis of variance (ANOVA) of pretest scores separated by exam content.
*** Performed at α = 0.0125 level**

ANOVA of pretest scores revealed differences between groups on exam 1 material. Only one treatment group (non-targeted traditional writing group, NR) scored statistically significantly higher than the comparison group. No other differences in pretest scores between the groups were observed.

Once the treatment groups and the comparison group were determined to be equivalent in general chemistry knowledge, an analysis of posttest performance was performed. Multiple factors can influence how well a student performs in general chemistry. Nordstrom has shown that three predictors, when used together, are successful at predicting 30-35% of the final course grades: high school GPA, SAT math subscore, and high school chemistry grade.[22] The inclusion of these criteria is discussed further in section 6.3.4.

6.3.2 Introduction to Multiple Regression Analysis

If multiple quantitative predictor variables are to be included in an analysis of student performance, a simple analysis of variance does not suffice. ANOVA is only capable of comparing treatment groups across categories and does not incorporate quantitative variables such as SAT math subscore. If quantitative variables are to be used, it is necessary to use an analysis of covariance (ANCOVA).[20] Likewise, if two or more quantitative dependent variables are used, then a multivariate analysis of covariance (MANCOVA) is applied.[23] When multiple covariates and independent variables are present, as is the case in this study, then a multiple regression framework can be utilized to detect differences between groups. In a multiple regression model, each independent variable is associated with a regression coefficient, β (eq. 2). The effect of x or z on the outcome variable is determined by the magnitude of β. For the

purposes of this analysis, x_n are n number of quantitative covariates (e.g. SAT math score), and z_m represents m number of categorical independent variables (e.g. treatment group).

When quantitative explanatory variables are used, it is possible that within each category, the predicted value of y is affected by the magnitude of the covariate. When a multiple regression is employed, any interactions between the quantitative and categorical variables must be tested for (eq 2).

$$E(y) = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 z_1 + \beta_4 x_1 z_1 + \beta_5 x_2 z_1 \quad (2)$$

E(post-test) = expected value of y
α = predicted value of y when covariates x_1 and x_2 equal 0.
β_1 = regression coefficient for covariate x_1
β_2 = regression coefficient for covariate x_2
β_3 = regression coefficient for dummy variable z_1
β_4 = regression coefficient for interaction between covariate x_1 and z_1
β_5 = regression coefficient for interaction between covariate x_1 and z_1

Equation 2 shows all possible terms in a "complete" regression model with quantitative variables x_1, x_2, and categorical variable z_1. However, all of these terms may not be necessary; there may be no statistical significance of the interaction terms, or a covariate may be redundant. Significance testing of the complete model to reduced models that do not contain certain terms is necessary to achieve an optimal regression model that best fits the data.

6.3.3 Assumptions when Using Multiple Regression Analysis

Before performing a multiple regression analysis, there are four assumptions that researchers should always confirm about their sample data in order to make valid generalizations to the population:[24]

1) The variables are normally distributed

2) The relationship between the independent and dependent variables is linear

3) The variables are measured reliably

4) The variables are homoscedastic

When these assumptions are not met, there is an increased likelihood of committing a Type I or Type II error.

Parametric tests such as regression require that each variable is normally distributed. Visual inspection of histograms and quantile-quantile (Q-Q) plots for each variable confirmed normality for posttest scores, SAT and ACT math sub-scores, and pretest score. Normality significance tests such as the Shapiro-Wilk test were not utilized to assess normality, as large sample sizes are known to inappropriately reject normality.[25]

Multiple regression analysis also requires that the outcome variable and independent variable have a linear relationship. Visual examination of the residual plots for each independent variable showed no evident curvilinearity.

In order for a multiple regression analysis to yield inferential conclusions, the items of the evaluative instrument must also be reliable. In psychometrics, reliability is a gauge of the amount of error in measurement, and any study from which inferences can be drawn must have a reliable instrument. The reliability of the instruments used in this study were found to be reliable with a Cronbach's alpha of 0.84 (section 6.2.2).

6.3.4 Selecting an Appropriate Model for Regression Analysis

Before beginning regression analysis of student performance, selecting a suitable model to base the regression on is necessary. The number of regression models that can be used to fit the data is dependent upon the number of variables that can affect posttest scores, e.g. treatment vs. control group, standardized test scores, or pretest scores. The explanatory variables that were tested in model optimization are elaborated on in this section.

SAT/ACT Math Subscores

Two of the most widely studied predictors of success in general chemistry are the Scholastic Aptitude Test (SAT) and the American College Testing (ACT) admissions exams.[26-28] These two tests are utilized almost universally as college admission criteria in the United States. Both tests include math subsections, and the math sub-score on the SAT (abbreviated in this study as SAT-M) and ACT (ACT-M) are well-known to be predictors of general chemistry course grades.[29] The University of Wisconsin-Madison requires either an SAT or the ACT score on its admission applications, although both testing scores may be reported on a student's application. Information about enrollees, also known as the Common Data Set (CDS) is released annually by UW-Madison for comparison to other universities in the US. According to the 2013-2014 CDS, 18% of students enrolled in the Fall 2013 semester reported an SAT-M score and 88% of applicants reported an ACT-M score. It is common for students in the Midwest to take the ACT as opposed to the SAT, and applicants to UW-Madison applying for the 2013-2014 academic year showed the same bias towards the ACT. ANOVA of both SAT-M and ACT-M scores for participants in the treatment and control groups were performed for study II and study III; no statistically significant differences between groups were found in either study.

Due to the large proportion of students reporting SAT-M scores but not ACT-M scores, a method of converting SAT-M to ACT-M scores and vice versa is necessary. For the purposes of this study, the 2013-2014 CDS data of all UW-Madison enrollees were treated as population data, and all inferences within this study will be focused on the population of UW-Madison as a large university (>30,000 students). CDS data was fitted to a Gaussian distribution and compared to the study sample data (Table 6.4). Normalizing participant data to UW-Madison enrollee data allows for a direct comparison of SAT-M and ACT-M data. Mean and standard deviations for each type of test are shown in Table 6.5.

Score Range	Score (Lower Bound)	CDS Cumulative %	Fit Cumulative %	Error
ACT Mathematics Score (broken into score intervals = 1)				
32-36	32	25.0	18.9	6.1
30-36	30	32.0	33.8	-1.4
26-36	26	75.0	69.7	5.3
24-36	24	91.3	83.7	7.6
18-36	18	99.4	99.1	0.3
12-36	12	100.0	100.0	0.0
SAT Mathematics Score				
750-800	750	25.0	21.2	3.8
700-800	700	44.9	42.2	2.7
620-800	620	75.0	77.9	-2.9
600-800	600	84.7	84.4	0.3
500-800	500	98.7	98.7	0.0
400-800	400	100.0	100.0	0.0
SAT Mathematics Score (broken into score intervals = 10)				
750-800	750	25.0	18.4	6.6
700-800	700	44.9	38.6	6.3
620-800	620	75.0	75.5	-0.5
600-800	600	84.7	82.5	2.2
500-800	500	98.7	98.5	0.2
400-800	400	100.0	100.0	0

Table 6.4. Comparison of CDS data for UW-Madison 2013-2014. CDS SAT and ACT data are reported in score ranges. A Gaussian fit of CDS data was used to predict the percentage of students who would score at the lower bound of a range in Study II. Error between fitted projections and Study II data is reported.

	Mean, $\bar{x}$	Standard deviation, s
SAT Math Subscore (SAT-M)	676.26	81.77
ACT Math Subscore (ACT-M)	28.21	4.29

Table 6.5. Mean and standard deviation for all enrollees at UW-Madison in fall 2013.

This concordance information can be used to determine a "z" math sub-score regardless of the type of admissions test the participant reported. If a participant reported both SAT-M and ACT-M scores, then an average of the two z-scores was used to determine an overall z-score for that participant (eq 3).

$$z_{Math} = \begin{cases} \dfrac{\text{ACT.M-28.21}}{4.29}, & \textit{If ACT math subscore present} \\ \dfrac{\text{SAT.M-676.26}}{81.77}, & \textit{If SAT math subscore present} \\ \dfrac{1}{2}\left(\dfrac{\text{ACT.M-28.21}}{4.29} + \dfrac{\text{SAT.M-676.26}}{81.77}\right), & \textit{If both ACT and SAT math subscores present} \end{cases} \quad (3)$$

Of the 544 participants in study II, 55 participants had both SAT and ACT math scores and served in validating the concordance method above. A plot of ACT and SAT math scores (Figure 6.4) for these participants yielded an $R^2 = 0.663$ ($p \leq 4 \times 10^{-7}$). The solid line y = x (perfect correlation) is present for comparison to the dashed line of best fit. In study III, 29 participants had both SAT and ACT math scores. The plot of ACT and SAT math scores for those participants resulted in an $R^2 = 0.503$ ($p < 0.0001$).

Our data supports the predictive power of the SAT-M and ACT-M score for student performance in both advanced general chemistry (study II) and second semester general chemistry (study III). An R^2 value of 0.404 ($p < 0.0001$) for study II indicates a strong, positive

correlation between the calculated z_{Math} score and final course grade. A moderate, positive correlation (R^2 = 0.314, $p < 0.0001$) between z_{Math} and final course grade was calculated for participants in study III.

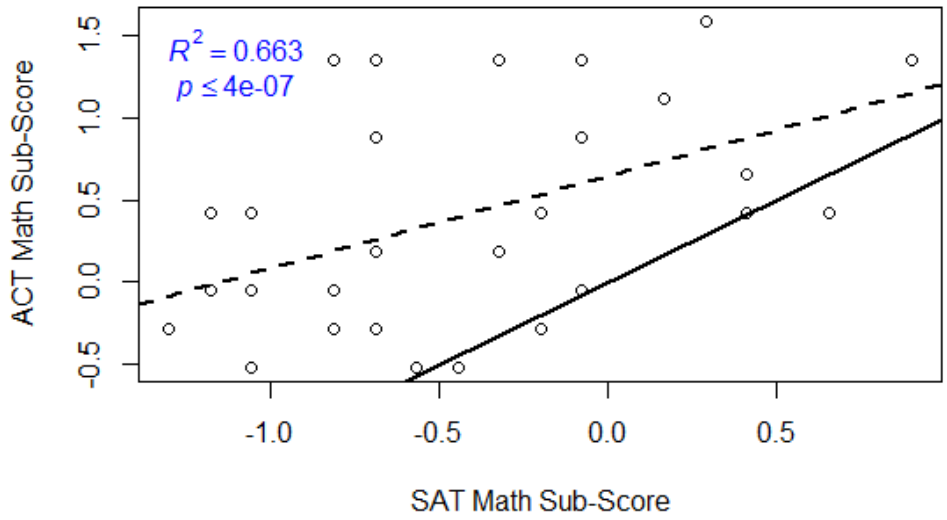

Figure 6.4. Concordance plot of participants with both a reported ACT and SAT math score (dashed line). Solid line indicates perfect concordance, $R^2 = 1$.

Pretest Score

The outcome variable in the analysis of this study is student posttest performance on a final exam acquired after treatment (or non-treatment in the case of the control group). A high pretest score might indicate a student's aptitude for the material presented in general chemistry, and it was expected that a student's posttest performance would correlate to his pretest score. However, weakly positive R^2 values (< 0.2, $p < 0.0001$) indicated that there is a weak or negligible correlation between pretest score and posttest score on the material on all four exams (Figure 6.5). However, these correlation data do not take covariance of z_{Math} into account, which should be considered when optimizing a regression model.

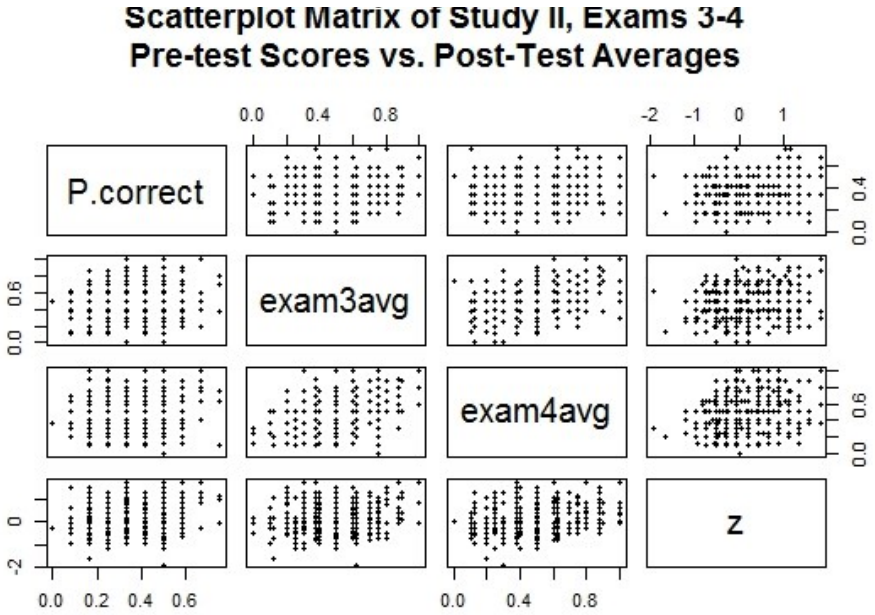

Figure 6.5. Scatterplot correlation matrix of pretest score, posttest averages for exam 3 and 4 material, and z_{math}.

No correlations between pretest score and z_{Math} were observed ($R^2 < 0.2$). The lack of correlation between pretest score and z_{Math} indicates that a student's inherent mathematical ability does not have an effect on his ability to perform well on the pretest.

Determining Regression Model of Best Fit

In order to obtain the optimal model for regression analysis, each variable was tested for significance by using a t-test (H_o: $\beta_i = 0$). A Bonferonni-corrected α level of 0.01 was used for model optimization. Pretest scores and standardized math test score were both found to be statistically significant predictors ($p < 0.01$) of posttest scores and were therefore included in the optimized model (see section 6.3.4). Interaction terms were also tested for significance, but were not found to be statistically significant ($p > 0.05$). Interactions between the treatment groups and

pretest score and standardized test score were therefore omitted from the optimized regression equation (eq 6).

$$E(post-test) = \alpha + \beta_1(z_{Math}) + \beta_2(pre-test) + \beta_3 z_1 + \beta_4 z_2 + \beta_5 z_3 + \beta_6 z_4$$

E(post-test) = expected value of post-test score
α = predicted post-test score when z_{Math} and pre-test score equal 0.
β_1 = regression coefficient for standardized math score
β_2 = regression coefficient for pre-test score
β_3 = regression coefficient for targeted concept wiki group (TW)
β_4 = regression coefficient for targeted concept writing group (TR)
β_5 = regression coefficient for non-targeted concept wiki group (NW)
β_6 = regression coefficient for non-targeted concept writing group (NR)

6.4 Multiple Regression Analysis of Student Performance

Once an optimized model was determined, regression analysis was performed with two semesters of general chemistry lectures. Study II (Chem 109\) and study III (Chem 104) posttest data were analyzed for differences between the control group and each treatment group.

6.4.1 Analysis of Chem 109, Fall 2013 (Study II)

To analyze posttest performance, the final exam questions were divided by content and coded as either exam 1, exam 2, exam 3, or exam 4 content. Each set of exam questions was analyzed for differences between the control group and each of the (wiki) writing groups. (See Table 6.6 for a complete list of assignments that each treatment group and the control group completed.)

Treatment Group	Code
Targeted Concept Wiki Page Writers	TW
Targeted Concept Traditional Report Writers	TR
Non-Targeted Concept Wiki Page Writers	NW
Non-Targeted Concept Traditional Report Writers	NR

Table 6.6. Codes used to identify writing treatment groups for regression analysis.

A t-test comparing each treatment group's regression coefficient versus the control group was then performed. This t-test compares the posttest score of each treatment group with the posttest score of the control group while holding other variables (pretest score, SAT-M, ACT-M) constant. A Bonferroni correction to account for the four different treatment groups led to a testing level of $\alpha = 0.0125$. Results of the analysis for material presented during exam 1 and exam 2 are presented in Table 6.7.

Exam 1: Stoichiometry (A) and Atomic and Molecular Structure (C)			**Exam 2: Organic Chemistry (C)**		
Treatment Group	Regression Coefficient, β	p-value	Treatment Group	Regression Coefficient, β	p-value
TW	-0.0145	0.455	**TW**	**0.808**	**< 0.001**
TR	0.00423	0.828	**TR**	**0.822**	**< 0.001**
NW	0.0498	0.0581	**NW**	**0.832**	**< 0.001**
NR	-0.00609	0.787	**NR**	**0.803**	**< 0.001**

Table 6.7. Comparison of posttest scores between the control group and various treatment groups. Statistically significant differences are highlighted in bold. T-test analysis comparing regression coefficients of the treatment group and control group was performed at the $\alpha = 0.0125$ level.

Analysis of the posttest of exam 1 material revealed no treatment effect of writing on exam performance. While two of the treatment groups performed better (TW and NR) and two groups performed worse (TR and NW) than the control group on the final exam, none of these differences between the treatment groups and control group are statistically significant. However, for exam 2 material, participants in all of the treatment groups (wiki writing and traditional writing groups) scored higher than the control group in a statistically significant fashion ($p < 0.001$). The regression coefficient, β, indicates the predicted difference between the treatment group and control group when z_{Math} and pretest score are controlled. Since the posttest score for each exam is an average of 6 questions, a change of 0.808 signifies that the posttest

score for the TW group is 80.8% higher than the predicted posttest score for the control group when z_{math} and pretest scores are controlled.

Halfway through the semester, treatment groups were switched so that all students had the opportunity to participate in both writing wiki pages and writing traditional reports during the course of the semester in accordance with the approved IRB protocol (Appendix B). For example, if a participant was assigned to write a wiki page for exams 1 and 2, he was assigned to write a traditional written report for exams 3 and 4. At the onset of this study, the effect (positive or negative) of each treatment was unknown, and it would be unethical for students in the same lecture to have different assignments contributing to their course grades. These circumstances require that the results of the exam 1 and 2 material be treated as separate experiments from the results of the exam 3 and 4 material. When analyzing the results of exam 3 and 4 material, it should be kept in mind that each group has already completed and is familiar with the alternative writing assignment, and the history (see section 6.2.1) of each treatment group is not uniform. Results of posttesting on exam 3 and 4 material are summarized in Table 6.8.

Exam 3: Chemical Kinetics (A) and Catalysis (C)			**Exam 4: pH Calculations (A) and Acids and Bases (C)**		
Treatment Group	Regression Coefficient, β	p-value	Treatment Group	Regression Coefficient, β	p-value
TW	-0.00606	0.702	**TW**	**0.528**	**< 0.001**
TR	0.00882	0.582	**TR**	**0.507**	**< 0.001**
NW	0.0.333	0.121	**NW**	**0.543**	**< 0.001**
NR	-0.0219	0.237	**NR**	**0.522**	**< 0.001**

Table 6.8. Comparison of posttest scores between the control group and various treatment groups after switching assignments at mid-semester. Statistically significant differences are highlighted in bold. T-test analysis comparing regression coefficients of the treatment group and control group was performed at the $\alpha = 0.0125$ level.

The same trend from the exam 1 and 2 material posttests was observed for exam 3 and 4 posttesting. On exam 3 material, participants in the treatment groups did not perform better than the treatment group in a statistically significant way. However, it should be noted that the targeted concept writing group (TR) and non-targeted concept wiki group (NW) did perform better than the control group while the targeted concept wiki group (TW) and the non-targeted concept writing group (NR) performed worse than the control group. While these results are not statistically significant, they do follow the exact pattern seen for exam 1 material.

Posttesting on exam 4 material also revealed a large, positive difference between the treatment groups and the control group. All four writing treatment groups exhibited a statistically significant ($p < 0.001$) better score on exam 4 material when compared to the control group. Again, the regression coefficient β indicates the predicted difference between the treatment group and control group when z_{Math} and pretest score are controlled. Since the posttest score for each exam is an average of 10 questions, a change of 0.528 indicates that the posttest score for the TW group is 52.8% higher than the predicted posttest score for the control group when z_{math} and pretest scores are controlled. This drastic improvement in the treatment groups' performance is identical to the trend seen for exam 1 and 2 material.

At this time, it is unclear which writing treatment is most effective in increasing student performance as all four writing treatments result in approximately equivalent increases in predicted posttest scores.

6.4.2 Analysis of Chem 104, Spring 2014 (Study III)

Many significant differences in posttest scores between the treatment and control groups were observed in study II. To discern if these effects were 1) reproducible, and 2) generalizable

to other general chemistry courses with different types of student populations, additional experimentation with another general chemistry class (Chem 104) was performed. Chem 104 consists of students completing a two-semester sequence of general chemistry rather than Chem 109, which is an accelerated one-semester general chemistry course. Chem 109 typically consists of academically gifted students who are normally younger than the population of students taking Chem 104. Thus, the motivations of Chem 104 and Chem 109 students can vary significantly (see section 5.2).

An analogous multiple regression analysis to that of study II was performed for study III. T-tests comparing each treatment group's regression coefficient versus the control group was performed using a Bonferroni correction to account for the four treatment groups ($\alpha = 0.0125$). Results of the analysis for the first two posttests are presented in Table 6.9. No statistically significant differences between the treatment and control groups were found during study III.

Exam 2: Kinetics (A) and Catalysis (C)			**Exam 4: pH Calculations (A) and Acids and Bases (C)**		
Treatment Group	Regression Coefficient, β	p-value	Treatment Group	Regression Coefficient, β	p-value
TW	-0.0551	0.035	TW	0.0141	0.642
TR	-0.0219	0.464	TR	0.0436	0.098
NW	-0.0587	0.031	NW	0.0215	0.454
NR	0.0127	0.655	NR	0.0542	0.048

Table 6.9. Comparison of posttest scores between the control group and various treatment groups. T-test analysis comparing regression coefficients of the treatment group and control group was performed at the $\alpha = 0.0125$ level.

6.5 Discussion of Findings

ANOVA of pretest scores (section 6.3.1) rendered a few differences between groups. For exam 1 material (study II), only one treatment group (non-targeted traditional writing group, NR) scored statistically significantly higher than the comparison group, which indicates that this

treatment group possessed considerably more knowledge about the content on exam 1. This observation has implications for measuring posttest scores. The high performance of the NR group could indicate a higher aptitude for learning exam 1-specific material, and a higher posttest score could result. This situation makes a straightforward analysis of exam 1 content difficult for the NR group in the analysis of exam 1 material. However, no other differences in pretest scores between the groups were observed.

Posttest Scores for Study II

When analyzing posttest scores in study II, a drastic change in performance between the treatment groups and the control group occurred between the first cycle of experimentation (exam 1 and 3 material) and the second cycle of experimentation (exam 2 and 4 material). This change may be attributed to a temporal effect within the treatment groups. As the participants became more familiar with the writing medium to which they were assigned, the participants spent less time on formatting and troubleshooting issues and more time on writing higher quality wiki pages or traditional reports. Feedback on the post-study survey revealed that the participants appreciated the utility of the wiki assignment once they became accustomed to using wikitext (see section 5.2.7).

It is entirely possible that the change in differences between the treatment and control groups on the exam 1 and 2 material is due to the difference in material presented on exam 1 (stoichiometry and atomic and molecular structure) versus material presented on exam 2 (organic chemistry). Investigation into the temporal effect of the writing treatments using the repeated material was not feasible for this study since the posttest was incorporated into the course exams in order to prevent testing issues from the participants (see section 6.2.1, "*Testing*"). The

reproducibility of the "delayed treatment effect" of exam 1/2 material versus exam 3/4 material suggests that the time effect of the treatment is more significant than the content of the material being utilized during the treatment. However, investigation into whether the differences between the treatment and control groups are maintained when the same material is used is a worthwhile objective.

The wiki writing groups (TW, NW) to the traditional writing groups (TR, NR) were also compared to see if either writing method resulted in a larger increase in posttest scores. Four pairwise comparisons between each of the four treatment groups were also performed, but no comparisons yielded statistically significant ($p < 0.0125$) differences between treatment groups.

It should also be noted that the targeted concept writing group (TR) and non-targeted concept wiki group (NW) did perform better than the control group while the targeted concept wiki group (TW) and the non-targeted concept writing group (NR) performed worse than the control group. While these results are not statistically significant, they do follow the exact pattern seen for exam 1 material. A stronger treatment (e.g. less time between treatment and posttest) or more powerful instrument (e.g. a longer pre- and posttest) may uncover statistically significant results that are not significant for the current study.

Posttest Scores for Study III

The lack of differences in performance between the treatment and control groups in study III has a few possible causes. First, inherent differences in the populations that were not accounted for in the regression analysis (e.g. personality or motivations) may be confounding the analysis. It is recommended that future studies incorporate these variables into the analysis. Another key difference between study II and study III is the difference in time between the

treatment and posttest. During study II, it was determined that four treatment cycles during the semester was burdensome for the students. The number of treatment cycles was therefore reduced to two treatments (one wiki page assignment and one traditional report assignment) during the semester. The students also had more time to complete these assignments (approximately 6 weeks), lengthening the time between treatment and the posttest. This larger time gap and the resulting lack of differences between the treatment and control group suggests that temporal effects may have a large effect on posttest scores, similar to what was observed during study II.

6.6 Summary

Quantitative analysis of posttest performance for participants utilizing different writing treatments yielded a few unanticipated results. In study II, participants who wrote about chemical concepts on both types of media (wiki or a traditional report) improved their posttest scores in reference to the control group. This treatment effect appears to be intrinsically temporal in nature; the treatment effect increases (by way of posttest improvement) over time. Although there was no treatment effect for the first treatment, statistically significant, positive effects after the second treatment were observed for all treatment groups when compared to the control group. This time-dependent improvement on posttest scores was repeated when writing treatments were switched at mid-semester. The second series of experiments in study II also yielded the same result of no treatment effect for the first treatment followed by statistically significant, positive effects during the second treatment for all treatment groups when compared to the control group. Study III, which was performed with students taking second-semester general chemistry, showed no statistically significant effect of writing on posttest performance.

This lack of differences could be attributed to a few factors (student motivation, aptitude, temporal effects) that warrant further investigation. In both study II and study III, no statistically significant negative effects on posttest performance were detected for any of the treatment groups. For instructors who wish to implement writing as part of their curriculum, it appears that utilizing writing assignments in both traditional formats or on a wiki platform does not diminish student performance. It is unclear at this point if wiki or traditional writing is superior, but both studies confirm that participants in the writing treatments scored as well (or better) than those who did not write about chemical concepts to further their knowledge.

6.7 References

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Chapter 7

Summary and Future Directions

7.1 Summary and Implications of the ChemWiki Study

Section II of this thesis described the development, implementation, and evaluation of a student-generated chemistry wiki in large (>300 students) general chemistry courses. The theoretical framework for using a wiki as a learning tool is based in the ideas of social constructivism and the principle that "A concept is not fully developed until it is represented in words."[1] The collaborative nature of using either a wiki (on a lecture scale) or writing traditional reports (on a scale of 3-4 students) reinforces the social nature of knowledge building as communities.

Over the course of three semesters, lecture-wide ChemWiki websites were developed for three separate lectures of Chem 104 (studies I and III) and Chem 109 (study II). The pilot study (study I, Chem 104) identified key issues to address in future implementations of ChemWikis in general chemistry courses. First, wiki pages are more likely to be cohesive to both the writers and the readers of the page when the page is written collaboratively among a small group of students. Secondly, significant measures such as thoroughly written instructions and video tutorials are necessary to initiate new users to editing wikitext. The implementation of appropriate introductory materials greatly reduces the logistical issues of constructing a ChemWiki on a large scale.

Each ChemWiki was filled with original hypertext from students in each respective course. Studies II and III were conducted with Chem 109 and Chem 104 students, respectively. In these studies, students who were assigned to write wiki pages were tasked with writing an original hypertext with three other students. By working collaboratively with their team members and cooperatively with other teams of students in their lecture, students constructed a purely student-generated chemistry wiki (>300 students). Students in studies II and III were also

assigned to write traditional reports, again in teams with three other students. These writing treatments were evaluated for their effectiveness in increasing student performance on sections of general chemistry mid-term exams.

At the onset of this study, three research questions were proposed:

1) Does the use of wiki and non-wiki writing affect student perceptions of chemistry?

2) Do students who compose original hypertext about chemical concepts perform better on general chemistry exams than students who do not write about chemical concepts?

3) Do students who compose original hypertext about chemical concepts perform better on general chemistry exams than students who compose original, non-hypertext writing?

Chapter 5 addressed the first of these research questions. Students in Chem 109, an accelerated general chemistry course which typically attracts more academically capable students, generally improved their chemistry self-concept over the course of the semester regardless of whether they were assigned to the treatment or control group. As a result, it appears that the increase in Chem 109 students' perception of their abilities in chemistry cannot be attributed to a treatment effect due to the same effect being observed in the control group. In contrast, Chem 104 students began the semester with a lower chemistry self-concept than Chem 109, and it appears as though the experimental treatment performed by the writing groups actually decreased student confidence in their ability to participate in chemistry discussions when compared to the control group. These results emphasize that the characteristics of the student

population undergoing the writing treatments are critical when determining the impact of (wiki) writing as a learning tool.

The evaluation of student performance in general chemistry also revealed a few interesting findings in regards to the second and third research questions. Upon implementation of a pretest and posttest, higher posttest scores were observed for experimental group participants than for control group participants in study II (Chem 109). However, this observation was not seen in study III (Chem 104); no statistically significant differences were found between the experimental and the control groups. This result highlights the possible impact that factors such as chemistry self-concept may have on the efficacy of a writing treatment. It is possible and likely that other factors beyond chemistry self-concept such as attitude, beliefs, interests, values, self-efficacy, and self-esteem have an appreciable effect on the utility of writing for students. The populations of Chem 109 and Chem 104 vary significantly in terms of demographics and chemistry self-concept, and the lack of a treatment effect for Chem 104 participants in study III reinforces the importance of these other factors.

Within study II, participants in all experimental groups did improve their performance on material written about concepts that were presented later in the semester. This trend, regardless of the type of material that was presented, was observed during each half semester of study II. These findings suggest that there may be a temporal effect of writing-to-learn. It is possible that factors such as becoming familiar with the wiki platform, team members, and assignment format are necessary for writing treatments to be advantageous. Although all treatment groups exhibited higher posttest scores than the control group after their second cycle of experimentation, no detectable differences were found between the various treatment groups (targeted wiki writers,

targeted report writers, non-targeted wiki writers, and non-targeted report writers). These results suggest that writing about chemical concepts, in any form, may increase student performance.

For educators wishing to implement assignments that increase student performance, these combined results suggest that writing can be used as a powerful tool for learning. A few considerations for implementing writing assignments into large classrooms should be taken into account:

- Characteristics of the student population should be considered. Writing treatments are more likely to be advantageous when used by students with higher chemistry self-concept.
- More than one writing assignment should be given per semester.

7.2 Future Directions

This study utilized large lecture courses of general chemistry. While general chemistry lectures were chosen for their large sample sizes, many other chemistry courses could benefit from the use of writing assignments as a tool for increasing student performance. Organic chemistry lectures are often quite large at UW-Madison (>200 students), and the creation of a student-generated chemistry wiki is quite feasible. Based on the results of this study, even smaller classes could benefit from the use of writing assignments. Although a large number of contributors is ideal when constructing a comprehensive chemistry wiki, both the wiki page and traditional report assignments were performed in teams of four students. Both types of assignments were found to be effective for increasing student performance and can be utilized by smaller classes as well. These assignments required not only summaries of chemical concepts but incorporated the creation of original practice problems as well. By putting on the “teacher’s hat”

and considering how the instructor would approach evaluation, students could be transitioning between the task of solely recounting knowledge and applying their knowledge in a meaningful way. This dual skill set would be well suited for courses beyond general chemistry, such as organic, inorganic, physical, and analytical chemistry. McNeil *et al*.[2] reported generally positive reviews of using wikis in graduate chemistry courses, and the implementation of the types of writing assignments described in this study in graduate courses would be worthy of investigation.

One of the observations of this study is the difference in treatment effects between study II and study III. In terms of chemistry self-concept, the two samples used in each study were quite different. Participants in study III exhibited an overall lower chemistry self-concept than participants in study II; subsequently, no treatment effect was found for participants in study III. Chemistry self-concept is defined as the "Evaluation an individual makes and customarily maintains with respect to himself or herself in general or specific areas of knowledge."[3] Bauer[4] has developed a valid and reliable questionnaire for various constructs of student attitude, including chemistry self-concept. The Chemistry Self-Concept Inventory (CSCI) is a 40-item survey that assesses a student's self-perception of his ability to learn chemistry. The complete CSCI survey takes 10 minutes to complete. Since this study investigated other factors (e.g. study resources used, feelings towards the ChemWiki) in addition to chemistry self-concept, an abbreviated version of the CSCI was used in this study. However, for educators seeking to evaluate only chemistry self-concept, it is recommended to use the CSCI in its entirety. It is likely that a group of students with a higher chemistry self-concept will see more tangible positive effects from writing assignments like those described in this study, and an investigation into whether self-concept correlates with student performance would be worthwhile.

Perhaps the most interesting observation of this study is the possible temporal effect observed in study II. In both halves of study II, the first cycle of experimentation was found to have no significant effects on the treatment group when compared to the control group, while the second cycle revealed a dramatic, positive treatment effect for all experimental groups compared to the control group. While this pattern could be attributed to different content being presented during each treatment cycle, the reiteration of this delayed effect is seen for two different groups of participants. This delayed effect is most likely a result of students adapting to the format and procedure of writing wiki pages or traditional reports. While these time-based effects are intriguing, it is not possible within this experimental design to discern the origin of these effects. Valuable future studies could be performed by exerting experimental control of the time students spend on their wiki or writing assignment. This type of experimental design would require isolating participants to work in teams together to complete their respective writing assignments. Conversely, a follow up study applying statistical control by using time spent writing as a covariate for predicting posttest performance would be prudent. Ideally, data logging software could be used to count and record the amount of time each user spends actively writing (in the case of hypertext writing on wiki pages). However, for traditional writing, self-reported time measurements would be necessary. In either case, a quantitative measurement of time spent on the assignment would lend great insight into the effect of time on the observed treatment effects found in this study.

Concluding Remarks

This thesis has detailed the application of writing as a learning tool in both hypertext and non-hypertext environments. Both of these methods aid in increasing student performance in general chemistry when applied more than once. While there are many online learning tools that

students may use to enhance their studies, the process of producing their own learning aids gives students the opportunity to learn through communication and language. Given the increasing interest and prevalence of free online technology, using tools like wikis to enhance the learning experience in undergraduate environments provides a forum that is as useful as traditional writing methods for students in large lecture courses.

7.3 References

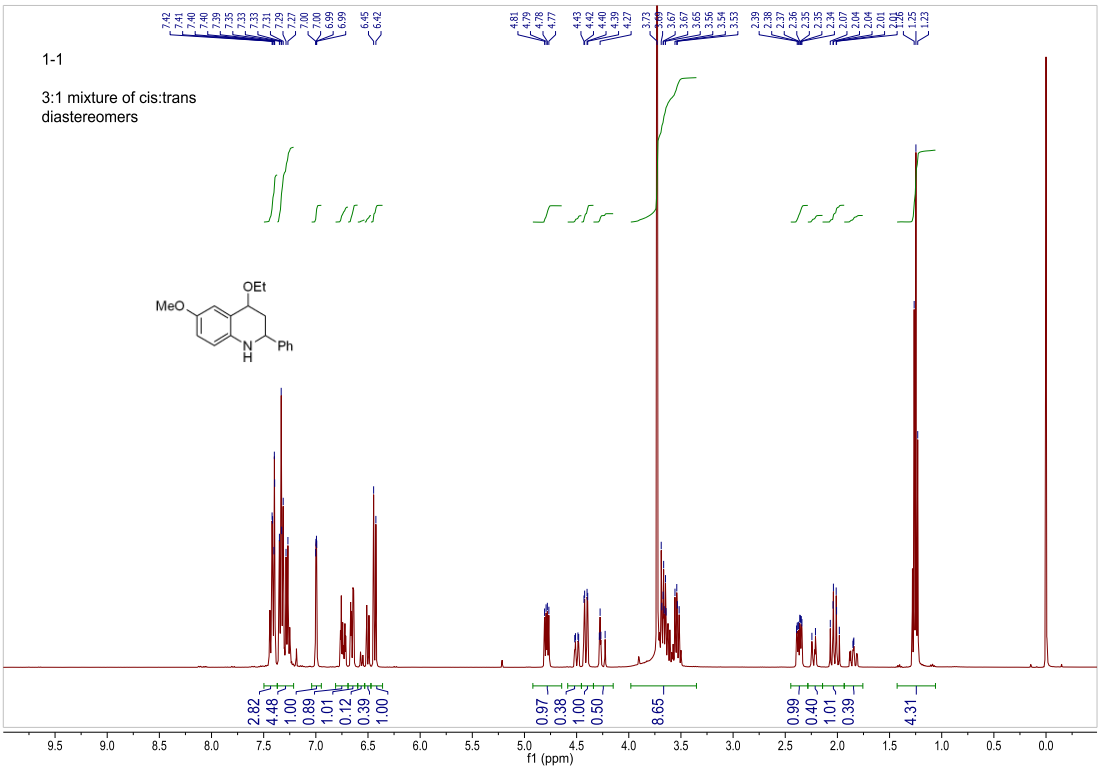
(1) Cakir, M. *Int. J. Env. Sci. Educ.* **2008**, *3*, 193-206.

(2) Moy, C. L.; Locke, J. R.; Coppola, B. P.; McNeil, A. J. *J. Chem. Educ.* **2010**, *87*, 1159-1162.

(3) Bauer, C. F. *J. Chem. Educ.* **2005**, *82*, 1864-1870.

(4) Bauer, C. F. *J. Chem. Educ.* **2008**, *85*, 1440-1445.

Appendix A: Characterization Data for Synthesis of Quinolines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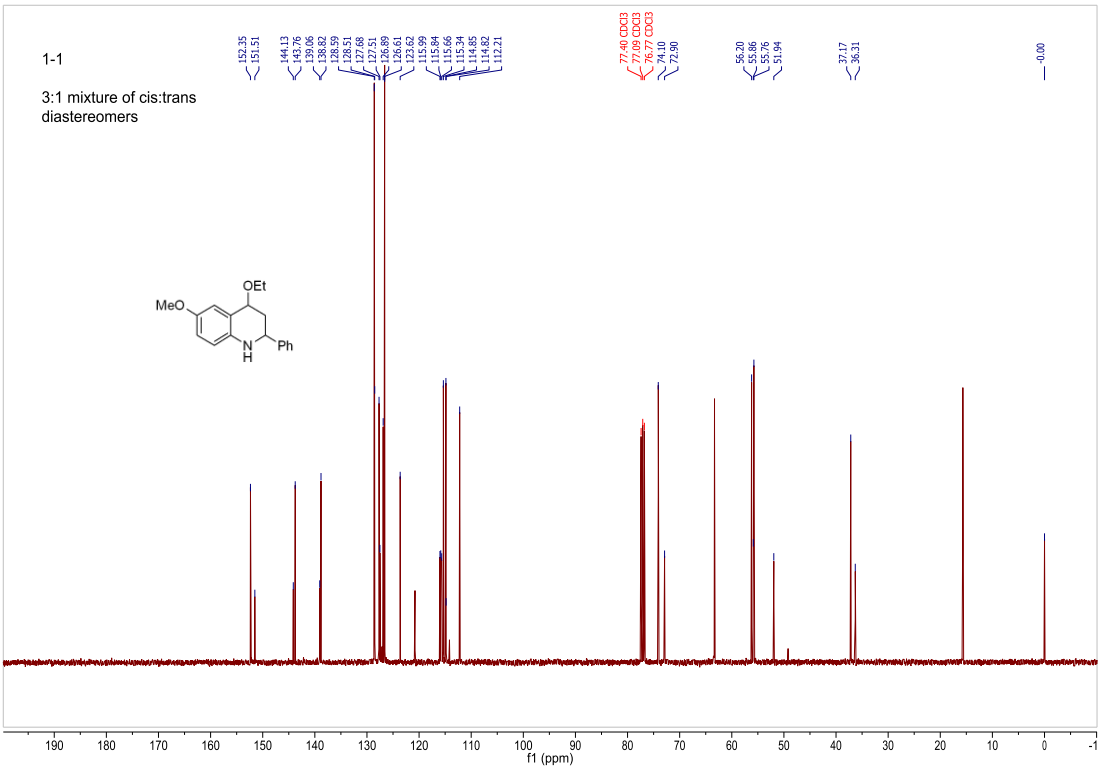
3:1 mixture of cis:trans
diastereomers
OEt
MeO
N
H
Ph
f1 (ppm)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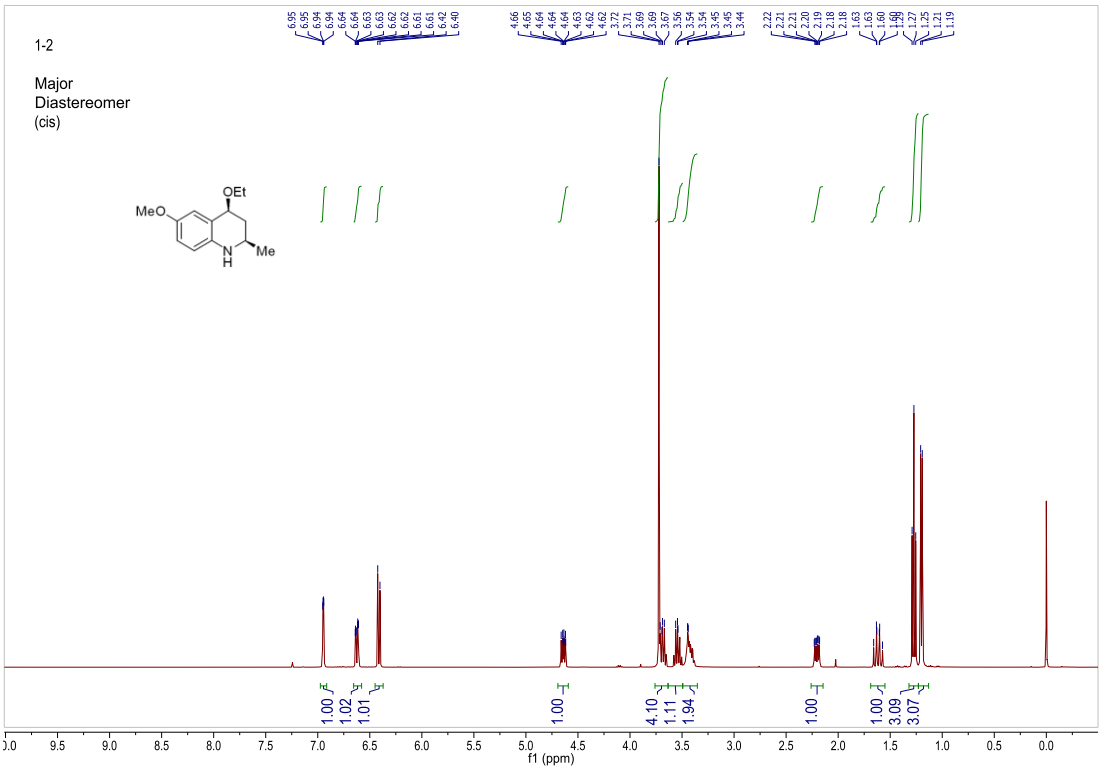
3:1 mixture of cis:trans
diastereomers
OEt
MeO
N
H
Ph
f1 (ppm)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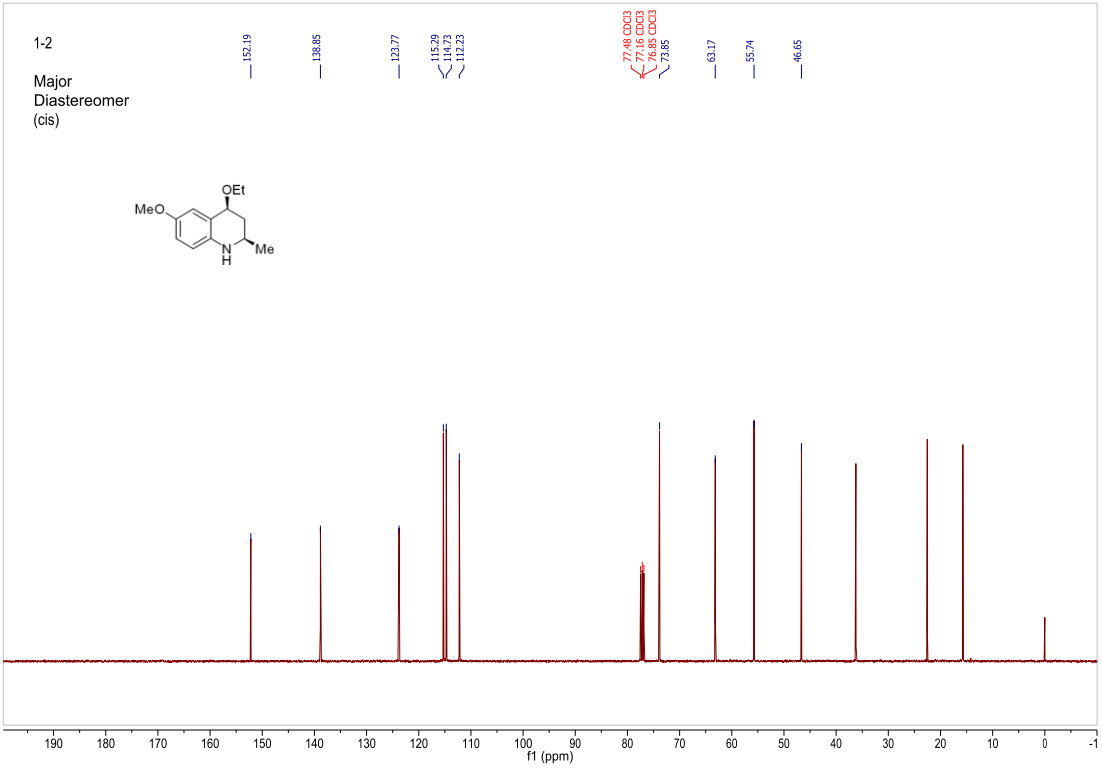
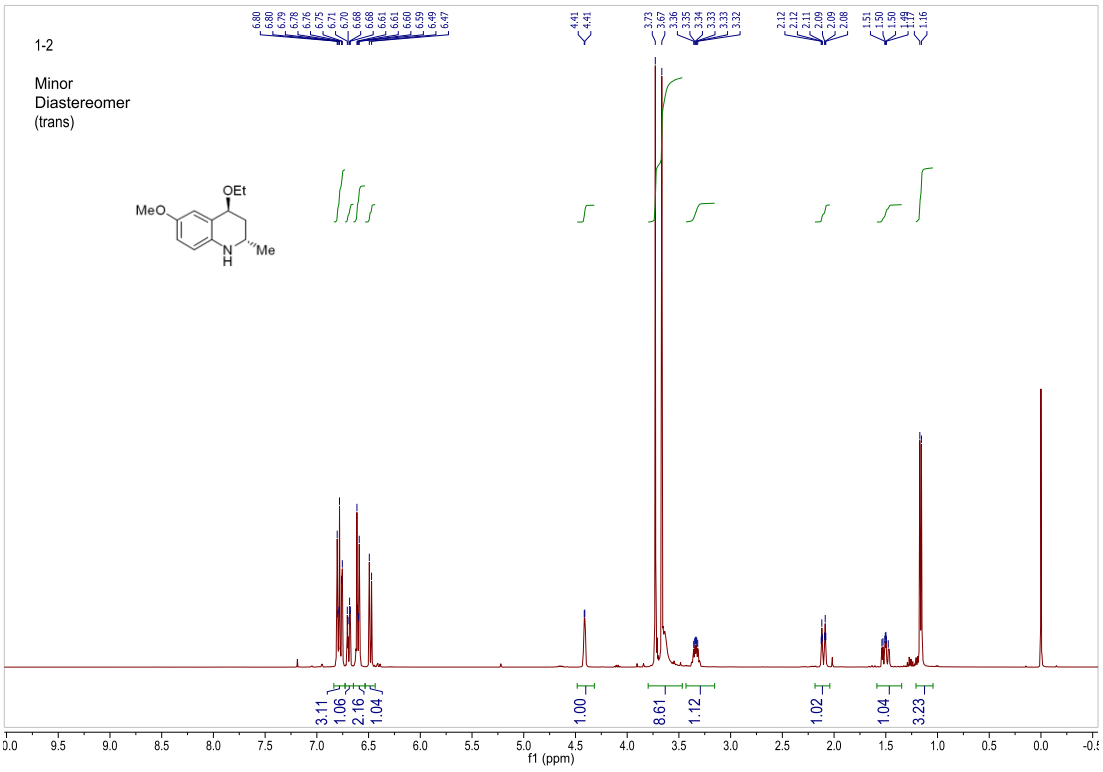
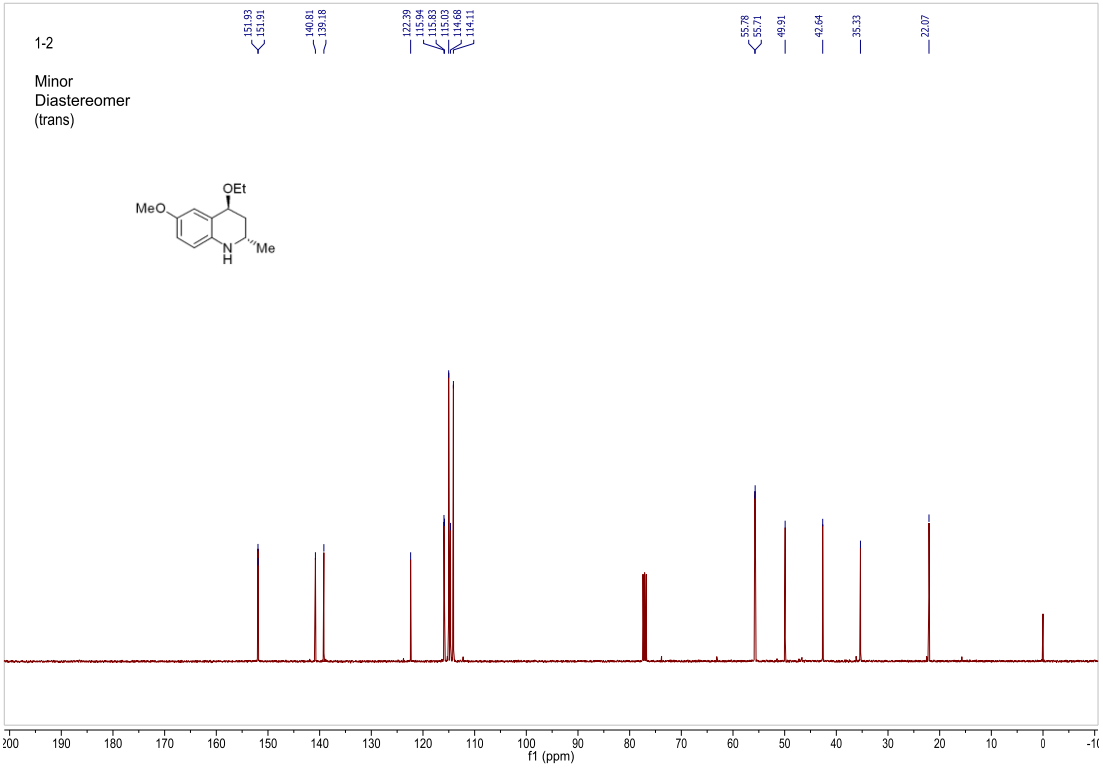
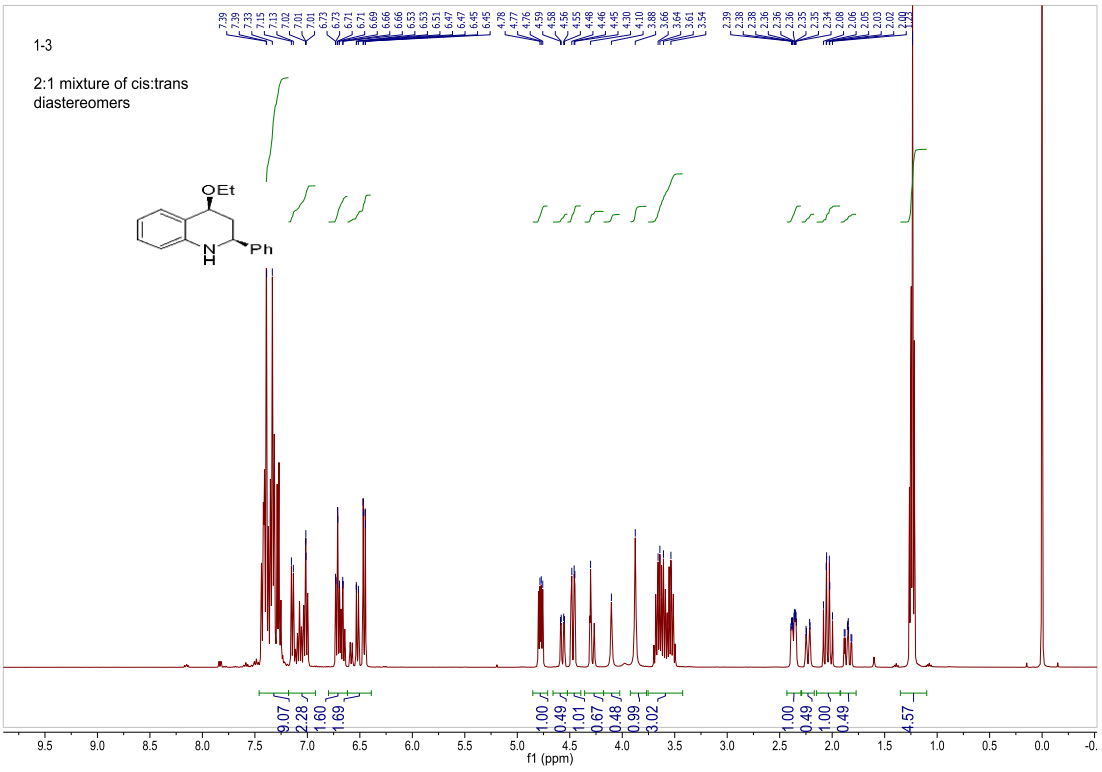
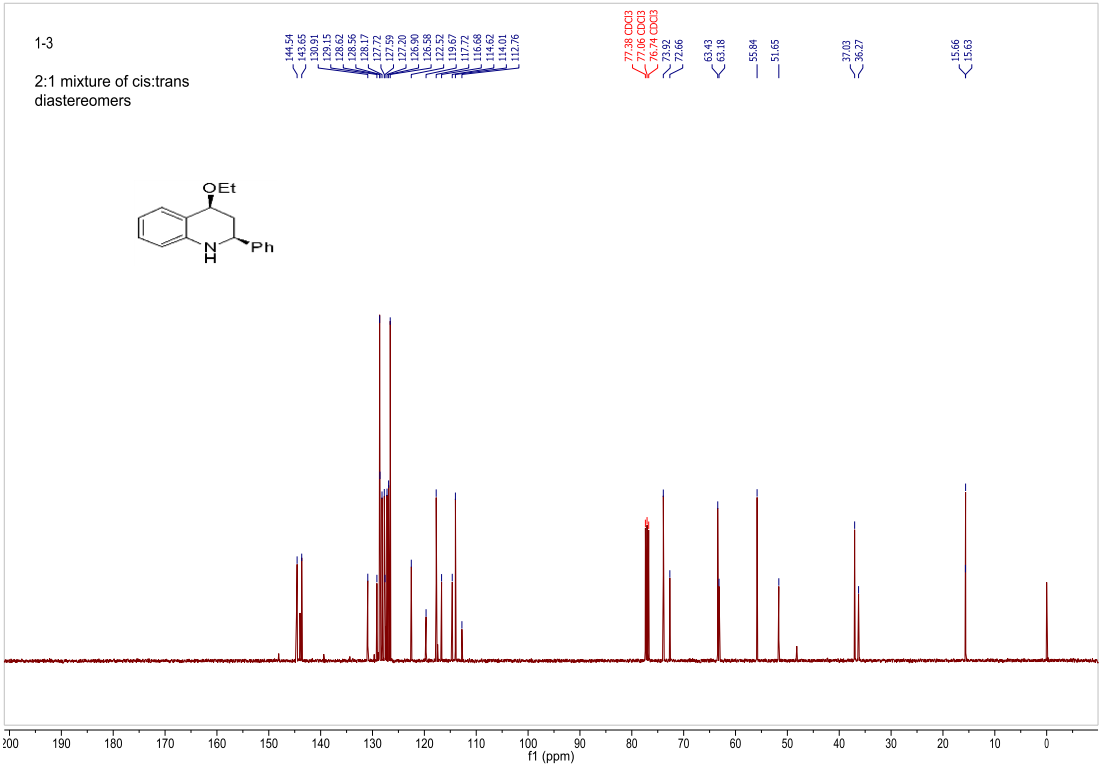
Major
Diastereomer
(cis)
OEt
MeO
N
H
Me
f1 (ppm)


1-2
Major
Diastereomer
(cis)
OEt
MeO
N
H
Me
152.19
138.85
123.77
115.29
114.73
112.23
77.48 CDCl3
77.16 CDCl3
76.85 CDCl3
73.85
63.17
55.74
46.65
f1 (ppm)


1-2
Minor
Diastereomer
(trans)
OEt
MeO
N
H
Me
f1 (ppm)


1-2
Minor
Diastereomer
(trans)
OEt
MeO
N
H
Me
f1 (ppm)


1-3
2:1 mixture of cis:trans
diastereomers
OEt
Ph
N
H
f1 (ppm)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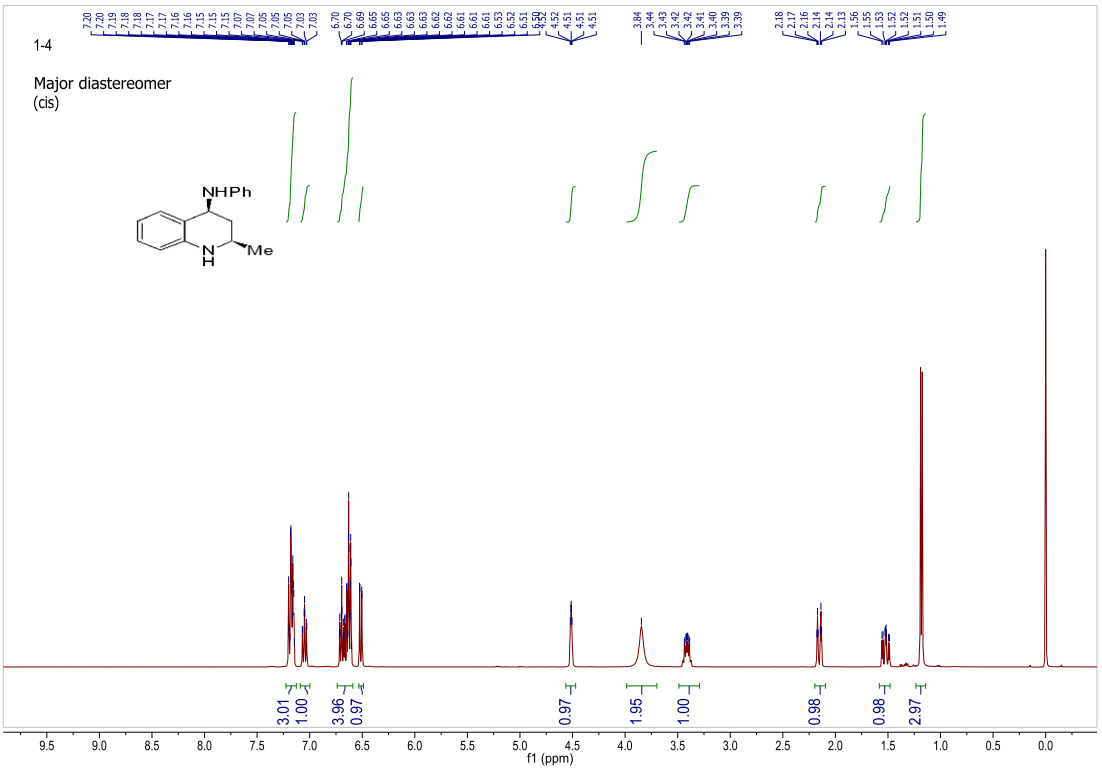
2:1 mixture of cis:trans
diastereomers
OEt
Ph
N
H
f1 (ppm)


1-4
Major diastereomer
(cis)
NHPh
N
H
Me
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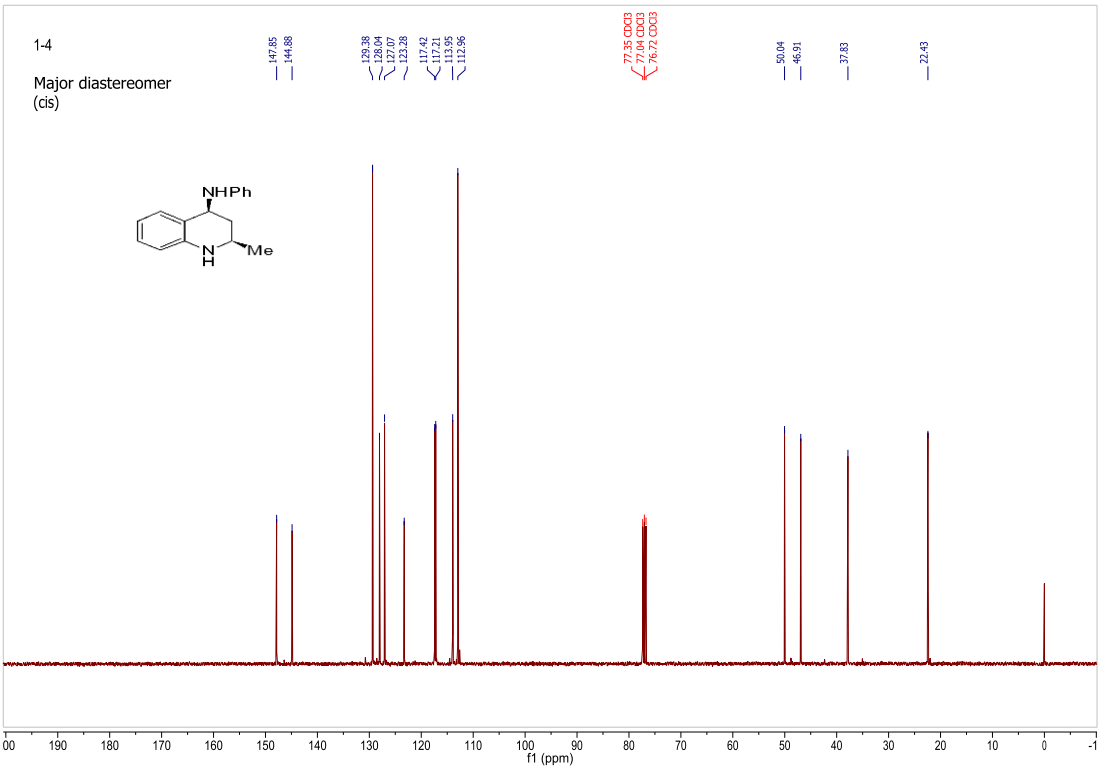
1.00
3.96
0.97
0.97
1.95
1.00
0.98
0.98
2.97
f1 (ppm)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Major diastereomer
(cis)
NHPh
N
H
Me
147.85
144.88
129.38
128.94
120.07
123.28
117.42
117.21
113.95
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77.35 CDCl3
77.04 CDCl3
76.72 CDCl3
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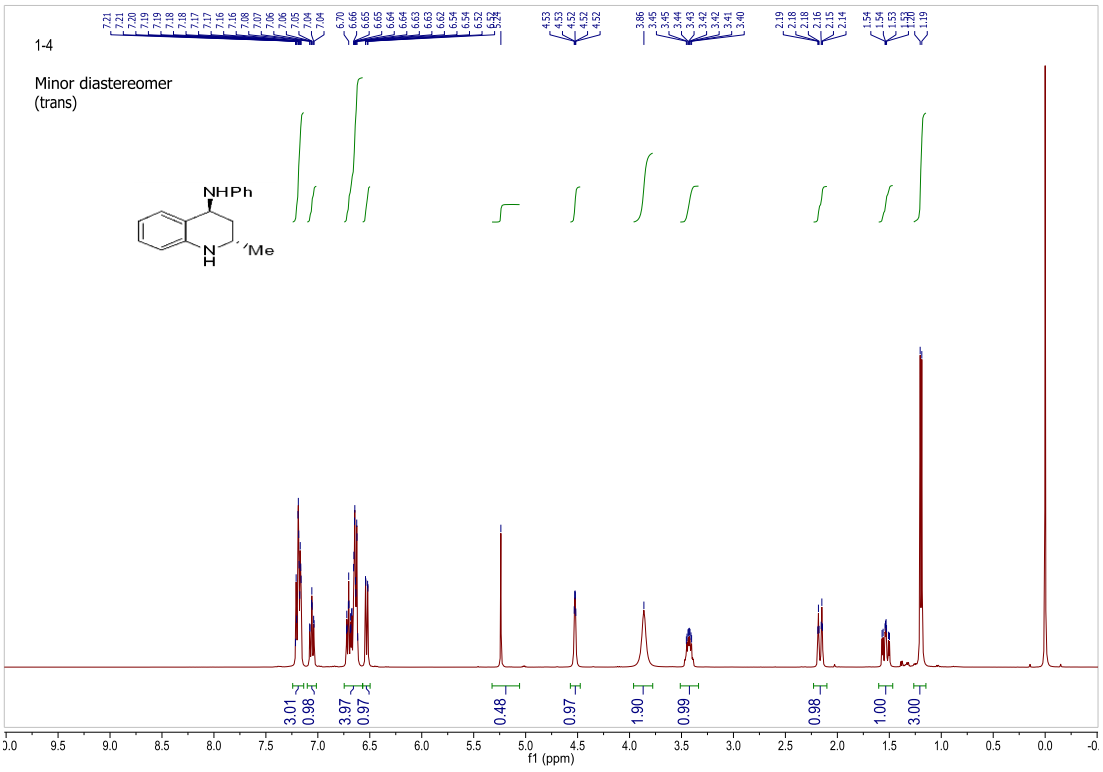
22.43
f1 (ppm)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Minor diastereomer
(trans)
NHPh
Me
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0.97
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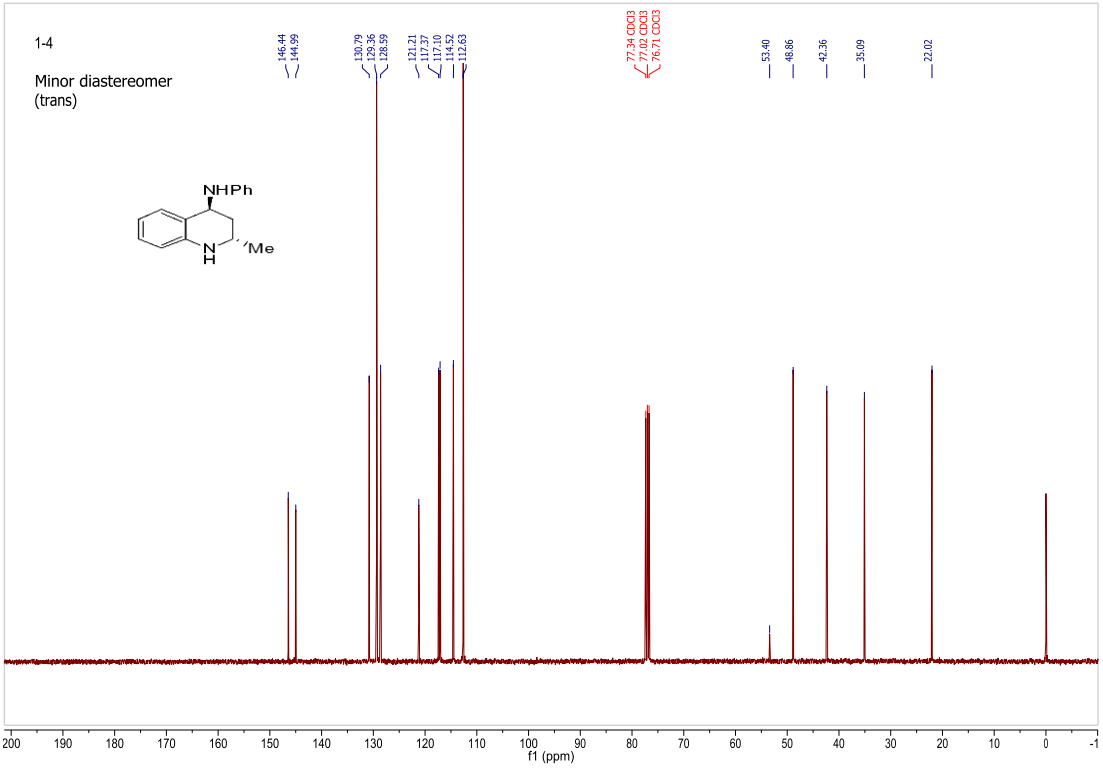
0.98
1.00
3.00
f1 (ppm)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Minor diastereomer
(trans)
NHPh
Me
146.44
144.99
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129.36
128.59
121.21
117.37
117.10
114.52
112.63
77.34 CDCl3
77.02 CDCl3
76.71 CDCl3
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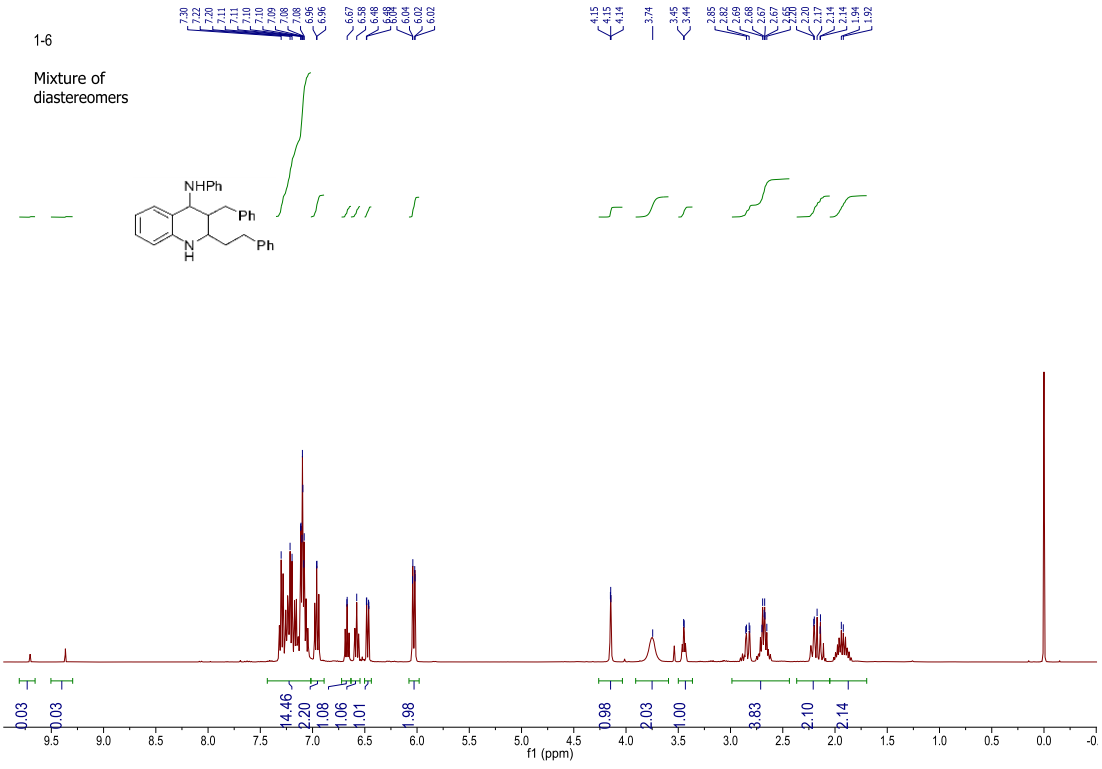
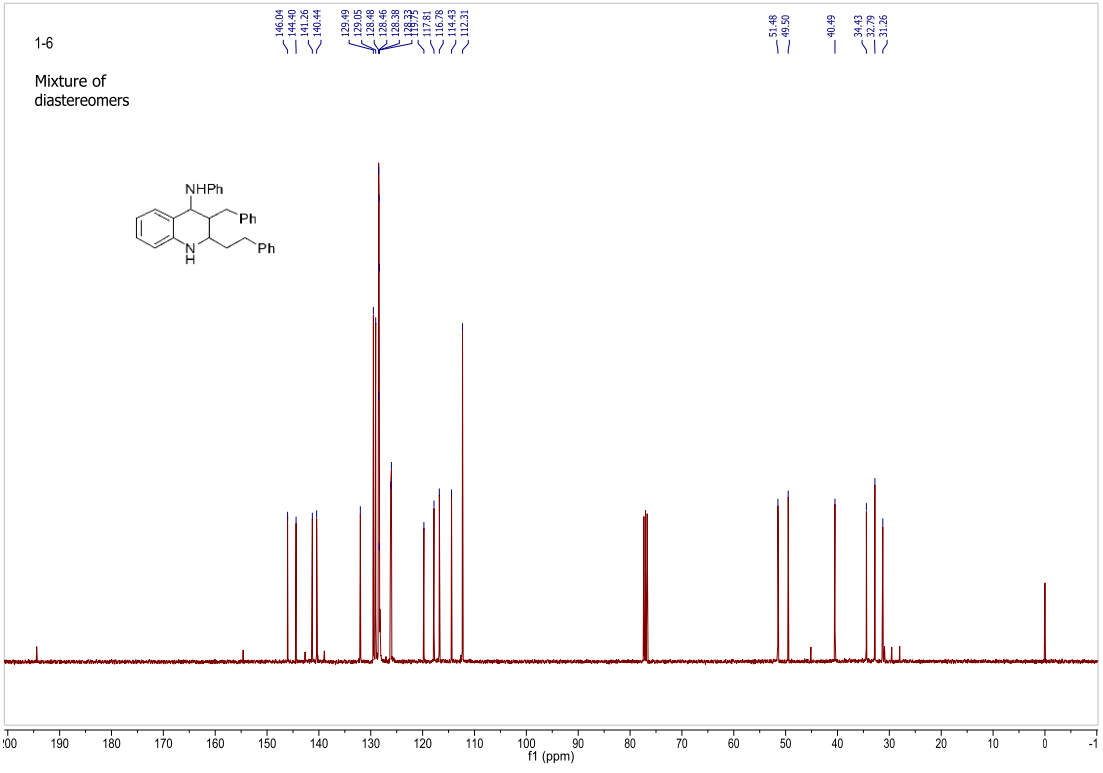
42.36
35.09
22.02
f1 (ppm)


1-6
Mixture of
diastereomers
NHPh
Ph
Ph
N
H
f1 (ppm)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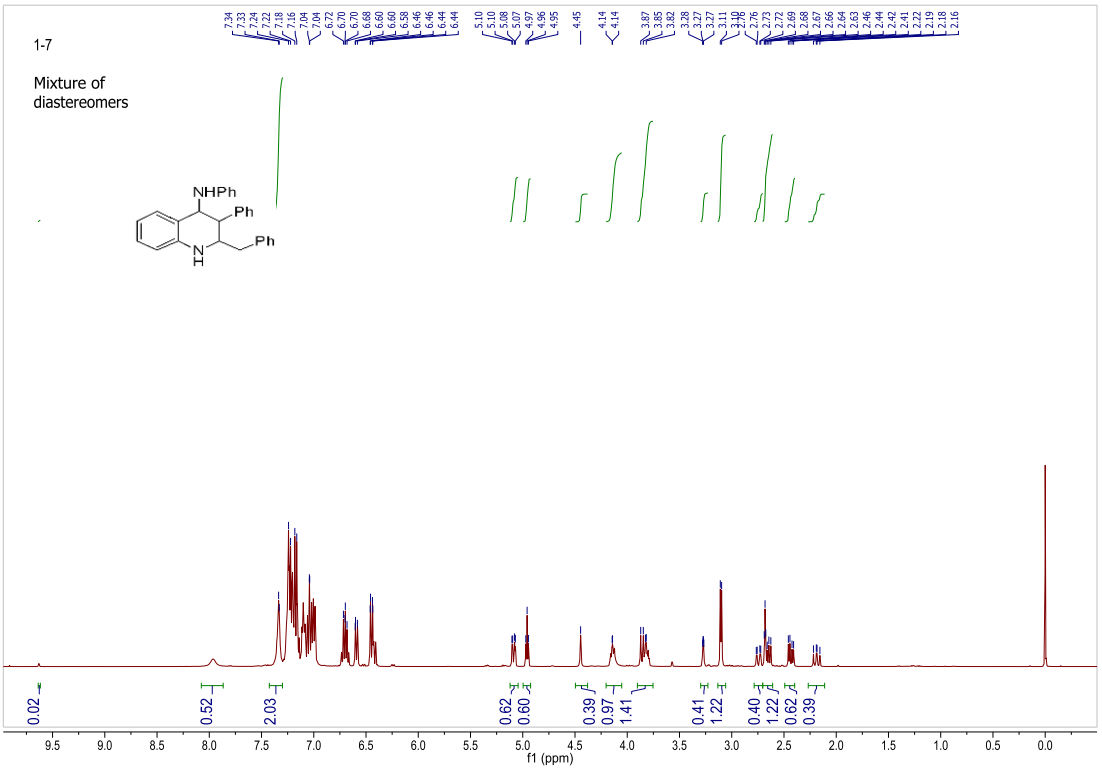
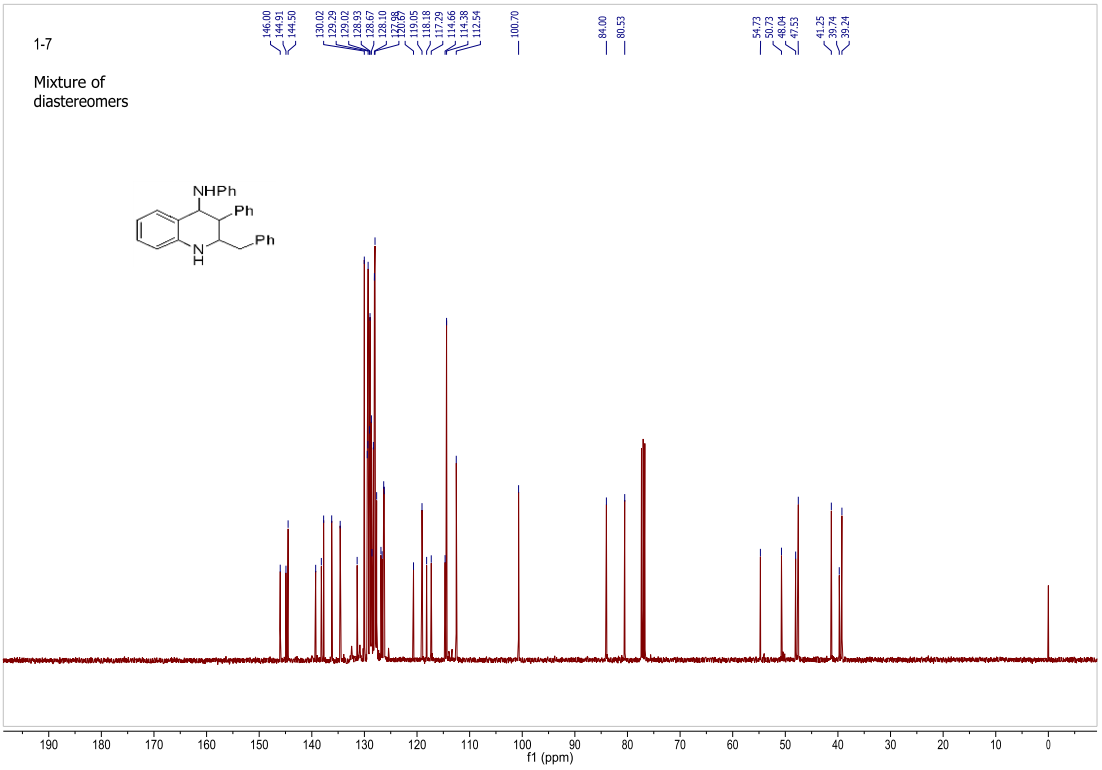
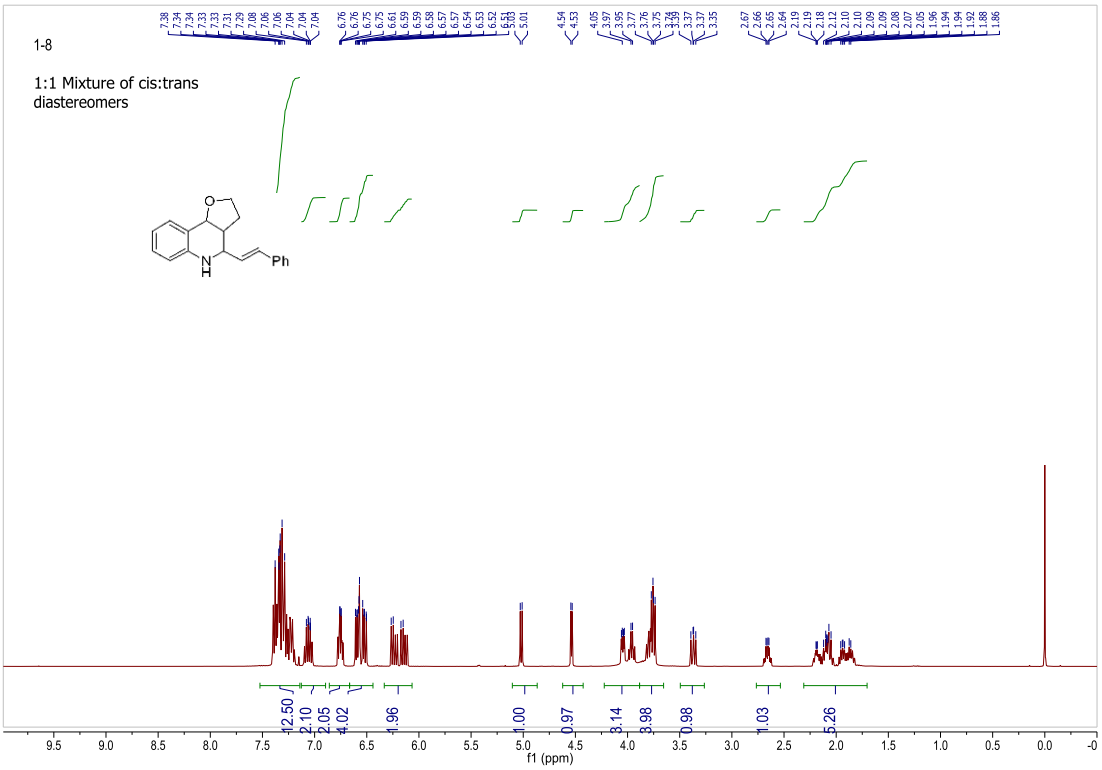
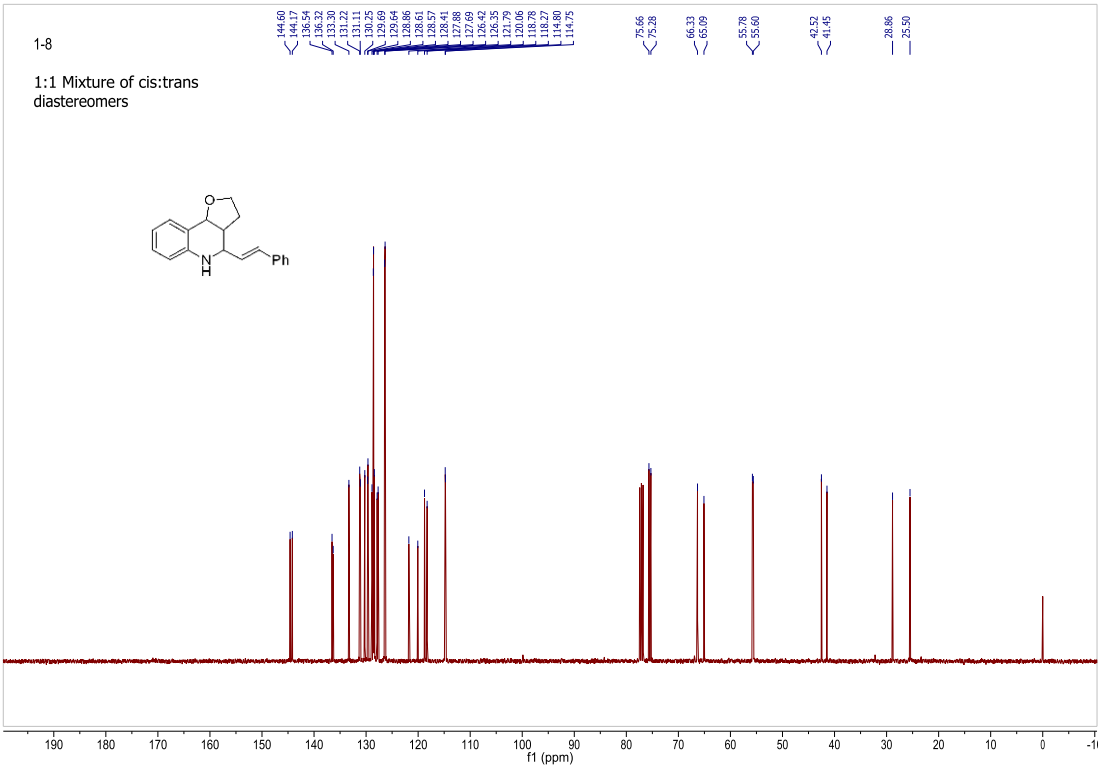
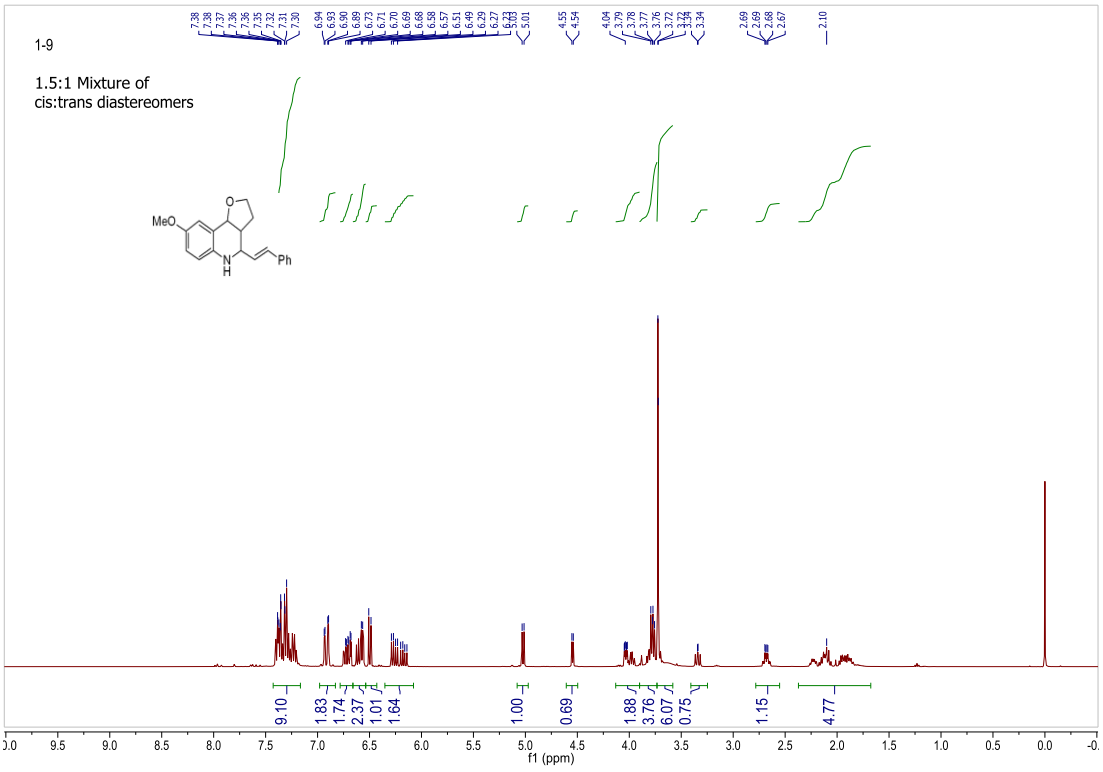
Mixture of
diastereomers
NHPh
Ph
Ph
N
H
f1 (ppm)

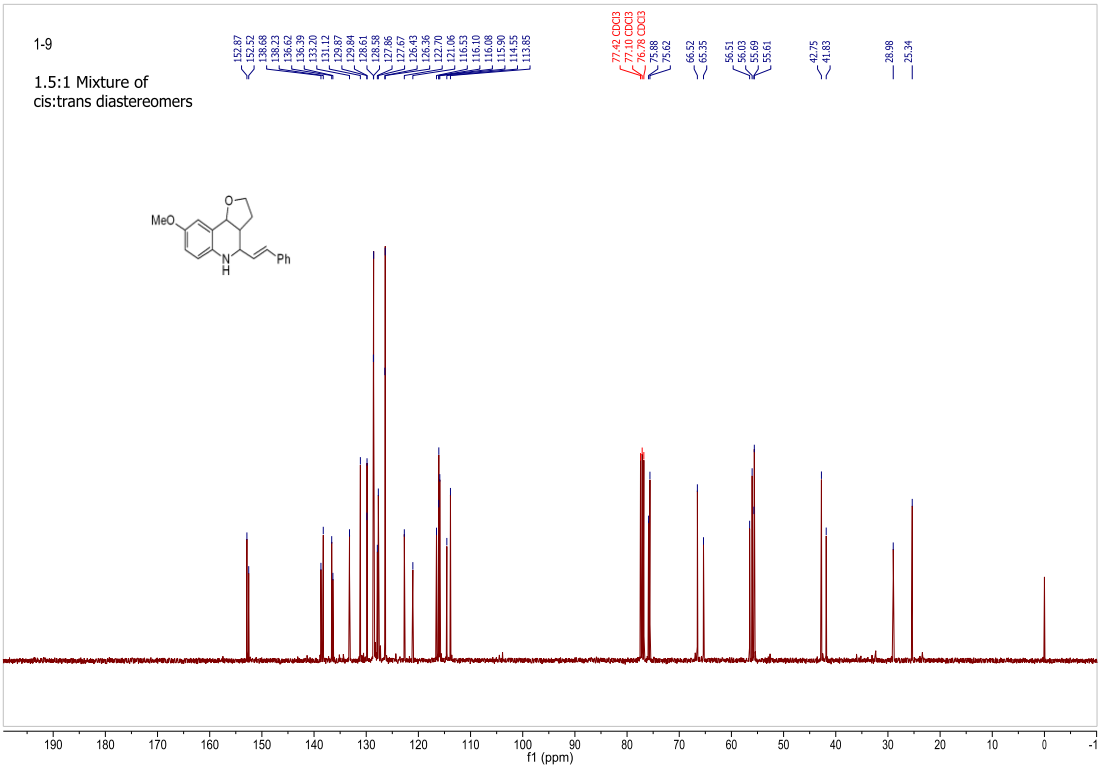

1-7
Mixture of
diastereomers
NHPh
Ph
Ph
N
H
0.02
0.52
2.03
0.62
0.60
0.39
0.97
1.41
0.41
1.22
0.40
1.22
0.62
0.39
f1 (ppm)

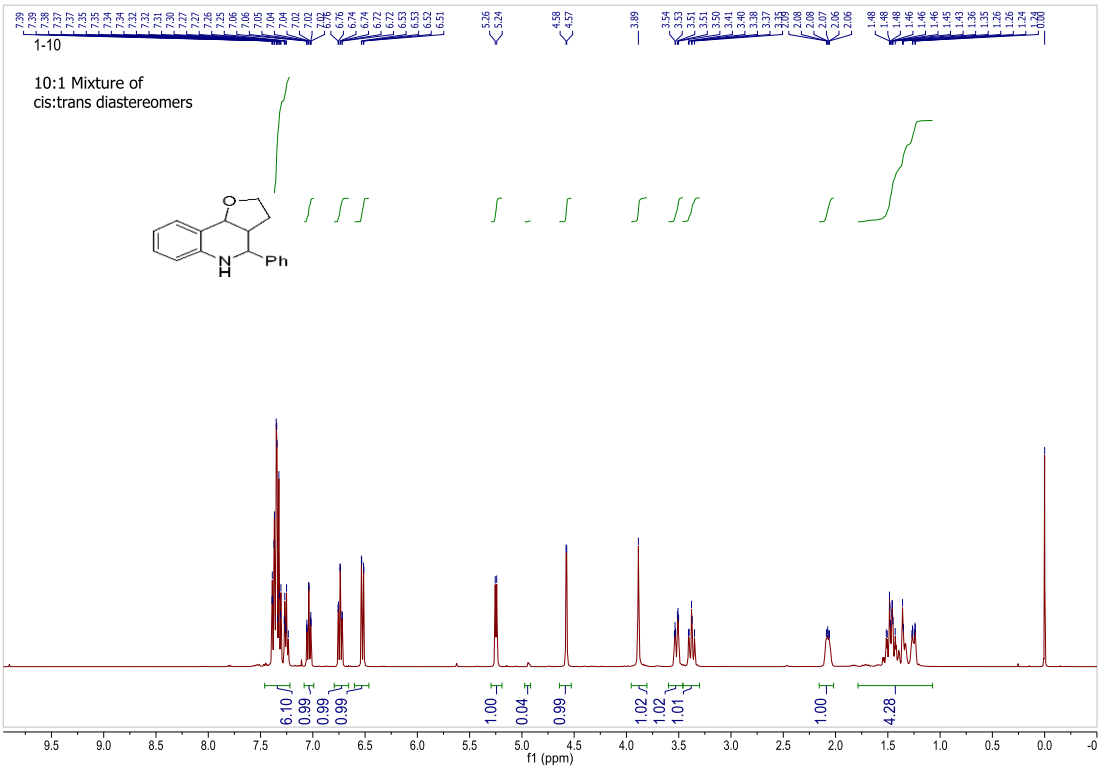

1-7
Mixture of
diastereomers
NHPh
Ph
Ph
N
H
f1 (ppm)


1-8
1:1 Mixture of cis:trans
diastereomers
Ph
12.50
2.10
2.05
4.02
1.96
1.00
0.97
3.14
3.98
0.98
1.03
5.26
f1 (ppm)


1-8
1:1 Mixture of cis:trans
diastereomers
Ph
f1 (ppm)


1-9
1.5:1 Mixture of
cis:trans diastereomers
MeO
Ph
9.10
1.83
1.74
2.37
1.01
1.64
1.00
0.69
1.88
3.76
6.07
0.75
1.15
4.77
f1 (ppm)


1-9
1.5:1 Mixture of
cis:trans diastereomers
MeO
Ph
f1 (ppm)


1-10
10:1 Mixture of
cis:trans diastereomers
Ph
6.10
0.99
0.99
0.99
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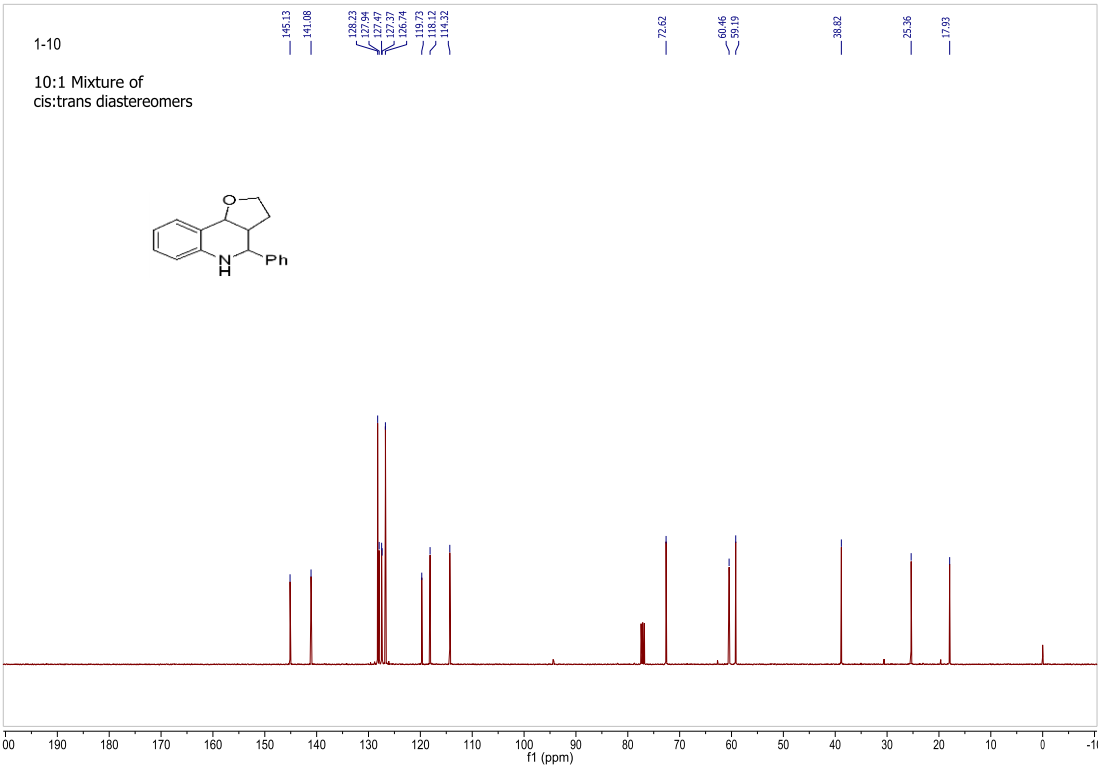
1.02
1.02
1.01
1.00
4.28
f1 (ppm)


1-10
10:1 Mixture of
cis:trans diastereomers
Ph
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127.94
127.47
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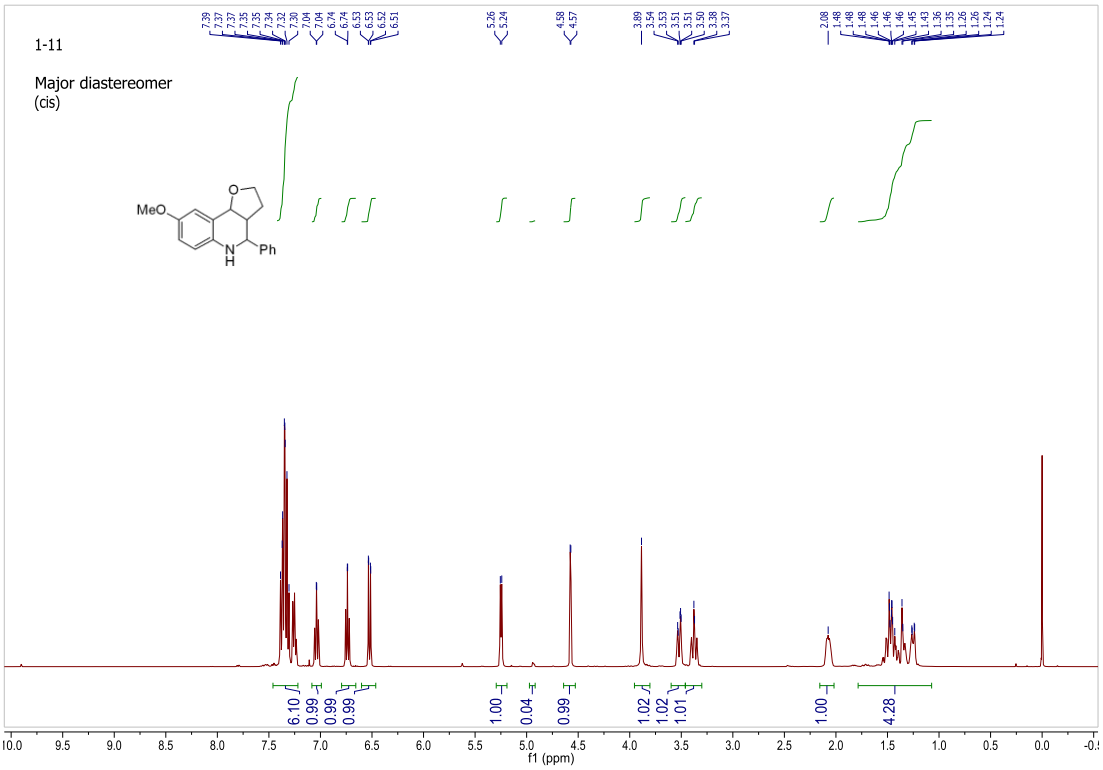
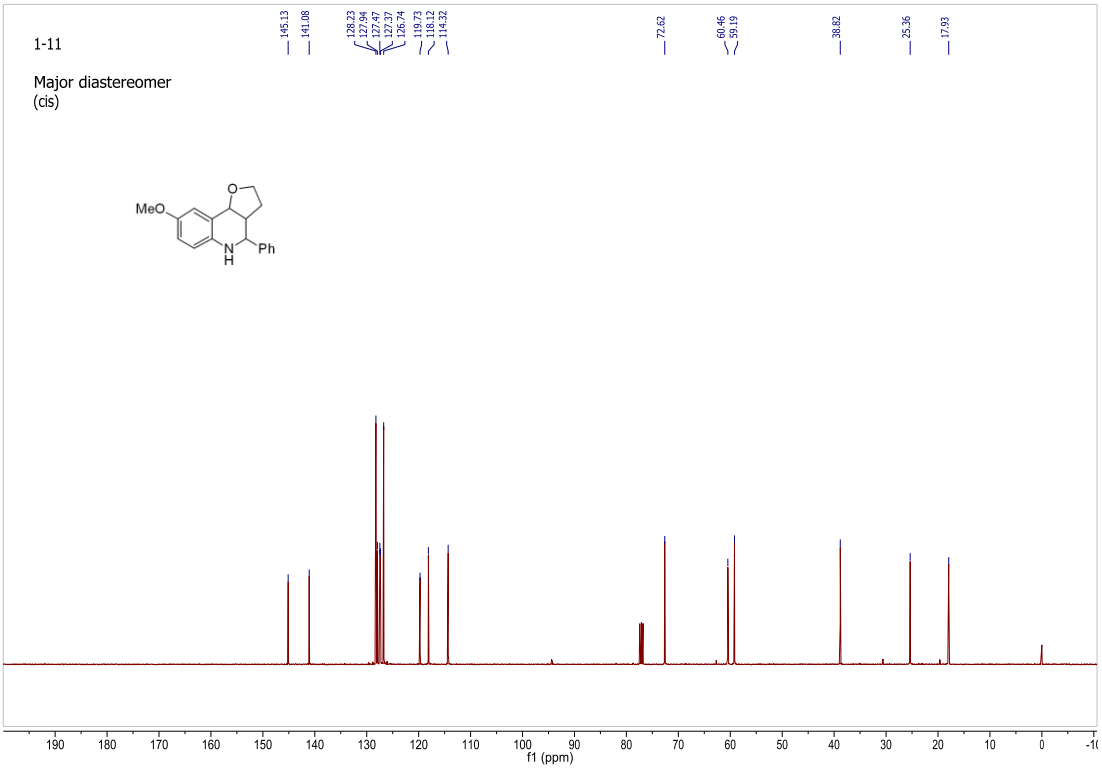
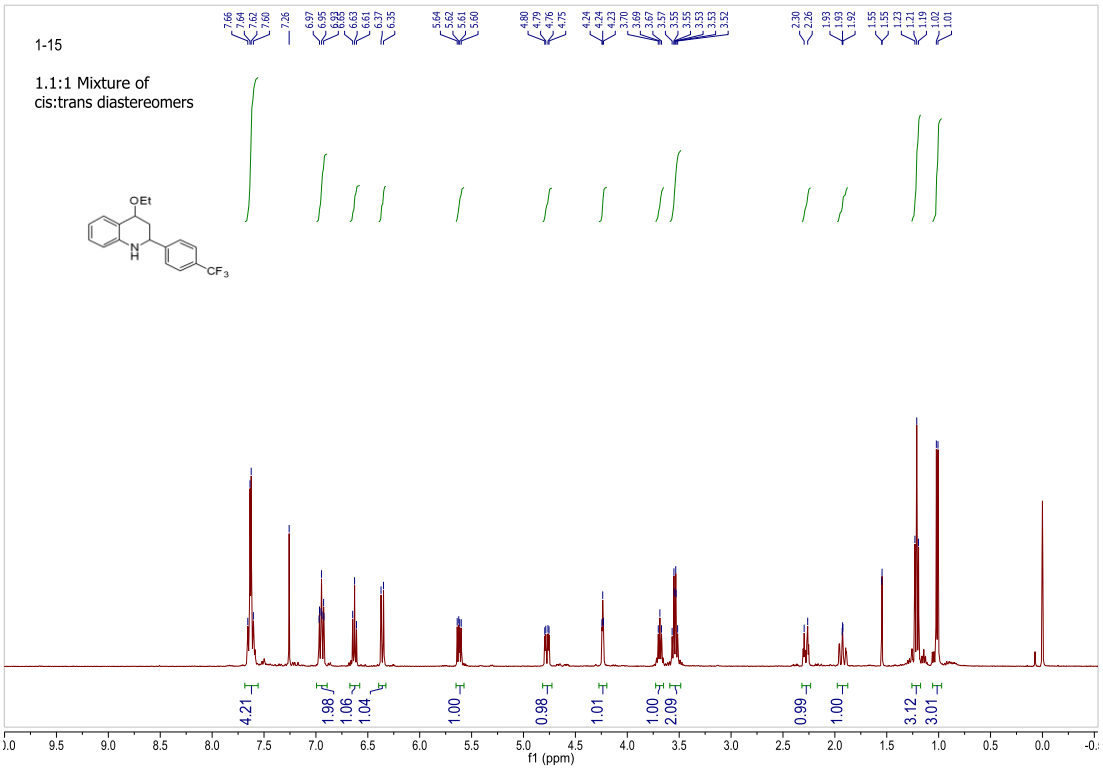
25.36
17.93
f1 (ppm)


1-11
Major diastereomer
(cis)
MeO
O
N
H
Ph
f1 (ppm)


1-11
Major diastereomer
(cis)
MeO
O
N
H
Ph
f1 (ppm)


1-15
1.1:1 Mixture of
cis:trans diastereomers
OEt
CF3
7.66
7.64
7.62
7.60
7.26
6.97
6.95
6.93
6.65
6.63
6.61
6.37
6.35
5.64
5.62
5.61
5.60
4.80
4.79
4.76
4.75
4.24
4.24
4.23
3.70
3.69
3.67
3.57
3.55
3.55
3.53
3.53
3.52
2.30
2.26
1.93
1.93
1.92
1.55
1.55
1.23
1.21
1.19
1.02
1.01
4.21
1.98
1.06
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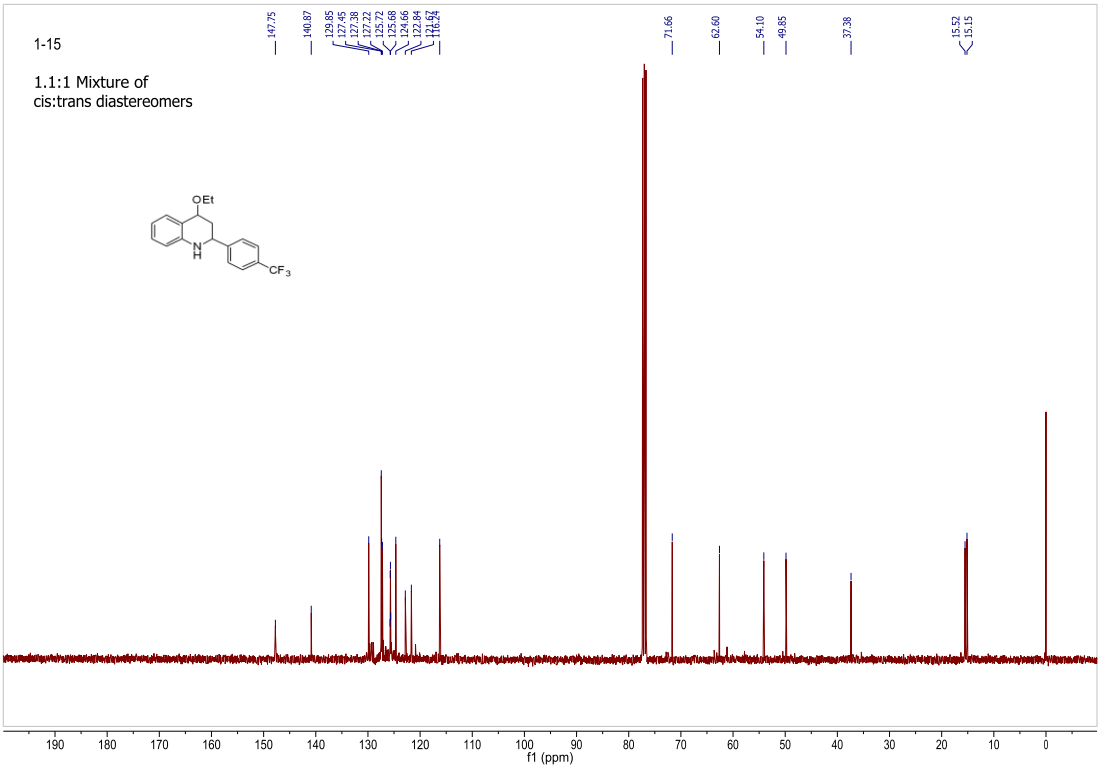
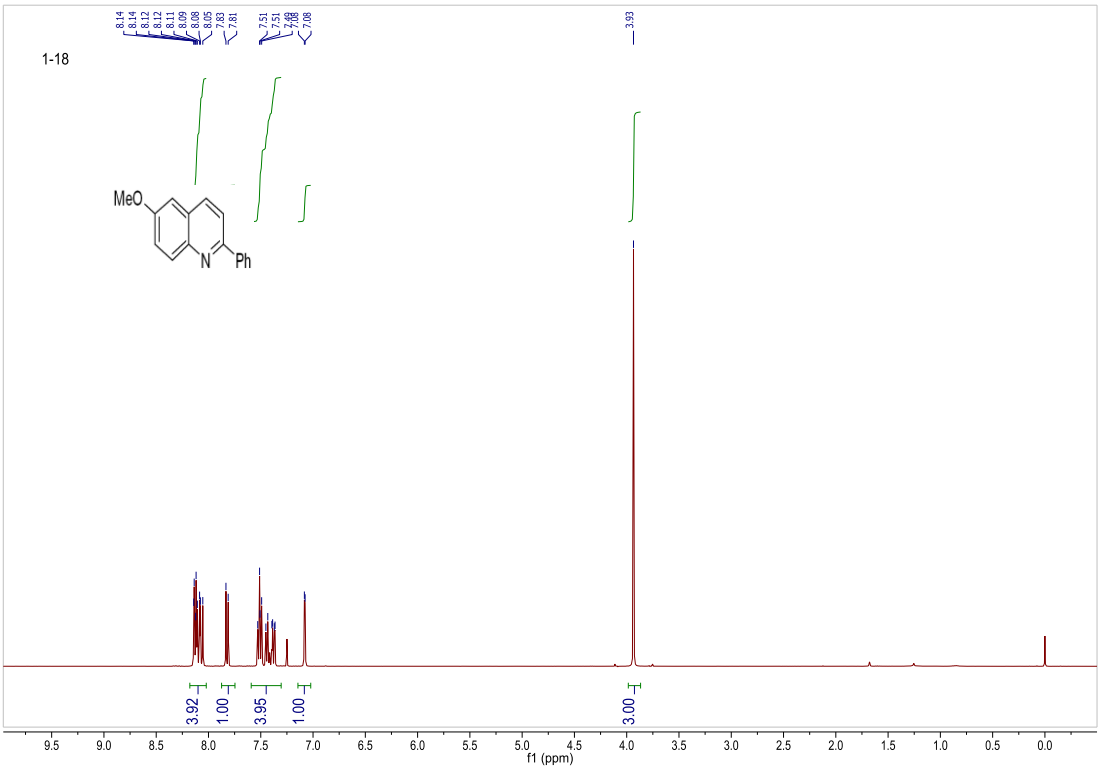
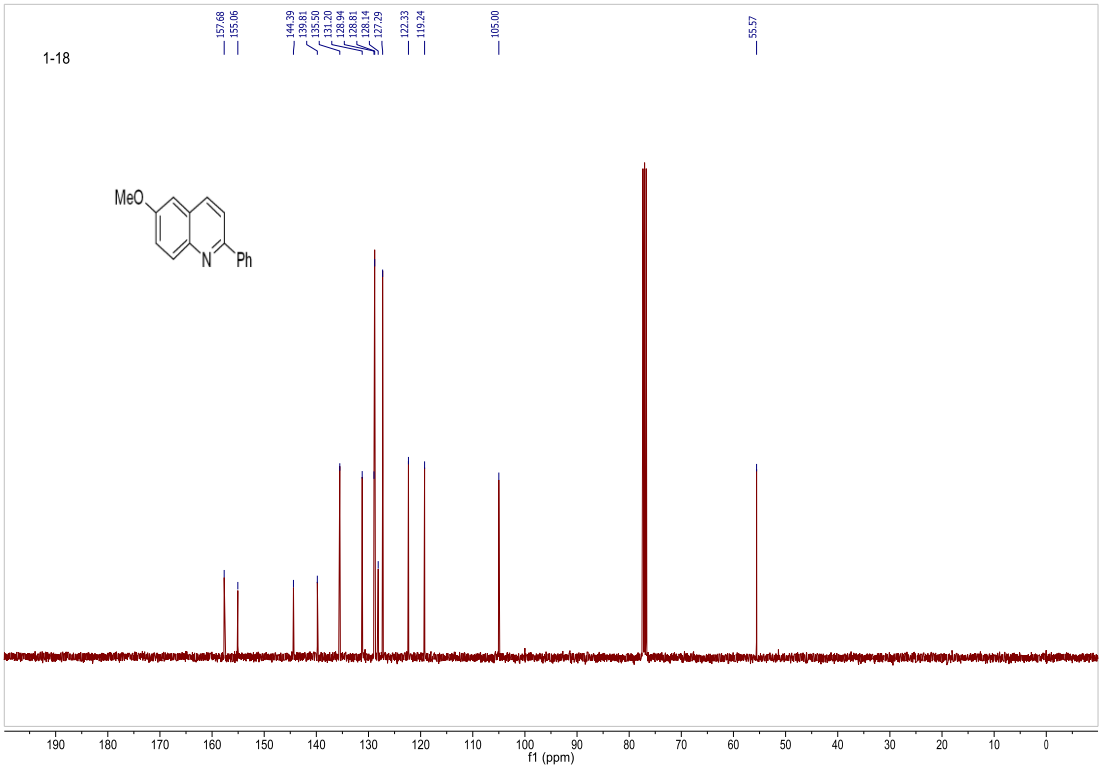
f1 (ppm)


1-15
1.1:1 Mixture of
cis:trans diastereomers
OEt
CF3
147.75
140.87
129.85
127.45
127.38
127.22
125.72
125.68
124.66
122.84
121.62
116.24
71.66
62.60
54.10
49.85
37.38
15.52
15.15
f1 (ppm)


1-18
MeO
N
Ph
8.14
8.14
8.12
8.12
8.11
8.09
8.08
8.05
7.83
7.81
7.51
7.51
7.48
7.08
7.08
3.93
3.92
1.00
3.95
1.00
3.00
f1 (ppm)


1-18
MeO
N
Ph
157.68
155.06
144.39
139.81
135.50
131.20
128.94
128.81
128.14
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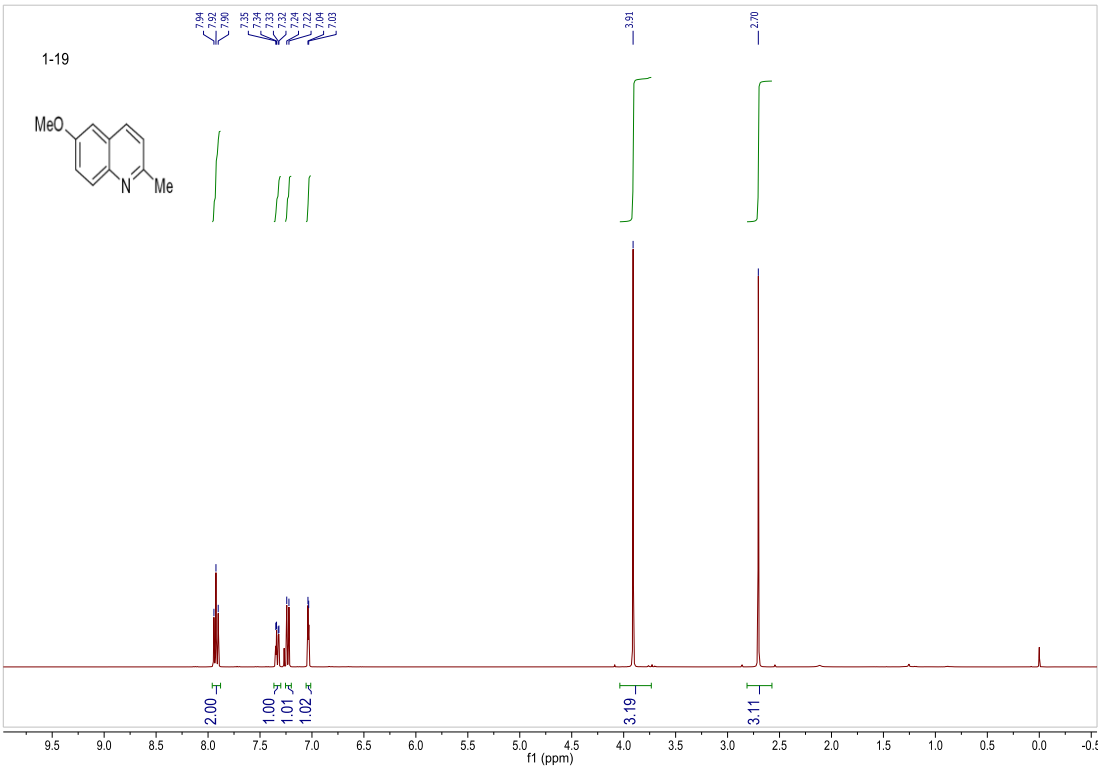
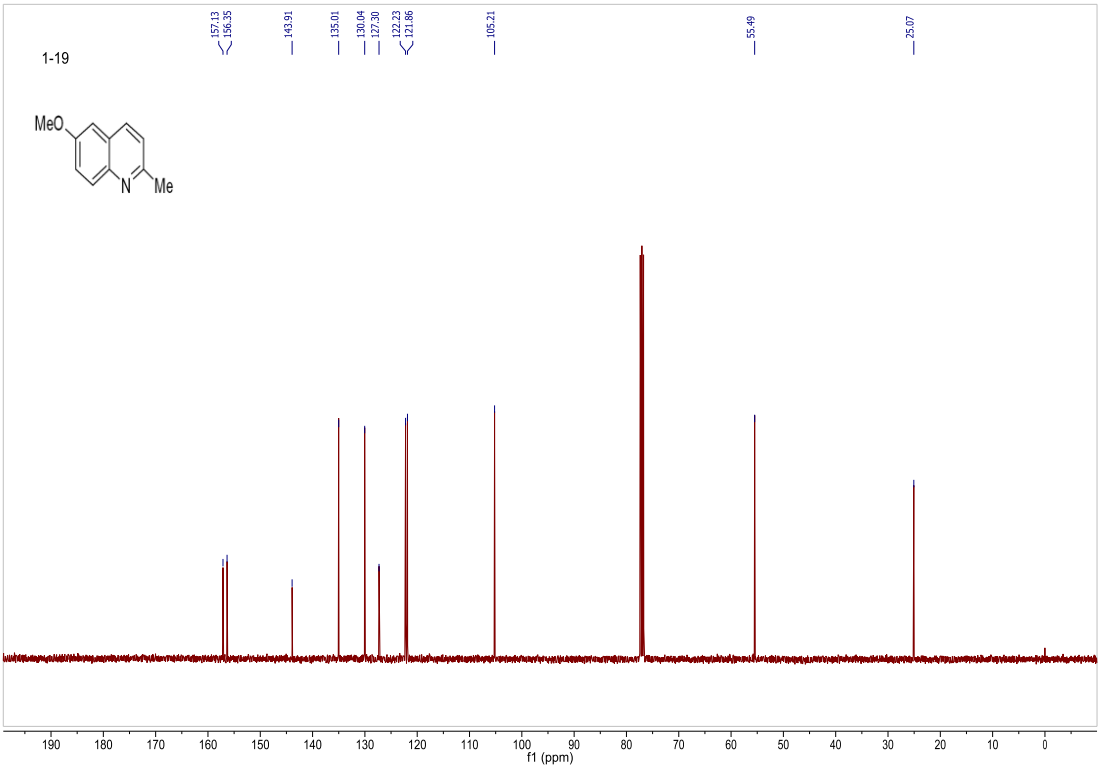
122.33
119.24
105.00
55.57
f1 (ppm)


1-19
MeO
N
Me
7.94
7.92
7.90
7.35
7.34
7.33
7.32
7.24
7.22
7.04
7.03
3.91
2.70
2.00
1.00
1.01
1.02
3.19
3.11
f1 (ppm)


1-19
MeO
N
Me
157.13
156.35
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135.01
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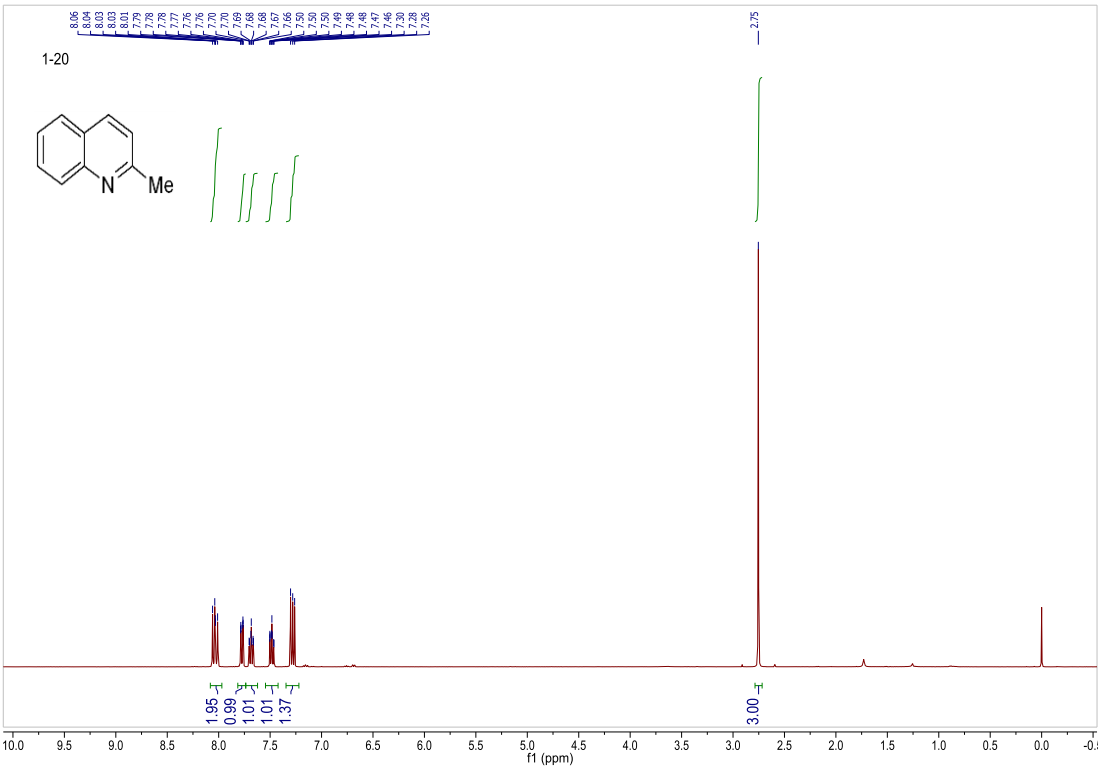
121.86
105.21
55.49
25.07
f1 (ppm)


1-20
N
Me
8.06
8.04
8.03
8.03
8.01
7.79
7.78
7.78
7.77
7.76
7.76
7.70
7.70
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7.48
7.47
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1.01
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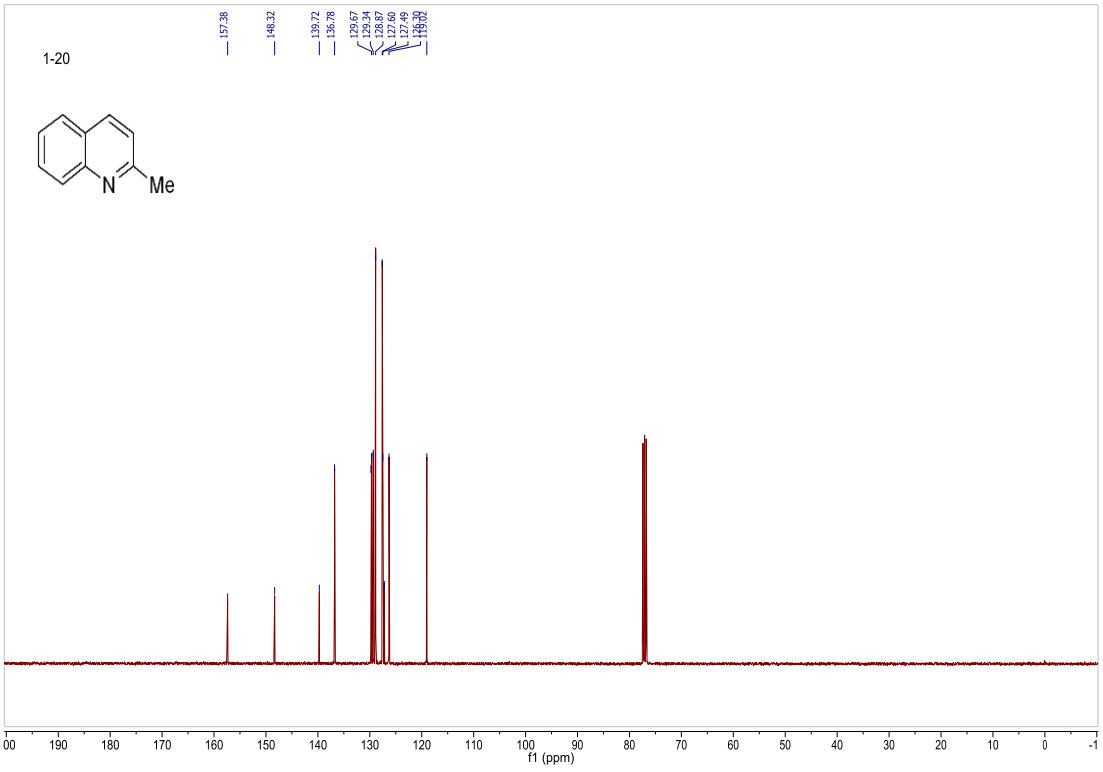
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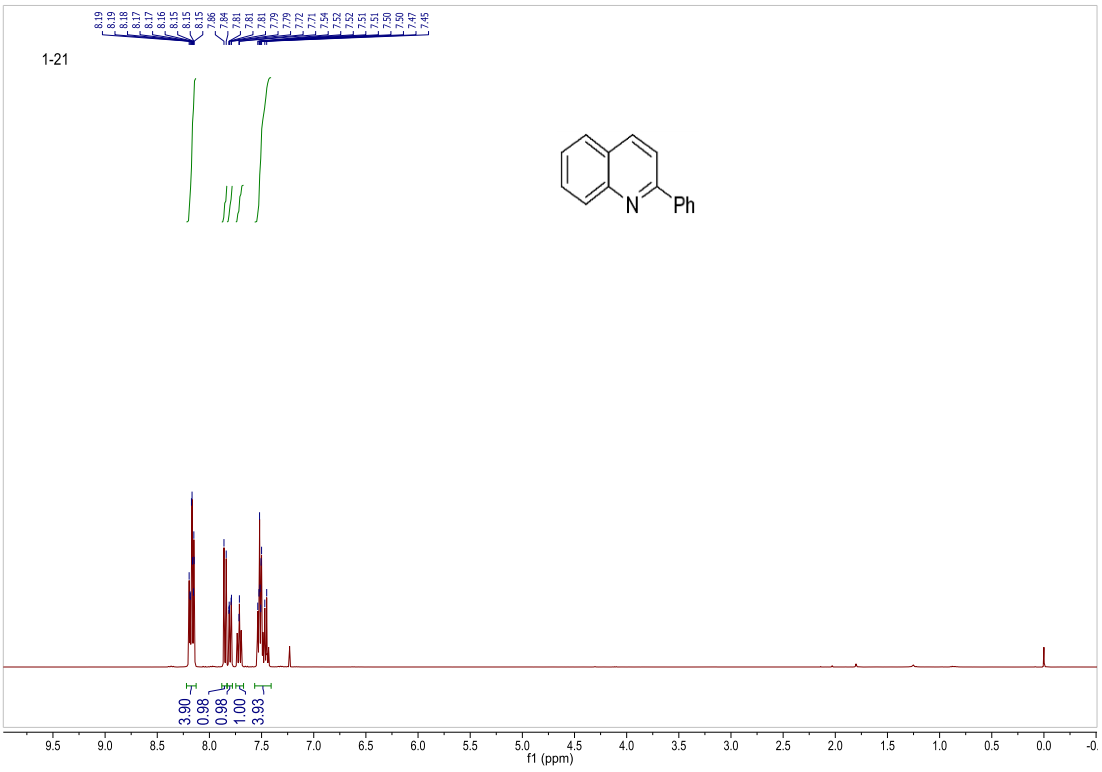
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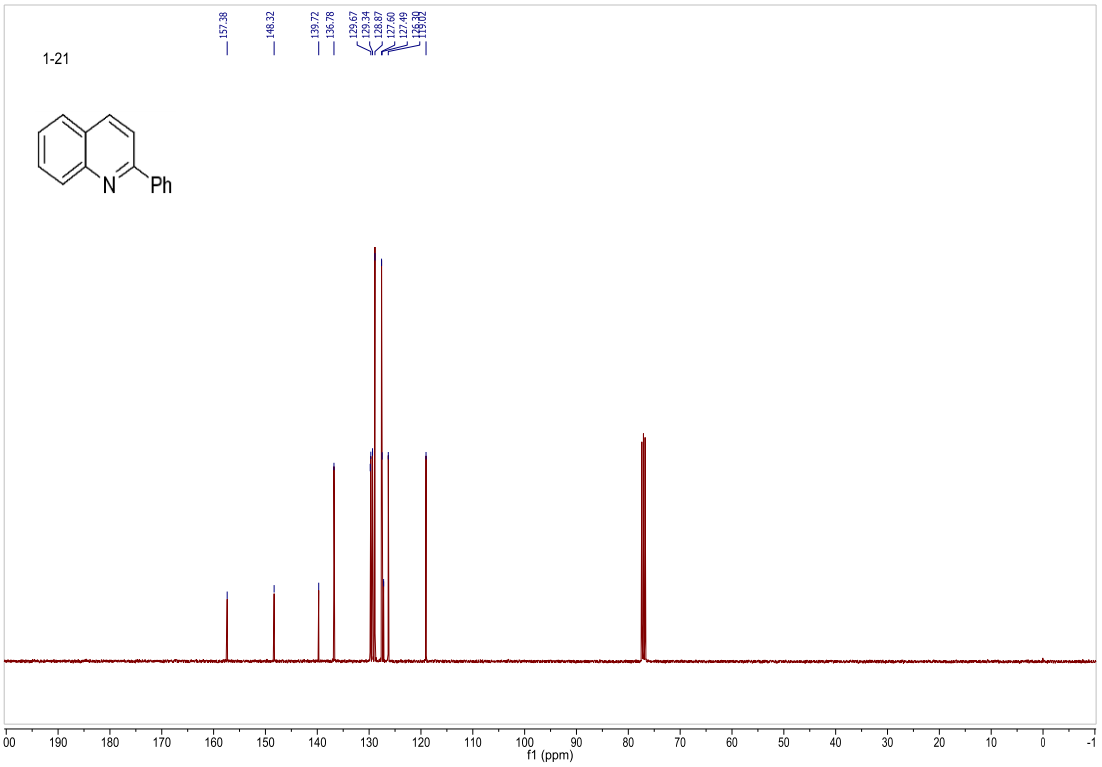
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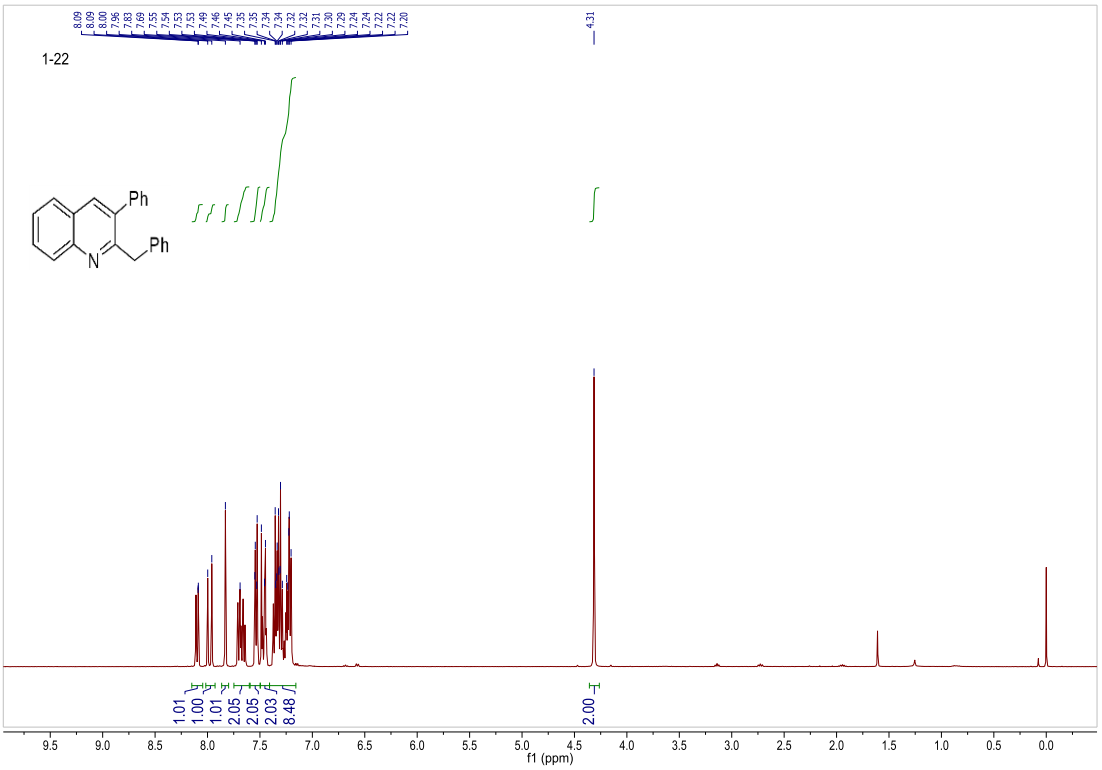
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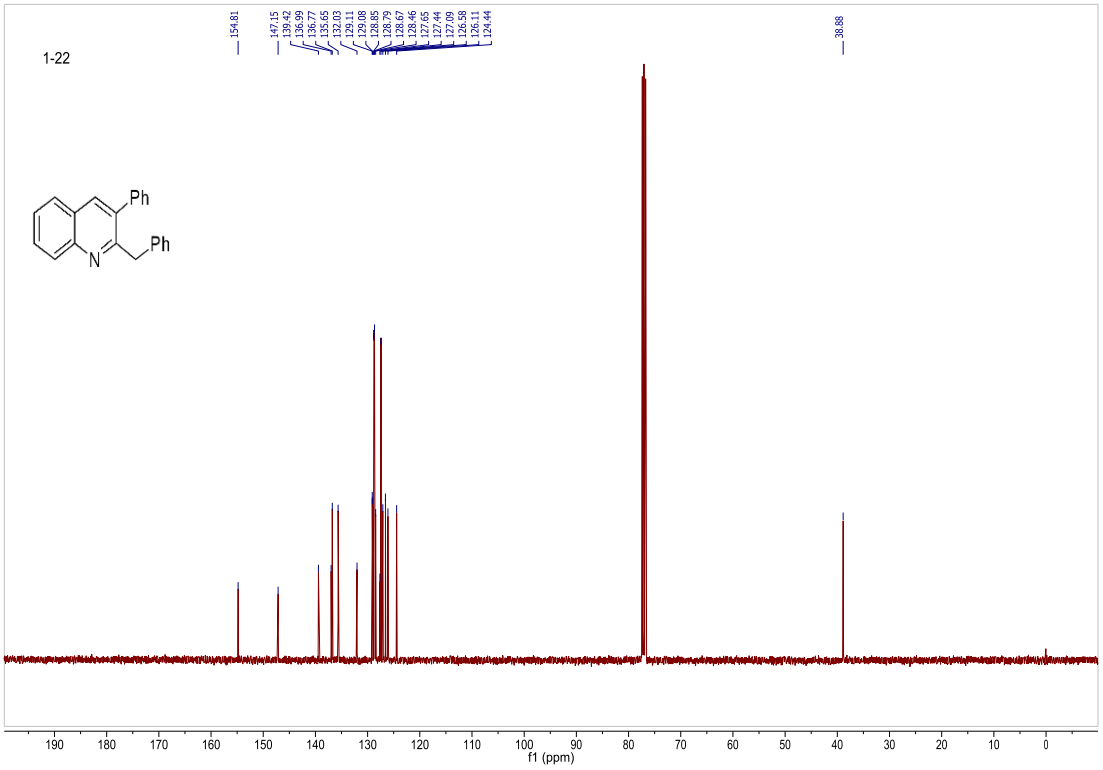
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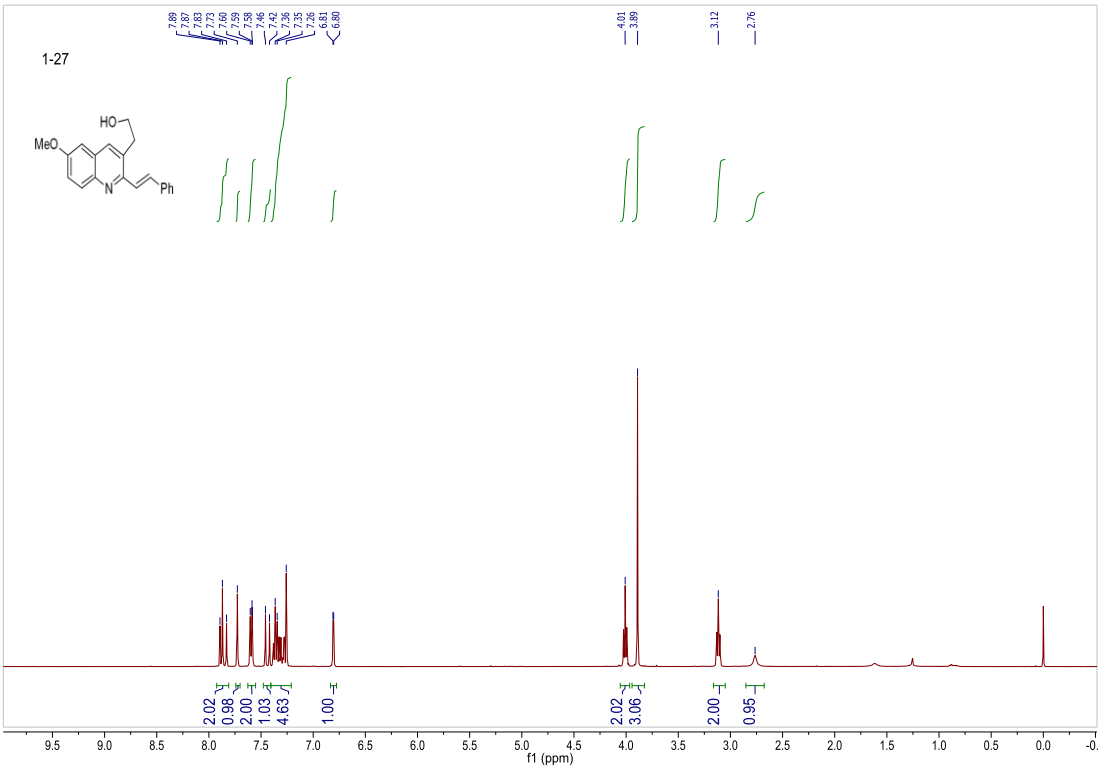
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7.35
7.26
6.81
6.80
4.01
3.89
3.12
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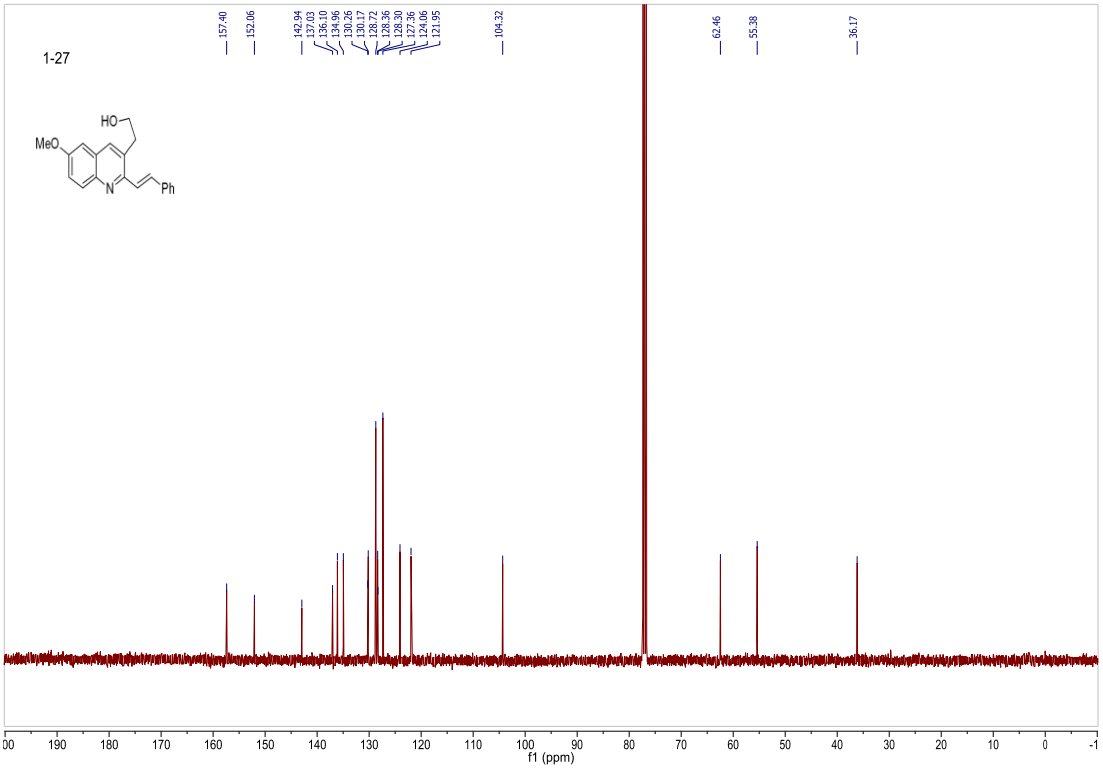
0.95
f1 (ppm)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137.03
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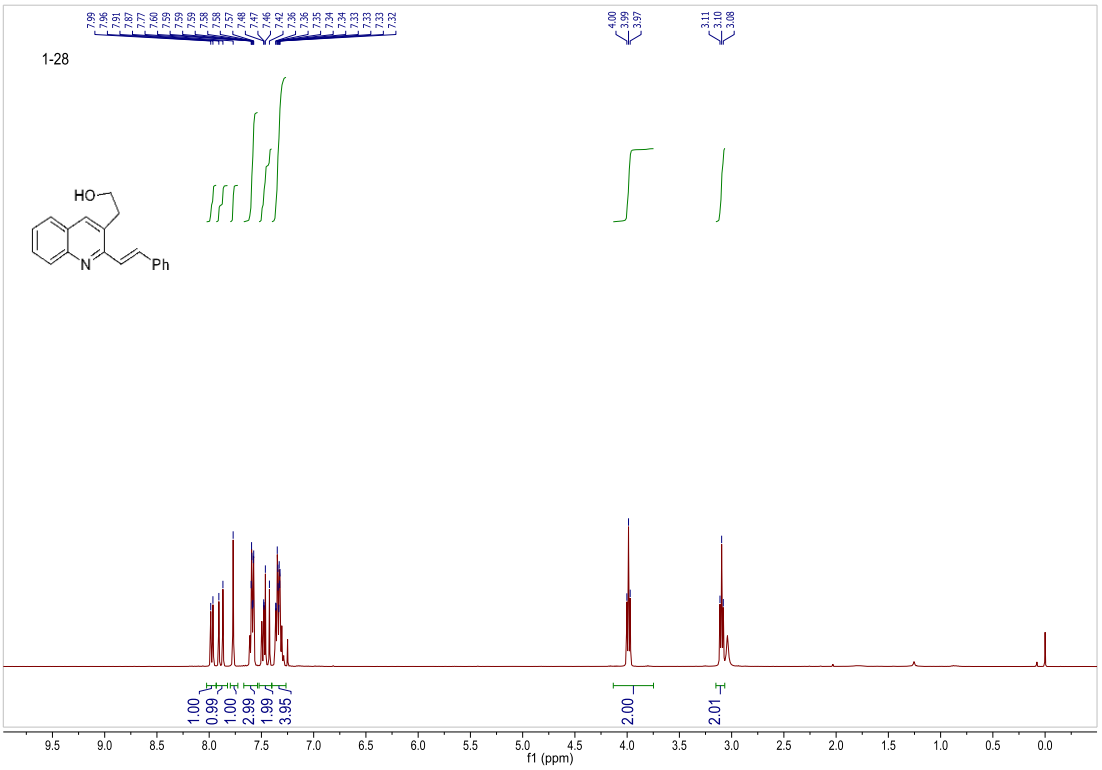
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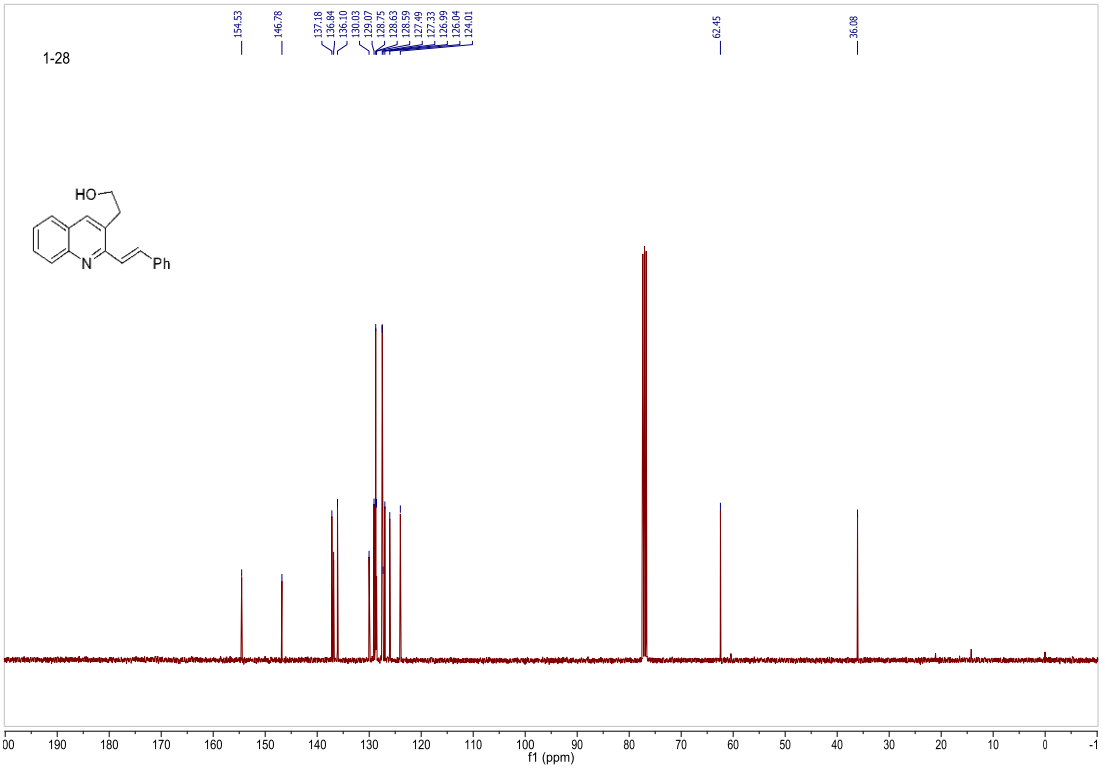
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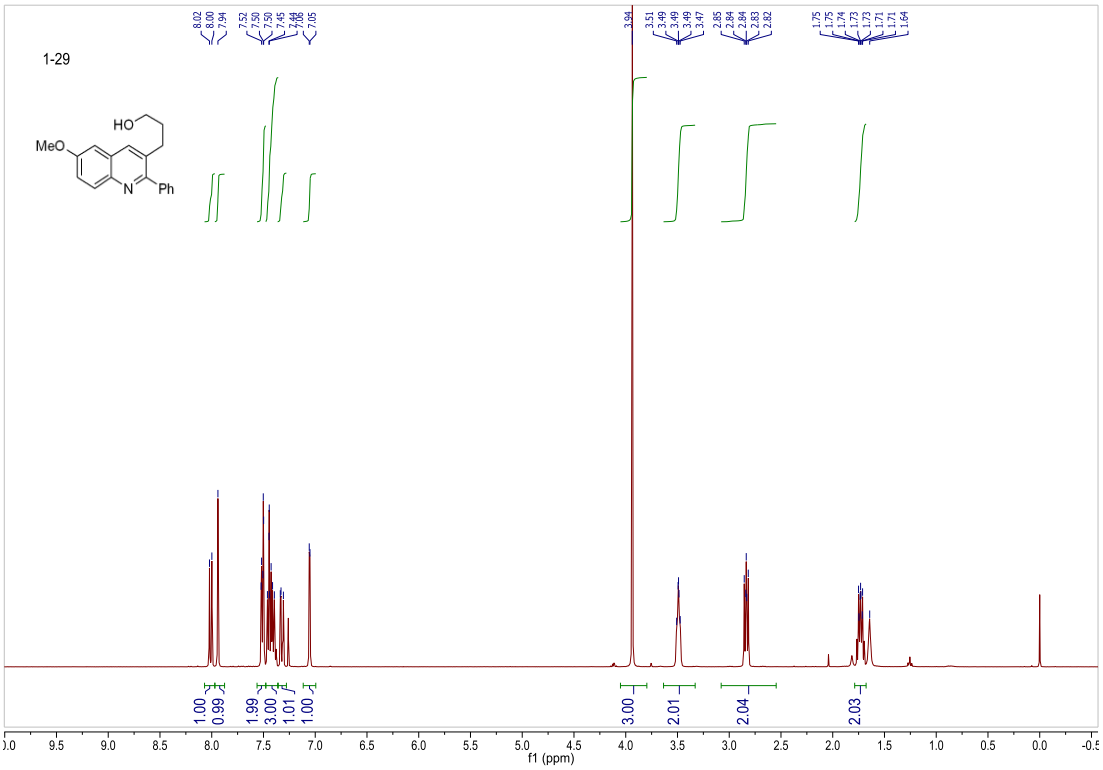
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2.83
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1.73
1.73
1.71
1.71
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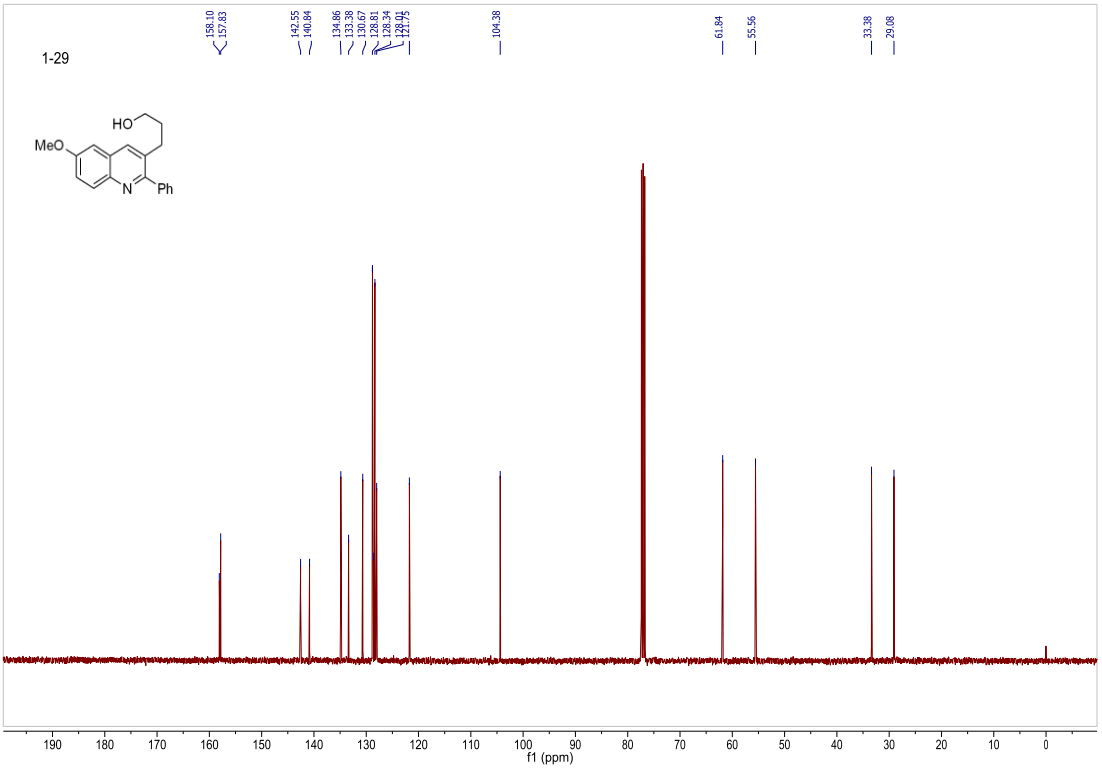
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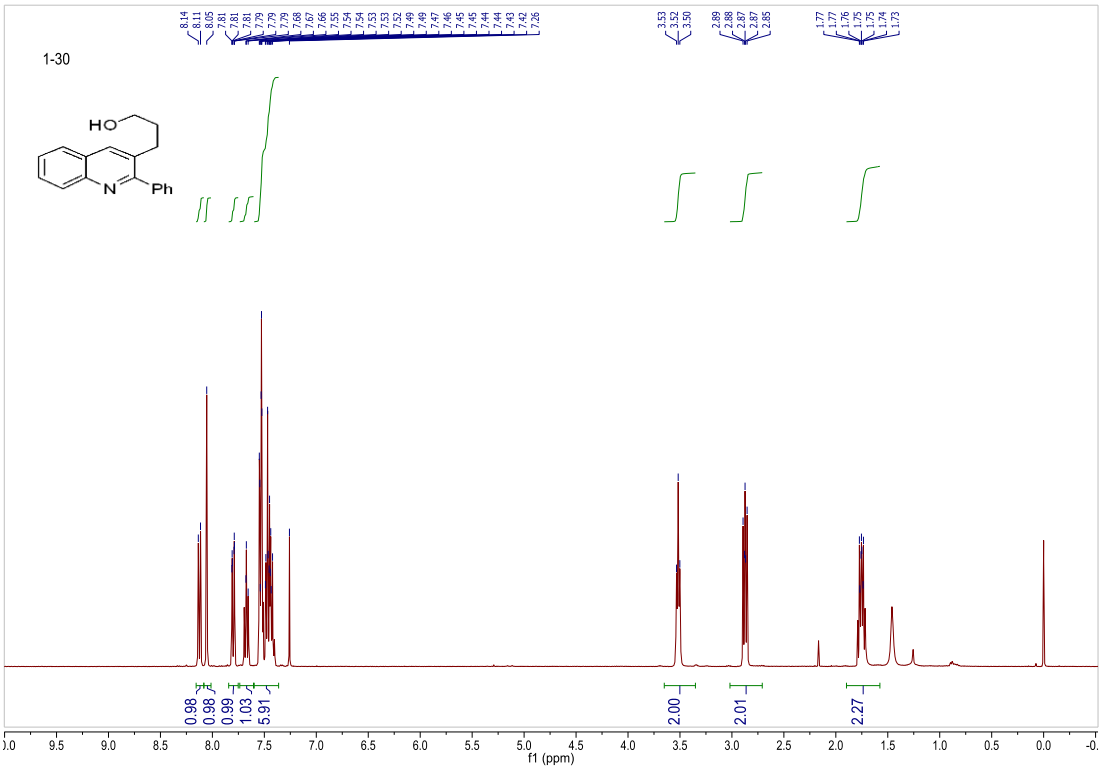
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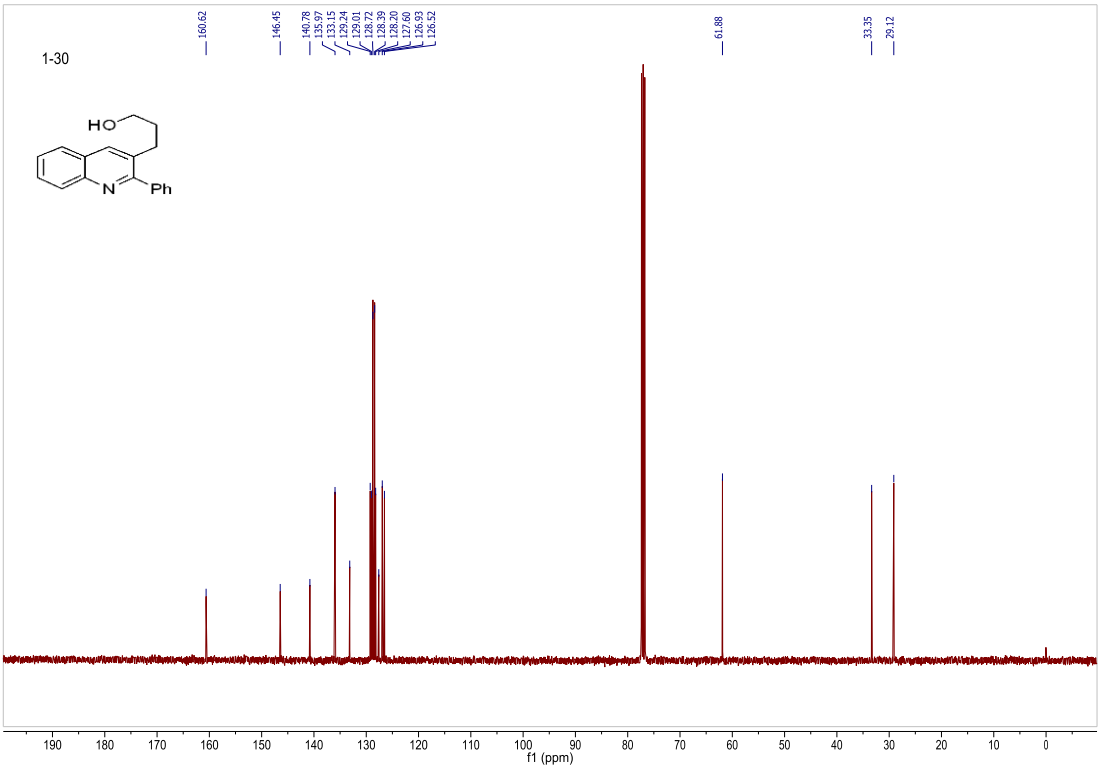
1-30
HO
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Ph
f1 (ppm)

Appendix B: Consent Form and Instructions for Consent Form Process

Appendix B contains the IRB-approved consent form used for all lectures, both experimental and control, for the spring 2013, fall 2013, and spring 2014 semesters (studies I-III). The consent form is followed by the full IRB protocol and notice of action, which was approved on January 18, 2013 and expired November 25, 2014.

BASIC STUDY INFORMATION

1.1 Indicate the appropriate IRB. NOTE:
If you are unsure which IRB to select, please refer to the guidance or contact an IRB office for assistance.

For studies that may qualify for review by the commercial (e.g., Western) IRB or NCI Central IRB, select the Health Sciences IRB below.
* Education and Social/Behavioral Science IRB
Health Sciences IRB
Minimal Risk IRB (Health Sciences)

1.2 Provide a short, lay-terms study title.

* Does the use of a student-generated chemistry wiki affect student performance in large general chemistry courses?

1.3 Provide the full, formal study title. NOTE: This is the title that will appear in correspondence.

* Does the use of a student-generated chemistry wiki affect student performance in large general chemistry courses?

1.4 Is this study being transferred from another institution?

* Yes No

1.5 Identify the Principal Investigator.
* JOHN MOORE

1.6 Identify the points of contact for this study (limit of four).

NOTE:
Points of contact can edit the application and will receive email notifications about this submission. For the HS and MR IRBs only, points of contact can also submit materials on behalf of the PI.
If the PI is serving as a study point of contact, indicate that here.

*JACLYN BROWN
JOHN MOORE

PRINCIPAL INVESTIGATOR

Principal Investigator:JOHN MOORE

2.0 Does the PI (listed above) have a faculty appointment at UW-Madison?
* Yes No

Madison VA (William S. Middleton VA Hospital)
University policy requires that your study be reviewed by the Health Sciences IRBs if this study involves any of the following:

Any personnel holding an appointment at the Madison VA (William S. Middleton VA Hospital)
Any funding from the Madison VA (William S. Middleton VA Hospital)
Any Madison VA (William S. Middleton VA Hospital) sites or facilities
Other Madison VA (William S. Middleton VA Hospital) resources

If your study involves any of the above, please return to the first page of this application, and select Health Sciences IRB or Minimal Risk IRB (Health Sciences).

If you have any questions, please contact the HS-IRBs office at 263-2362.

STUDY TEAM

NOTE: All members of the study team (key personnel) must be listed on this page. Study team members can be listed as having either edit/email access or read-only access, but all study team members (apart from the PI and POC) must be listed in one category or the other.
If the study team includes anyone (including students) who is not affiliated with (e.g., employed by, holds an appointment at) the UW-Madison AND for whom you are requesting that UW-Madison serve as IRB of record, these individuals must be listed in either 3.1 or 3.2. If the study team includes anyone who is not affiliated with the UWMadisonfor whom you are NOT requesting that UW-Madison serve as IRB of record, DO NOT list these individuals in either 3.1 or 3.2. The study protocol must include all external collaborators and their roles in this study.

3.1 Identify study team members with edit/email access. NOTE: Study team members listed here will be able to edit the application and receive email notifications regarding this study. Only the PI can formally submitmaterials to the IRB.

3.2 Identify study team members with read-only access. NOTE: Study team members listed here will be able to read the application but will not be able to edit the application or receive email notifications.

STUDY TEAM: ROLES

NOTE: Depending on the nature of the study or project, it is possible that some or all study team members will not fit
into the categories below. If this is the case, select Not Applicable.

4.1 Identify the study team members who will be involved in identification and recruitment of subjects for this study, if applicable.
Person

JACLYN BROWN

4.2 Identify the study team members who will be responsible for obtaining informed consent, if applicable.

JACLYN BROWN

4.3 Identify the study team members who will be intervening or interacting with subjects (e.g., administering surveys, conducting physical interventions), if applicable.

JACLYN BROWN

FUNDING: GENERAL

7.1 Identify the specific department or organization unit under which the research study will be conducted:

* CHEMISTRY-GEN (A481500)

7.2 Are you or do you plan on receiving funding to support this project (includes internal UW-Madison funds)?

* Yes No

7.2.1 If the answer to 7.2 is Yes, will any of the funding be administered by the University of Wisconsin-Madison AND be at least one of the following types of accounts: 133 (not federally sponsored), 144 (federally sponsored), 233 (gift account), or 135 (WARF gift account). NOTE: For a 136 revenue account, please answer No to this question.

Yes *No

7.3 If there is no grant or contract funding this research, how will this research be funded?

FUNDED STUDIES
8.1 Identify all sources of funding for this study or project:
* Other

8.1.1 If other, specify.

Project SERAPHIM fund, 233ES68

8.1.2 If 8.1 is fee-for-service, provide information about the funding sources.
Sponsor UDDS UW fund/account number Accounting Point of Contact

FUNDING INFORMATION FOR STUDY CONDUCTED UNDER UW-MADISON
10.1 Provide information about each funding source administered by the UW-Madison that will support the activities of the study.
*
Funding Source Information
View
Funding
Source
Type
Lite Project
Fund 233
MSN
Number *No Value Entered*
Project ID 233ES68
PI Name MOORE,JOHN W
Start Date Fri Feb 22 00:00:00 CST 2002
End Date Fri Dec 31 00:00:00 CST 9999
Sponsor MULTIPLE DONORS
Primary
Sponsor *No Value Entered*
Title Project SERAPHIM
Status Active
Federal No
Pending No
FA Rate *No Value Entered*
Department
ID 481500
Agency
Reference
Number
06/17/2014
Budget 169256
Grant
Application
View: SF: COI General

CONFLICT OF INTEREST (COI)

13.1 Do ANY of the study team involved in the design or conduct of the research study, or their immediate family (spouse or dependent children), have a financial interest in an entity that (a) sponsors the study or (b) owns or licenses technology tested or evaluated in the study (including any agent, device, or software) that meets or exceeds one of the thresholds below:

(a) Compensation of $20,000 or more in a calendar year from a publicly traded or privately held business entity;
(b) An ownership interest in a publicly traded business entity valued at $20,000 or more or a 5% or greater equity interest;

(c) Any ownership interest in a privately held business entity whatever the value;
(d) A combination of compensation and ownership interest in a publicly traded business entity valued at $20,000 or more;
(e) A leadership position in a business entity (Leadership positions are positions with fiduciary responsibility, including senior managers (e.g., presidents, vice presidents, etc.) and members of boards of directors). Scientific advisory board membership is not a leadership position.

Yes * No

13.1.1 If yes, identify the personnel who have this interest.

13.1.2 Upload the COI management plan(s).

13.2 Do ANY of the study team involved in the design or conduct of the research study, or their immediate family (spouse or dependent children), have a proprietary interest in the research, such as royalties, patents, trademarks, copyright, or licensing agreement, that is relevant to this research study (including any agent, device, or software being evaluated as part of the research study)? NOTE: If this proprietary interest is managed through WARF, select Not Applicable.
Yes *No

13.2.1 If yes, identify the personnel who have this interest.

13.2.2 Upload the COI management plan(s).

13.3 Do ANY of the study team involved in the design or conduct of the research study have a financial interest that requires disclosure to the sponsor or funding source?
Yes * No

13.3.1 If yes, identify the personnel who have this interest.

CONFLICT OF INTEREST (COI): CONTINUED

14.1 In addition to the sponsor(s) of this study or project, are other companies or business entities involved or potentially affected in a significant way by this study or project?
Yes * No

14.1.1 If yes, list those companies/business entities.

14.1.2 If yes, describe the nature of each company/business entity's involvement.

14.2 Do ANY of the study team involved in the design or conduct of the study or project have any other financial interest that the investigator believes may interfere with his or her ability to protect subjects?
Yes * No

14.2.1 If yes, identify the personnel who have this interest.

14.3 Do any of the study team receive any incentives for recruiting human subjects or any other purpose directly related to the study or project?
Yes * No

14.3.1 If yes, describe the nature of the incentive.

CLINICALTRIALS.GOV REGISTRATION

NOTE: Registration at Clinicaltrials.gov may be required in the following situations:
Per FDA regulations, most studies involving the testing of a drug, biologic, or device must be registered.
If publications resulting from this study will be published in a member journal of the International Committee of Medical Journal Editors (ICMJE) or in a publication that adheres to the standards of the ICMJE, the study must be registered. Click on the help link above for additional information on these requirements.
20.1 Does this study need to be registered at Clinicaltrials.gov?
Yes * No

20.1.1 If yes, who has or will register the study prior to the enrollment of the first subject?
20.1.1.1 If other, specify.

TYPE OF APPLICATION

1.1 Indicate the type of application:

* Initial review application

STUDY LOCATION: GENERAL

1.1 Is this a multi-site study? NOTE: A multi-site study involves at least one site or individual NOT affiliated with the UW-Madison. Select Yes if this study:
Will be conducted at sites outside the UW
Includes study team members NOT affliated with the UW
Involves sending or receving samples/data/images to/from collaborators outside the UW

* Yes No

NOTE: A lead site or coordinating center is typically responsible for coordinating activities at all other sites, receiving and analyzing data, and developing and updating the study protocol as needed.

1.2 Will UW-Madison personnel or personnel under UW-Madison IRB purview conduct research activities at sites outside of the US?

Yes * No
1.2.1 If yes, specify.

STUDY LOCATION(S): UW-MADISON SITES

3.1 Describe where the study will occur.
* UW-Madison Department of Chemistry

1.1 Will study activities involve interaction and/or communication with human subjects, even if only to obtain informed consent?
* Yes No

1.2 Provide the expected duration of the study (i.e., the time from IRB approval to completion of all study activities).
* 2 years

SPECIAL CONSIDERATIONS AND PROCEDURES
2.1 If your study involves any of the following special procedures or considerations, additional information may be needed. Select all that apply. If none apply, check Not Applicable.
* Interviews, focus groups, surveys, questionnaires, assessments (e.g., QOL, SCID, BDI, etc.)
* Research activities occurring in an educational setting (e.g., classroom)
* Use of new media (Facebook, Twitter, blogs, etc.)

RESEARCH DESIGN AND PROCEDURES
1.1 What is the overall purpose of this project or study?
* The goal of this study is to establish the effect on student educational performance when a student-generated
wiki (a collaboratively generated website in which all participants have access to and can freely add and edit content) on general chemistry concepts is created by students in a large general chemistry course.

1.2 Briefly describe the procedures and interventions that will be performed for this project or study and all study arms involved.

* 1) Two surveys will be conducted prior to and at the conclusion of a semester-long study. These surveys will be emailed to the students via the instructor or the link will be posted on Learn@UW.

2) A pre-semester assessment consisting of multiple choice questions on concepts that will be learned during general chemistry will also be administered during the first discussion section of the semester. Students will get course credit on a pass/fail basis for completing this assignment. Proctors will be used to adminster this assignment. (See "Proctor script for pre-semester assessment".)

3) Experimental group: Each participant will complete two types of assignments: 1) textual group contributions to a web-based wiki and 2) writing a group report about pre-assigned chemical concepts. Four assignments total are required. One assignment will need to be completed prior to each midterm exam and final exam. Each participant will be required to complete 1 group assignment on the wiki in addition to 1 group report (totaling 2 assignments over the semester).
Control group: the participants in the control group will take the 2 surveys, the pre-semester assessment, and will be given the same conceptual content midterm and final exams as the experimental group.

4) On two midterm exams and the final exam, the participant will be asked multiple choice questions focused on a specific chemical concept. (Each exam will cover all of the required curriculum, not just the randomly selected topic.) The participant will also be asked on the exam to indicate which concept they contributed to on the wiki or the concept they wrote their group report on. Average scores of those who contributed to that specific section will be compared with the average score of those who did not contribute to that section as well as the control group (which will not perform any assignment associated with this study). No student will receive more or less credit on the exam for contributing to a specific section of the wiki. The TAs of the course will grade the exams, and a research team member will tally the results of the targeted questions on an Microsoft Excel sheet that is not accessible to either the TAs or the instructor of the course.

RISKS AND BENEFITS: GENERAL

1.1 Describe any potential direct benefits to subjects. If there are no direct benefits, state this.

* There are no direct benefits to the subjects of this study.

1.2 Describe the potential benefits of this research to society.

* The development of student-generated wikis could provide a free resource to students that could potentially increase their educational experience and performance.

1.3 Does this study involve direct physical intervention with subjects? NOTE: A physical intervention refers to study procedures that may pose a risk (however minimal) to a subject's body (e.g., blood draws, MRIscans, drug or device trials, exercise, dietary restrictions/supplements). Examples of activities that are NOT physical intervention include obtaining informed consent and administering surveys.

Yes * No

RISK/BENEFIT ANALYSIS
4.1 Describe any potential psychosocial risks to subjects, such as psychological stress or confidentiality risks (including risk to reputation, economic risks, and legal risks).

* The instructor of the targeted course is the PI of this study and therefore at risk of holding a status relationship. Confidentiality of the student's participation in this study may be breached if the professor gains access to the identities of the participants. Breach of confidentiality on the participant's score on his or her exams could potentially occur.

4.2 Describe how ALL the risks of the study will be minimized.

* Although Prof. Moore is a member of the research team, only the student researcher (Jaclyn Brown) will have access to the identities of those participating in this study. Consent forms will be obtained during the students' laboratory section by either the student researcher or a proctor. The PI will not be present while these are collected and thus will be unaware of the identities of those participating in this study. The grading of assignments and exams of participants will be handled in an identical manner to those who are not participating. To protect against breach of confidentiality, the results of this study (survey responses and partial scores on exams) will be secured on password-protected computers available only to the student researcher. Student responses will not be reported in an identifiable way in any publication resulting from this research.

Student exams and any information derived from them will be handled only by the conductors of this study and teaching assistants of the targeted chemistry course. Data will not be analyzed until final grades have been posted.

4.4 Describe the provisions in place to identify and address unanticipated problems or complications.

* If a subject experiences a breach of confidentiality as a result of this study, they will be instructed to contact the Department of Chemistry to mitigate their dispute.

SUBJECT POPULATION: GENERAL

1.1 Provide the total number of subjects required from all study locations. NOTE: You must provide an integer. If you are enrolling a range of subjects (e.g., 50 to 100 subjects), enter the larger number.

* 2000

1.2 Provide the number of subjects that will be recruited at sites under UW-Madison purview. NOTE: You must provide an integer. If you are enrolling a range of subjects (e.g., 50 to 100 subjects), enter the larger number.

* 2000

1.3 Describe the main inclusion criteria.

* Enrollees of general chemistry at the UW-Madison Department of Chemistry

1.4 Describe the main exclusion criteria.

* Absence of a completed consent form

1.5 If any racial/ethnic group will be targeted for or excluded from this study, identify the group that will be targeted or excluded and provide justification for this. If this does not apply to your study, select Not Applicable.

Not Applicable

1.6 If men or women will be targeted for or excluded from this study, identify which sex will be targeted or excluded and provide justification for this. If this does not apply to your study, select Not Applicable.

Not Applicable

SUBJECT POPULATION: VULNERABLE GROUP CHECKLIST

2.1 If your study involves *targeted* enrollment of any of the following populations, additional information may be needed. Check all that apply. NOTE: If inclusion of any of these populations is only *incidental*, do not select that population. If none apply, check "None of the above."

*Status Relationship: Individuals with a status relationship with the PI or other study team members (e.g., employees, students, family members)

STATUS RELATIONSHIPS

2.7 Please explain the status relationship.

The PI will be the instructor for one of the targeted lecture courses. The PI will not have access to any research
data (e.g. participants' identities, survey answers) until after course grades are submitted to the registrar.

2.8 Please identify which member of the study team has a status relationship with study participants:

JOHN MOORE

2.9 Will this research take place in a classroom?
* Yes No

SUBJECT POPULATION: VULNERABLE POPULATIONS

3.1 What is the justification for the inclusion of these subjects?

* The PI teaches a large general chemistry lecture in the spring and the fall.

3.2 Describe the additional safeguards that have been included in this study to protect the rights and welfare of these subjects. Include the measures that will be taken to minimize any potential coercion or undue influence in recruitment and ongoing participation in the study.

* The PI will be the instructor for one of the targeted lecture courses. The PI will not have access to any research data (e.g. participants' identities, survey answers) until after course grades are submitted to the registrar. He will also not be present when consent forms are distributed and collected.

SUBJECT IDENTIFICATION AND RECRUITMENT: GENERAL
1.1 From what sources or by what methods will subjects be identified and/or recruited?
* Other

1.1.1 If other, specify.

Subjects will be identified and recruited by their enrollment in general chemistry at the UW-Madison Department of Chemistry.

RECRUITMENT METHODS

2.1 Describe the recruitment plan for this study. NOTE: This description should address what methods will be used, when and how often they will be used, and how many times potential subjects will be contacted.
Potential subjects will be recruited by verbal announcement of the intended research by the student researcher (Jaclyn Brown) during class time (lecture) in the first week of the semester. (See "Research announcement script".) The students will also be informed of their ability to participate in the study immediately prior to the dissemination of consent forms. The "consent form script" will be used by the student researcher, who will hand out and collect consent forms.

2.2 If any advertisements will be posted, list locations and describe what advertisements will be posted at which locations. NOTE: Study teams must obtain permission from each location prior to posting recruitment materials.

Not Applicable

2.3 Upload copies of recruitment flyers. NOTE: Recruitment flyers are any advertisement that will be posted in public locations.

2.4 Upload copies of any other recruitment materials, including scripts, brochures, or advertisements (radio, newspaper, mailed letters, etc.).

Research Announcement Script.docx

2.5 Are you using an IRB approved recruitment database to disseminate recruitment materials or to contact subjects?

* Yes No
2.5.1 If yes, provide the IRB protocol number of the recruitment database.
2.5.2 Describe what will be disseminated to individuals who agreed to be included in the recruitment database.

2.5.3 If the recruitment database is not the investigator's own, upload a letter of support for the use of the database.
File

SUBJECT RECRUITMENT: CONTINUED

3.1 Will subjects be paid or offered other material inducements to participate in the study?

Yes * No

3.2 Will subjects undergo a preliminary screen to determine basic eligibility?
Yes * No

PRIVACY AND CONFIDENTIALITY

1.1 Describe the precautions that will be used to ensure subject *privacy* is protected (e.g., research intervention is conducted in a private room; collection of sensitive information about subjects is limited to the amount necessary to achieve the aims of the research).

* Subjects' scores on midterm and final exams will not be disclosed to anyone other than the conductors of this study and the teaching assistants of the subjects. The PI will be the instructor of the targeted course for at least one semester. The PI will not have access to research data (such as a student's participation in the research study) for any course in which he is an instructor until the conclusion of that class's semester, i.e. after course grades are submitted.

1.2 Select how subjects are identified in the research records. Check all that apply:

*Directly: Information identifying subjects is stored directly on data records

1.3 Describe the measures that will be implemented by your research team to safeguard the identifiable subject information from unauthorized use or disclosure for both paper and electronic forms of information. Include how and where data will be stored.

* The data will be stored electronically on the private computer of a study team member. These data will be password protected and inaccessible to anyone other than the study team members.

1.4 Are you planning to retain data collected for this study for purposes not described in this application (e.g., future unrelated research project)?

Yes * No

1.4.1 If yes, do you confirm that any future uses not described in this application will be submitted separately for IRB review?

PRIVACY AND CONFIDENTIALITY: CONTINUED

2.1 Will data be stored on laptops or portable devices?

* Yes No

2.1.1 If yes, what additional safeguards have been put in place (e.g., link for coded data will be stored separately, data will be deidentified) to protect these data from risk of breach of confidentiality (e.g., theft of laptop, loss of portable device)? NOTE: Consult with your IT department about security of data storage on laptops or portable devices.

The laptop containing research data will be password protected. In addition, data will be stored in Microsoft Excel spreadsheets, which will also be individually password protected.

2.2 Will subject data, specimens, or images be shared outside the UW-Madison? NOTE: This is not referring to industry-sponsored clinical trials or cooperative group studies. For such studies, select Not Applicable.
Yes * No

INFORMED CONSENT: GENERAL

1.1 What consent process or waivers of consent are you requesting for this study?

* Consent process with signed consent documentation

INFORMED CONSENT: OVERVIEW

6.1 Describe when the consent process will occur.

* Consent forms will be collected and documented during the first week of the targeted course's semester.

6.2 Describe where the consent process will occur.

* Consent forms will be distributed and collected in the laboratory section in which the course is held. A research team member or proctor will be responsible for collecting consent forms, documenting them, and returning photocopies to the participants.

6.3 Do you confirm that all study personnel responsible for obtaining informed consent have the following qualifications:
Are familiar with the details of the study;
Will ensure subjects are provided with sufficient information to make an informed and voluntary decision about study participation;
Are familiar with UW-Madison policies regarding informed consent.

* Yes No

6.4 Upload all consent documents and, if applicable, information sheets (e.g., consent form, assent form, translated consent documents). NOTE: If the main consent document for this study is over 5 pages long and/or if the CTRC will be used for this study, an information sheet MUST also be uploaded.
* Consent Form and Assessment Script
Wiki Project Consent Form

INFORMED CONSENT: STATUS RELATIONSHIPS

9.1 Will the consent process be conducted by someone with whom the potential subject has a status relationship?

Yes * No

9.1.1 If yes, justify why this is necessary and describe how potential for coercion will be minimized.

HIPAA: GENERAL
NOTE: For guidance on the HIPAA privacy rule, including what constitutes individually identifiable information and
Protected Health Information (PHI), refer to the HIPAA website. If the purpose of this study or project is to create a
database or registry, contact the HIPAA Privacy Officer to determine whether it needs to be registered.

1.1 Will the research involve the access, collection, use, or disclosure of individually identifiable information and Protected Health Information (PHI)?

Yes *No

1.1.1 If yes, are you or any member of the study team conducting the study under an appointment that is within the UW-Madison Health Care Component (HCC)? NOTE: The HCC of the UW-Madison currently includes SMPH clinical departments; School of Pharmacy (clinical units only); School of Nursing; University Health Services (non-student records only); State Laboratory of Hygiene; and Waisman Center (clinical units only).
Yes * No

INTERVIEWS, FOCUS GROUPS, SURVEYS, QUESTIONNAIRES, ASSESSMENTS
1.1 Describe the interview tools, questionnaires, or surveys that will be used. Click the add button to provide information about each tool to be used.

* Post-study survey now includes additional questions that were not present in the initially submitted survey.

File name Pre-Study Questionnaire.docx
Post-Study Questionnaire- Experimental.docx
Post-Study Questionnaire- Control.docx

1.2 Are any of the uploaded instruments used to assess cognitive or psychological status or function?

Yes * No

INTERVIEWS, FOCUS GROUPS, SURVEYS, QUESTIONNAIRES, ASSESSMENTS: CONTINUED

3.1 Is information that is potentially sensitive, stigmatizing, or psychologically disturbing (e.g., HIV status, illicit drug use, sexual abuse) being collected?

Yes * No

3.1.1 If yes, justify why this information is necessary.

3.1.2 If yes, describe how the risk of disclosure will be minimized, including addressing whether a Certificate of Confidentiality will be obtained.

3.1.2.1 If you already obtained a Certificate of Confidentiality, upload it here.

3.1.3 If yes, describe any arrangements made to provide professional counseling or support resources to any subjects desiring such assistance as a result of their participation in the study.

3.2 If the study involves conducting focus groups, describe how the identity of individuals participating will be protected.

Not Applicable

3.3 If the study involves in-home visits, describe how mandatory reporting requirements (e.g., suspected child/elder abuse) will be met and how subjects will be informed of this reporting requirement.

Not Applicable

RESEARCH ACTIVITIES OCCURRING IN AN EDUCATIONAL SETTING (E.G., CLASSROOM)

1.1 Describe the educational setting(s) in which the study will take place.

* General chemistry course

1.2 Select whether the study is limited to any of the following:

* None of the above

1.3 Will any of the activities be conducted regardless of the research study?

* Yes No

1.3.1 If yes, describe the activities being conducted regardless of the research study.

All students in a targeted lecture session will contribute to both the student-generated wiki and traditional group reports. Non-participants will also receive the same questions on midterm and final exams for the same amount of credit; however, their scores will not be recorded as part of the study.
All students will be required to take the surveys. Results for students not participating in the study will not be recorded.

1.4 Are you randomizing students to different instructional methods that deviate from normal educational practices? NOTE: If yes, the study would not qualify for exemption.
Yes * No

1.5 Upload letter(s) of support from the appropriate school administrator(s). NOTE: If this is a UWMadison instructor's research and is conducted in a UW-Madison classroom, a letter of support is not required.

1.6 Does your research involve the use of education records? NOTE: Education records are those directly related to a student and maintained by an educational agency or institution (e.g., transcripts, University Health Services medical records). If you answer YES and are requesting exemption or a waiver of informed consent, additional regulations may apply in order for the IRB to grant this request.

* Yes No

USE OF NEW MEDIA

1.1 Describe the types of new media and/or sites you will be using.

* A student-generated and student-edited wiki will be set up and monitored for usage over the course of this study. A wiki is a freely constructed and edited website that is accessible to all students taking the general chemistry course of interest. Mediawiki will be used as the software application to construct the wiki through the chem.wisc.edu server. Only those students enrolled in the targeted lecture course will have access to the wiki.

1.2 Upload privacy policies from each site.

Mediawiki Privacy policy.pdf

SUPPLEMENTAL INFORMATION

1.1 Does this submission represent a replacement of a protocol previously approved by a UW-Madison IRB (e.g., one closed under the campus Five Year Renewal Policy)?

Yes * No

1.1.1 If yes, please provide the reason for the replacement (e.g., IRB required closure due to Five Year Renewal Policy):

1.1.2 If yes, provide the previous number assigned to this protocol by the UW-Madison IRB that approved the study:

2.1 Provide any additional relevant documents (e.g., supplemental statistical justification information), if applicable.

2.2 Describe what additional documents were added in 2.1.

FINAL PAGE

1.1 Do you certify that the information presented in this application is accurate?

* Yes No

To complete and submit this application to the IRB office, please follow the steps below:

1. Select Hide/Show Errors at the top of this page to identify any omissions in the application;
2. Select Finish or Exit on this page to return to the study workspace;
3. To submit this application to the IRB office, click the Submit activity in the study workspace. NOTE: The Submit activity is only available to certain study team members.

Consent Form Script: Experimental Group

"Hi, my name is [insert name] and I'm here asking for your help on a Chemical Education Research project here in the UW Department of Chemistry. We are asking students in your general chemistry lecture section to participate in this study. Neither your professor nor your TA will be informed of your participation in this study, and I will ask him/her to leave the room at this point.

[Hand out consent forms once professor and TA are not in room]

The title of this project is "Does the use of a student-generated chemistry wiki affect student performance in large general chemistry courses?" During the semester, a part of the curriculum will be to construct a general chemistry wiki that will be accessible to everyone in your lecture. You will be asked to sign up for a username and make two group contributions about chemical concepts that you learn in lecture. You will also be responsible for writing two group reports that will be turned into your TA. The purpose of this study is to evaluate whether this interactive approach has an effect on student performance. While your contributions to the wiki will be visible to your professor, TA, and other students in your class, your responses to pre- and post-study questionnaires, your score on the pre-semester assessment that you will do today and your participation in this study will be available only to me, the student researcher, if you decide to sign a consent form. Your instructor will not know if you participate in this study. If you are enrolled in a lecture with Professor Moore, the principle investigator of this study, he will not have access to your data until after your final course grade is submitted. *If you are under the age of 18, we ask that you not participate in the research study.* Your participation in the research study will have no effect on your grade, and you will still be asked to contribute to the wiki and take the pre-semester assessment today as part of the course curriculum, even if you do not participate in this research study.

Finally, I want to point out that at the bottom of the consent form, there is a place for you to give permission to quote you anonymously. The feedback that you give on the post-study survey may be reported but is in no way directly traceable to you, and your statement will not be biased, i.e. it will be reported word-for-word. If you do not mind being quoted anonymously, please indicate so at the bottom of the consent form. Also, there is a space for you to write in your student ID number. This information is necessary so that I as a member of the research team can identify participants in the study in a confidential manner.

You are not obligated to participate in the research aspect and disclose your responses, and your coursework will not be any different than study participant. Even if you do not consent to release your data to the student researcher, you will still be required to complete the same assignments as study participants.

Are there any questions?

[Answer questions]

If you have any additional questions, there is contact information on the front of your consent form. A copy will be made and returned to you for your records. When you are finished reading the form, please sign and date the form at the bottom if you would like to give your permission for participation in this study. When you are done with your form, please turn it in along with your pre-test and scantron sheet.

Today we are going to take a pre-semester assessment. This assessment is necessary to gauge your learning gains during this semester. You may not know how to do some of these problems, and that's OK- the purpose is to establish a baseline for comparison. Even if you are not sure or do not know the answer, please make sure that you indicate an answer for all 24 questions on your scantron sheet. All 24 questions must have an answer for you to receive credit for this assessment. When you are done, please give me your pre-test, scantron sheet, and consent form.

[Hand out pre-semester assessment]

Thank you very much for your help in this study and thank you for your time.

[Let students fill out consent forms, assessments, place in sealed envelope]

Consent Form Script: Control Group

"Hi, my name is [insert name] and I'm here asking for your help on a Chemical Education Research project here in the UW Department of Chemistry. We are asking students in your general chemistry lecture section to participate in this study. Neither your professor nor your TA will be informed of your participation in this study, and I will ask him/her to leave the room at this point.

[Hand out consent forms once professor and TA are not in room]

The title of this project is "Does the use of a student-generated chemistry wiki affect student performance in large general chemistry courses?" Another general chemistry lecture will construct a wiki on general chemistry topics. The purpose of this study is to evaluate whether this interactive approach has an effect on student performance. The lecture that you are enrolled in will function as a control group, that is a group that we will compare with those who are writing in the wiki. You will get course credit for filling out two surveys and taking a pre-semester assessment during discussion today.

Your responses to pre- and post-study questionnaires, your score on the pre-semester assessment and your participation in this study will be available only to me, the student researcher if you decide to sign a consent form. Your instructor will not know if you participate in this study. Also, your instructor will not have access to your responses- they will only know if you completed the assignment. *If you are under the age of 18, we ask that you not participate in the research study.* Your participation in the research study will have no effect on your grade, and you will still be asked to complete the two surveys and the pre-semester assessment as part of the course curriculum, even if you do not participate in this research study.

Finally, I want to point out that at the bottom of the consent form, there is a place for you to give permission to quote you anonymously. The feedback that you give on the post-study survey may be reported but is in no way directly traceable to you, and your statement will not be biased, i.e. it will be reported word-for-word. If you do not mind being quoted anonymously, please indicate so at the bottom of the consent form. Also, there is a space for you to write in your student ID number. This information is necessary so that I as a member of the research team can identify participants in the study in a confidential manner.

You are not obligated to participate in the research aspect and disclose your responses, and your coursework will not be any different than study participants. Even if you do not consent to release your data to the student researcher, you will still be required to complete the same assignments as study participants.

Are there any questions?

[Answer questions]

If you have any additional questions, there is contact information on the front of your consent form. A copy will be made and returned to you for your records. When you are finished reading the form, please sign and date the form at the bottom if you would like to give your permission for participation in this study. When you are done with your form, please turn it in along with your pre-test and scantron sheet.

Today we are going to take a pre-semester assessment. This assessment is necessary to gauge your learning gains during this semester. You may not know how to do some of these problems, and that's OK- the purpose is to establish a baseline for comparison. Even if you are not sure or do not know the answer, please make sure that you indicate an answer for all 24 questions on your scantron sheet. All 24 questions must have an answer for you to receive credit for this assessment. When you are done, please give me your pre-test, scantron sheet, and consent form.

[Hand out pre-semester assessment]

Thank you very much for your help in this study and thank you for your time.

[Let students fill out consent forms, assessments, place in sealed envelope]

UNIVERSITY OF WISCONSIN-MADISON
Research Participant Information and Consent Form

Title of the Study: Does the use of a student-generated chemistry wiki affect student performance in large general chemistry courses?

Principal Investigator: John W. Moore (email: jwmoore@chem.wisc.edu)

Student Researcher: Jaclyn R. Brown (email: jackie.brown@chem.wisc.edu)

DESCRIPTION OF THE RESEARCH

You are invited to participate in a research study about the effect of student-generated wikis on student performance in general chemistry.

You have been asked to participate because of your enrollment in general chemistry.

The purpose of the research is to assess the effect of contributing to wikis on knowledge assimilation and communication of scientific knowledge.

This study will include consenting individuals in lecture sections of general chemistry at UW-Madison.

WHAT WILL MY PARTICIPATION INVOLVE?

If you decide to participate in this research, you will be asked to allow researchers access to scores on portions of each of your midterm exams and final exam, your pre-study assessment score, your standardized test scores (i.e. SAT and ACT scores), your high school GPA, your course grade, and your answers to pre-study and post-study surveys. In addition, the information you provide on the web-based wiki (visible to all enrollees of your general chemistry lecture) will be evaluated through a research team member at the UW-Madison Department of Chemistry. Neither your instructor nor your TA will have access to the researcher's information until after your final grade has been submitted to the registrar.

ARE THERE ANY RISKS TO ME?

Participants in Prof. Moore's section: Although Prof. Moore is a member of the research team, only the student researcher will have access to the identities of those participating in this study. Prof. Moore will not know if you are participating in this study, and the grading of your assignments and exams will be handled in an identical manner to those who are not participating.

All participants: To protect against breach of confidentiality, the results of this study (your survey responses, your pre-study assessment, your standardized test scores, your high school GPA and partial scores on your exams) will be secured on password-protected computers available only to the student researcher. Your answers will not be reported in an identifiable way in any publication resulting from this research. Student exams and any information derived from them will be handled only by the conductors of this study and teaching assistants of the targeted chemistry course.

ARE THERE ANY BENEFITS TO ME?

We don't expect any direct benefits to you from participation in this study. Access to the student-generated wiki will be given to all students in your lecture, regardless of your participation in this study.

HOW WILL MY CONFIDENTIALITY BE PROTECTED?

While there may be publications as a result of this study, your name will never be used. Only group characteristics will be published, and your identity will never be disclosed to Prof. Moore. If you participate in this study, we would like to be able to quote you directly without using your name. These quotations include any comments you make on the pre- or post-study surveys as well as contributions you make on the ChemWiki. Your name will not be associated with any quotations. If you agree to allow us to quote you, please initial at the bottom of this form.

WHOM SHOULD I CONTACT IF I HAVE QUESTIONS?

You may ask any questions about the research at any time. If you have questions about the research after you leave today, you should contact the Principal Investigator (John W. Moore) or the Student Researcher (Jaclyn R. Brown). (Contact information is on the front of this consent form.)

If you are not satisfied with the response of the research team, have more questions, or want to talk with someone about your rights as a research participant, you should contact the Education Research and Social & Behavioral Science IRB Office at 608-263-2320.

Your participation is completely voluntary. If you decide not to participate or to withdraw from the study, it will have no effect on your grade in this class.

Your signature indicates that you have read this consent form, had an opportunity to ask any questions about your participation in this research and voluntarily consent to participate. You will receive a copy of this form for your records.

Name of Participant (please print legibly):_____

UW Student ID number: _____

_____ _____

Signature Date

_____ I give permission to be directly quoted in publications without using my name.

Appendix C: Student Guides, Screenshots of ChemWiki, and Gradebooks

Appendix C contains the full "Student Guide to the ChemWiki". This document was distributed to students to provide clear instructions on how to format the ChemWiki. Appendix C also contains examples of student contributions to the ChemWiki. The gradebooks used by the Chem 104 and Chem 109 teaching assistants are also included. These gradebooks were based on similar Microsoft Excel gradebooks used by general chemistry teaching assistants at UW-Madison to grade lab reports.

Student Guide to the ChemWiki

(chem109wiki.chem.wisc.edu)

Questions? Contact Jackie Brown at jackie.brown@chem.wisc.edu

Section 1. Overview

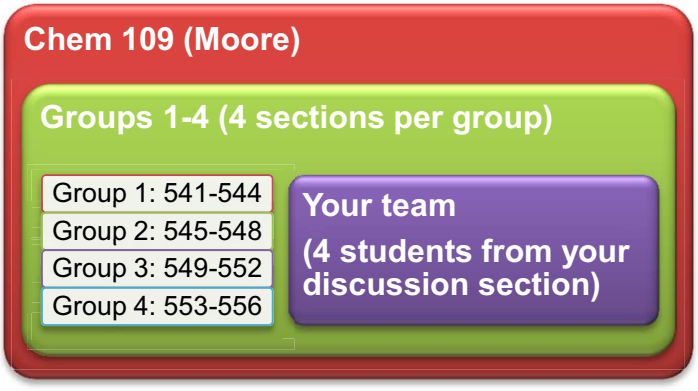
Part of your grade this semester will be based on your contributions to a wiki that is written by the entire class. A wiki is a collaborative website in which the content is added and edited freely. The wiki that your Chem 109 class will construct will be a free resource that anyone enrolled in the class may use.

The goal of using this interactive website is to determine the effect of this media on student performance in general chemistry. A chemical education research project will be conducted by a student researcher (Jackie Brown) during the course of the semester, which you may participate in if you decide to give consent.

Mandatory wiki contributions:

One wiki contribution per exam period is required (see section 6, "Wiki Contribution Guidelines") and must be documented on the wiki by 11:55 P.M. one week before the exam (see deadline schedule below). It would be wise to not wait until the last minute to submit your contribution- if for some reason the webpage is not working, you do not want to have to panic and hope it gets fixed in time for you to submit your contribution.

You will be assigned to a group (e.g. "Group 1"), which is determined by what section you are in. There are four groups total (Group 1-4) in your lecture, 1 group for every 2 TAs. You will then choose a *team of 4 students that are in your discussion section* and will be required to complete either a) one page in the wiki, or b) a written, traditional report that you will submit to your TA.



Before each exam, check your group's home page (http://chem109wiki.chem.wisc.edu/mediawiki/code/index.php/Group) on the ChemWiki to confirm your group and your assignment.

If you are assigned to write a Wiki Page, you may contribute to any page that is within your group's assigned topics. You may not contribute to topics on future exams until the current exam is finished. For each exam, you need to select one page on the wiki to fill out as a group. **This page must be under your assigned group heading**. Please do not edit the other team's

page- remember, a digital log is created for all edits made on the wiki! Your finished wiki page is due 1 week before the exam.

If you are assigned to write a Traditional Report, you will submit a report on an assigned topic 1 week before the exam. See Section 12, "Traditional Report Requirements" for more information.

Point Breakdown and Deadline Schedule

Contribution	Points	Deadline
Wiki Assessment	5 points	Sept. 5th - Sept. 6th (in discussion)
Signing up for a Username*	0 points	Saturday, Sept. 7th at 11:55 P.M.
Pre-Semester Survey	5 points	Tuesday, Sept. 10th at 11:55 P.M.
User Page Assignment	5 points	Friday, Sept. 13th at 11:55 P.M.
Group Page or Report for Exam 1	10 points	Wednesday, Sept 18th at 11:55 P.M.
Group Page or Report for Exam 2	10 points	Monday, Oct. 14th at 11:55 P.M.
Group Page or Report for Exam 3	10 points	Monday, Nov. 11th at 11:55 P.M.
Group Page or Report for Final Exam	10 points	Monday, Dec. 9th at 11:55 P.M.
End of Semester Survey	5 points	Friday, Dec. 13th at 11:55 P.M.
Total	60 points	

*You must use your NetID (e.g. JDoe5) as your username- no other username is acceptable.

Section 2. Restrictions on Wiki Contributions

Please do not edit the content (i.e. change other students' contributions) for current exam material. Once the exam has passed, then the content may be freely edited.

This wiki will be monitored for abuse. *Any spam, vandalism, profanity, or vulgar content will be immediately removed and your account will be blocked.* Keep in mind that a digital record is made for every contribution on this wiki. If you see inappropriate content, please notify Jackie immediately at jackie.brown@chem.wisc.edu.

Plagiarism will not be permitted on this website. Please see UW-Madison's information for students on plagiarism at http://students.wisc.edu/doso/students.html. The Writing Center at UW-Madison (http://writing.wisc.edu/Handbook/Acknowledging_Sources.pdf) is also a good resource for how to avoid plagiarism and cite your sources. If you ever have any questions on phrasing or how to appropriately cite sources, it is best to *ask your TA or Prof. Moore before you turn anything in*, either here on the wiki or on other class assignments. Plagiarism is taken very seriously here at UW, and you should not take it lightly, either.

This wiki is for **chemistry content only**. While adding chemistry "trivia" such as historical perspectives, fun facts, etc. are encouraged, we ask that you do not litter the wiki with extraneous pages or links to non-chemistry related items.

Section 3. ChemWiki Video Tutorial

Before you get started, you MUST watch the ChemWiki Video Tutorial. The ChemWiki Video Tutorial is a 21-minute video on YouTube that introduces the ChemWiki Project and guides you through the various sections of the wiki. You will also learn how to edit wikitext using a step-by-step guide on how to do your first assignment, the User Page Assignment. **YOU MUST WATCH THE ENTIRE VIDEO BEFORE YOU BEGIN CONTRIBUTING TO THE CHEMWIKI!** Follow the link below to watch the full video:

https://www.youtube.com/watch?v=wA7skDRxlFg

Note: Be sure to change the quality of the video to 720p so that you can see the video clearly.

The video has also been broken up into sections for quick reference (see below).

1) Intro to Project and How to Sign Up for a Username: https://www.youtube.com/watch?v=jCBHdRwDiTA

   *Note: **You must use your NetID (e.g. JDoe5) as your username**- no other username is acceptable.*

2) Editing Your Preferences: https://www.youtube.com/watch?v=eRp_epkcUeY

3) Navigating the Main Page: https://www.youtube.com/watch?v=_RevBQSxKvE

4) How to Add Text: https://www.youtube.com/watch?v=tavoEt0l3-s

   Note: This video is a description of where you will edit the wiki. For information on how to format wikitext, watch "Editing Your Userpage/First Assignment".

5) Editing Your Userpage/First Assignment: https://www.youtube.com/watch?v=7eSNp7u5_Vo

Section 4. Avoiding Plagiarism

What is plagiarism?

Plagiarism is the use of someone's words or ideas without giving proper credit to the original author. While some instances of plagiarism are very easy to identify (and avoid), there are less obvious ways to commit plagiarism. Avoiding plagiarism should be a top priority for you during your academic career. **You alone are responsible for making sure that you know what constitutes plagiarism; ignorance is not an excuse**. For more information/examples of what constitutes plagiarism, please see the following links:

The Writing Center at UW-Madison. Avoiding Plagiarism: Quoting and Paraphrasing: http://writing.wisc.edu/Handbook/QPA_plagiarism.html

Indiana University- Plagiarism: What It Is and How to Recognize and Avoid It http://www.indiana.edu/~wts/pamphlets/plagiarism.shtml

UW-Madison Policy on Plagiarism

The following information is from the UW-Madison Dean of Students Office.[1]

"As a UW-Madison student, it is your responsibility to be informed about what constitutes academic misconduct, how to avoid it and what happens if you decide to engage in it. Examples of academic misconduct include (but are not limited to):

- Plagiarism (turning in work of another person and not giving them credit),
- Stealing an exam or course materials,
- Copying another student's homework, paper, exam
- Cheating on an exam (copying from another student, turning in an exam for re-grading after making changes, working on an exam after the designated time allowance)

How to Avoid Academic Misconduct?

- Know how to cite sources in a paper, lab report or other assignments
- Use the writing center for help with citations. They are experts in APA, MLA and other citation styles.
- *Avoid copying and pasting directly into your paper from the internet*
- Understand the expectations and limitations when working in groups (i.e., Is collaboration allowed on the project and the written paper, or only the project and your written paper should be done alone)

What Happens If I Engage in Academic Misconduct?

The University of Wisconsin-Madison takes academic misconduct allegations very seriously. Your professor will contact you if they believe you have engaged in academic misconduct and ask you to explain your work. If they still believe you engaged in such an act after meeting with you, they will decide on a sanction, which may include a zero on the assignment or exam, a lower grade in the course or failure in the course. The Dean of Student's Office is informed and will contact the student about their rights. Repeated acts of academic misconduct may result in more serious actions such as probation or suspension."

Examples of Plagiarism and How to Avoid It

Below are examples of plagiarism. Here's the original passage:[2]

> *"In an inquiry focused on correcting the record and explaining how such fraud could have been sustained within the ranks of The Times, the Times journalists have so far uncovered new problems in at least 36 of the 73 articles Mr. Blair wrote since he started getting national reporting assignments late last October. In the final months the audacity of the deceptions grew by the week, suggesting the work of a troubled young man veering toward professional self-destruction."*

Type of Plagiarism	"New" paragraph	What's wrong with this paragraph?
Cut and paste plagiarism	In an inquiry focused on correcting the record and explaining how such fraud could have been sustained within the ranks of The Times, the Times journalists have so far uncovered new problems in at least 36 of the 73 articles Mr. Blair wrote since he started getting national reporting assignments late last October. In the final months the audacity of the deceptions grew by the week, suggesting the work of a troubled young man veering toward professional self-destruction.	It's exactly the same, word for word. Definitely not acceptable.
Cut, paste, and replace plagiarism	In an inquiry focused on fixing the record and explaining how such fraud could have continued at The Times, the Times journalists have found new instances of plagiarism in at least 36 of the 73 articles Mr. Blair wrote since he started reporting late last October. In the last few months the audacity of the deceptions increased, the work of a young man, clearly troubled, veering towards a path of self-destruction.	It is obvious by comparing the original paragraph and this one that the plagiarizing author simply consulted a thesaurus to change some of the words.
Potpourri plagiarism	Times journalists have found 36 of the 73 articles that Mr. Blair wrote had problems. In the final months, the audacity of deceptions kept growing, indicating a troubled young man set on a course for professional self-destruction. Reporters at the times have found new problems in at least 36 of the 73 articles that Mr. Blair has written since starting last October.	This type of plagiarism is probably the most common. All of the elements of the original paragraph are still here except that a few of the words have been replaced and the order of the ideas has been scrambled.
Self-plagiarism	In an inquiry focused on correcting the record and explaining how such fraud could have been sustained within the ranks of The Times, the Times journalists have so far uncovered new problems in at least 36 of the 73 articles Mr. Blair wrote since he started getting national reporting assignments late last October. In the final months the audacity of the deceptions grew by the week, suggesting the work of a troubled young man veering toward professional self-destruction.	Even if you are Dan Barry, David Barstow, Jonathan Glater, Adam Liptak or Jacques Steinberg (the authors of this article), you can't reclaim this as "new" content because it has already been published. Similarly, you cannot use previous contributions you have made on the wiki without citing where you got it from!

To avoid plagiarizing, you need to be able to do these things:

1) Know how to cite your sources properly
2) Be able to write your contributions/reports without looking back frequently at the original text. If you really understand what you want to say, you shouldn't be reliant on looking back at your source constantly.
3) If you are worried that you might be in a "gray area" of plagiarizing, ask your TA or a knowledgeable writer (e.g. The Writing Center: http://writing.wisc.edu/)
4) When working in groups, you are responsible for **everything with your name on it**, not just the sections you write. Make sure to keep your collaborators honest and read everything your group submits!

If you suspect plagiarism on either the wiki or any class assignment (traditional report, lab report, exam, etc.), notify your TA, professor, or proctor. Plagiarism only hurts the integrity of the classes at UW, and we want to make sure that everyone is getting a high quality education.

Section 5. Putting References in the Wiki

To cite a reference in the wiki, you should use an inline citation. An inline citation means that you will put the reference content in the body of the text.

Using **<ref>** and **</ref>** tags before and after your content will automatically generate a reference list that is present at the bottom of the page.

Example:

> Buckingham U. Badger, or Bucky, is the official mascot of the University of Wisconsin-Madison. **<ref>**The Official Web Site of the Wisconsin Badgers - Spirit Squad. http://www.uwbadgers.com/spiritsquad/bucky-badger.html (accessed May 28, 2013).**</ref>**

would result in the following text:

> Buckingham U. Badger, or Bucky, is the official mascot of the University of Wisconsin-Madison.[1]

Your reference information will then be listed where there is a **</references>** tag. This tag should go at the bottom of your page under a "References" heading. (See the ChemWiki Video Tutorial for more information). The number it is listed as will be automatically generated and will depend on the order of references within the wikitext.

Note: Use ACS style notation when citing your sources.

ACS style notation was developed by the American Chemical Society (ACS) and is used to cite sources in chemistry research papers. You can find a thorough guide to ACS style notation at this website: http://library.williams.edu/citing/styles/acs.php

Section 6. Wiki Contribution Guidelines

What does a contribution consist of?

A contribution consists of a single page and has all three types of entries (see below). Do not edit a page that someone else has already started- if there is already text there, find another page to edit! Each group page must have all of the following in order to be considered for full credit:

a) *At least 10 internal links* to other *pre-existing* relevant pages in the ChemWiki. If you think that a page needs to be created, feel free to create a new page!

> *To get full credit, you must link to a page that already exists- broken links (which appear in red) are not properly linked.* See the "Wikitext Cheatsheet" (Section 8) for information on how to fix broken links.

b) *External references* (listed at the bottom of the page under "References") to where the original information came from. References should be cited in ACS-style format (see Section 5, "Putting References in the Wiki").

> ***A contribution that does not cite its sources will not receive credit.***

c) *Clear, concise text and figures* that help your peers understand the concept at hand. Feel free to write in colloquial language or in a style that you feel will best explain your chosen topic to the uninitiated.

Each page must have:

1. Enough text to adequately explain the topic.
2. At least 4 embedded figures.
3. At least 4 original practice problems.

1) Chemical descriptions of the concept.

Text should sufficiently illustrate the concept at hand to a fellow student who is learning the material for the first time. Your contributions are a report on your topic, and as such, it should give an in depth explanation of your topic. The example paragraph below is an example of a single paragraph- your wiki report should be much longer than this! (Internal links are shown in blue.)

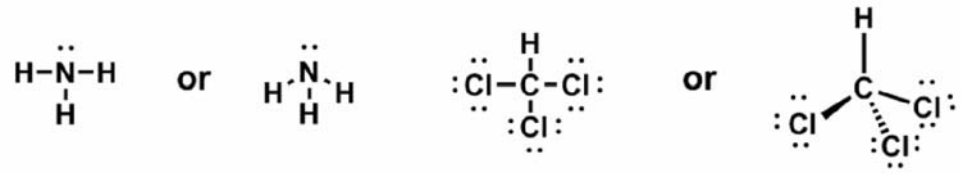
Example: Lewis dot structures

Wiki contribution	Note
A Lewis dot structure, named after the chemist Gilbert Lewis, is a representation of the bonding of a molecule.[3] It is composed of lines that signify a covalent bonds and dots (:) that represent lone pairs, or electrons that do not participate in bonding. One line signifies a single bond, two lines represent a double bond, and three lines indicate a triple bond. When a Lewis dot structure is drawn correctly, it gives information as to how the molecule is assembled. Lewis dot structures can also be drawn using wedge-dash notation in order to illustrate the principles of valence shell electron pair repulsion (VSEPR) theory.	This entry is a very general description of what a Lewis dot structure is, what it's used for, and why it's important to learn. It also has internal links to the appropriate topics.
Lewis dot structures can be drawn with any atoms on the periodic table and can be approached systematically.[4] To draw a Lewis dot structure, a) You must first count the number of valence electrons present in each atom in the molecule. (For example, CO_2 has 4 + 6 + 6 = 16 valence e^-). b) Arrange the atoms in the molecule so that the least electronegative atom is the central atom. H's are always on the outside because they can only form one bond. Halogens are usually on the outside, too. c) Place one bond (—) between the central atom and each outer atom to form a bond. Each single bond uses 2 e^-. d) Use the remaining electrons as lone pairs around the outer (non-central) atoms, except on H. e) If an atom does not have an octet, use the 2 e- from a lone pair to form double bonds or triple bonds until all atoms (except H) have a full octet.	This entry elaborates on how to actually draw Lewis dot structures, step by step. It should be easy to follow, as if you were teaching your classmate (who has never heard of a Lewis dot structure) how to draw one.

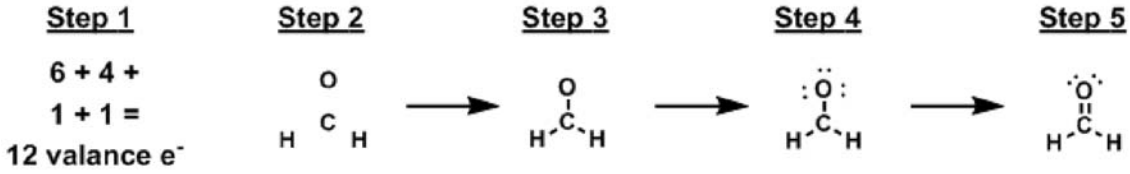
2) At least 4 graphics or tables that helps illustrate the concept.

If you use a graphic that you did not create, you MUST cite where you obtained the graphic!

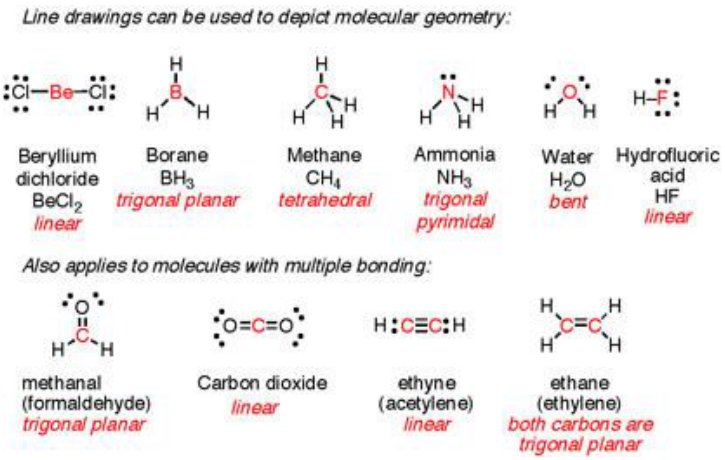
For Lewis dot structures, a figure which shows a few examples (ammonia and chloroform) would be appropriate:



or a step-by-step of how to draw Lewis dot structures (e.g. formaldehyde):



You could also insert some exceptions to the octet rule and using Lewis structures to depict molecular geometry[5] in hydrocarbons, amines, alkenes, etc.



3) At least 4 example problems where the solution is worked out or a concept is illustrated.

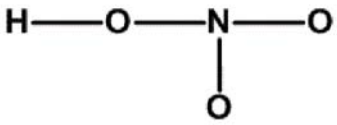
You must also create your own "exam"-type questions here for concepts that are more conceptual (rather than solution-based) in nature. Make sure that you include an answer and an explanation of how that answer was formulated.

Example 1: Draw the Lewis dot structure for HNO_3.

Answer:
a. HNO_3 has 1 + 5 + 6 + 6 + 6 = 24 valence e^-

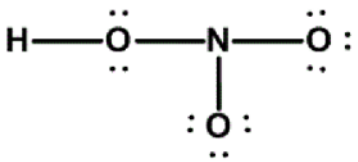
b. Nitrogen is the least electronegative, non-H atom, so it goes in the center:

c. Put one bond between each atom:

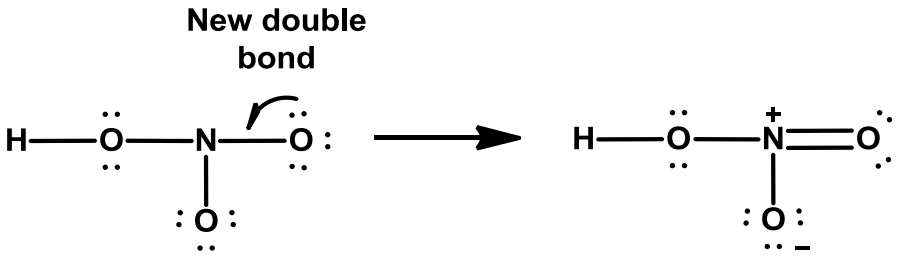


d. Put in the remaining electrons (except H) as lone pairs

- I already used 8 e^- (2 for each single bond)
- I will use the remaining 16 e^- to fill in the octets of the non-central, non-H atoms:

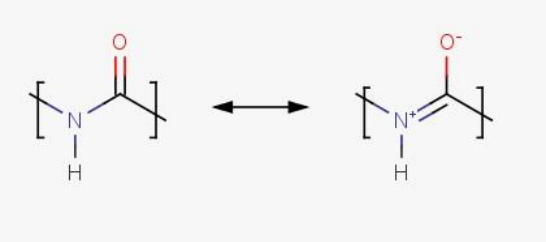


e. Nitrogen does not have a full octet, so I will use a lone pair on one of the oxygens to make a double bond. No new electrons are being introduced, just shifted around. When making double and/or triple bonds, try to make the least amount of charged species possible.



Example 2: Even though both carbohydrates and proteins release the same amount of energy per unit mass (4 cal/g), proteins provide a longer-lasting source of energy for the human body than carbohydrates provide.[6] This means that proteins are more difficult for the body to digest (i.e. break down into amino acids). Give an explanation why proteins may be harder to digest than carbohydrates.

Answer: Proteins are long chains of amino acids and are formed by the condensation of one amino acid with another amino acid to make a peptide bond. Since proteins are harder for the body to digest, the peptide bonds formed in the molecule must be very strong. We learned that peptide bonds result in an sp^2-hybridized nitrogen due to resonance, or delocalization of electrons along the N-C-O chain (see figure below). The resonance effect thus makes this type of bond very strong and so breaking the bond should be difficult for the body to do.



Section 7. Adding Images to the Wiki

The best way learn how to upload images to the wiki is watching the ChemWiki Video Tutorial. (https://www.youtube.com/watch?v=7eSNp7u5_Vo).

Adding an image to a wiki page is a 2-step process. You must complete both steps, or you will not see the picture displayed on your wiki page.

Step 1: Uploading the file to the wiki

- Save your file on your computer and name it using the following notation: DDMM Description of image. This format will prevent images from being overwritten by other users' files. e.g. If I uploaded the image below on January 21st, I might call it "0121 Memescience".
- To upload images to the wiki, simply click the "Upload photo" link in the toolbox panel on the left side of this screen. **DO NOT PUT ANY TEXT INTO THE "SUMMARY" BOX- ALL OF YOUR TEXT NEEDS TO GO ON THE WIKI PAGES THEMSELVES.**
- Click "Upload File". Your image is now in the wiki directory, but has *not yet been loaded onto the page* (See step 2).
- If you would like to make your own images of molecules, MarvinSketch (see Section 10) is a useful program.

Step 2: Adding the image to a wiki page

Once your file has been uploaded to the wiki, you can add it to your wiki entry by **putting the following wikitext into the textbox of your entry**:

[[File:Name|Type|Border|Location|Alignment|Size|Caption]]

Only Name is required. The other details are optional and can be placed in any order.

- Type: Displays the image with specific formatting (see below). ("thumb", "frame", or "frameless".)
- Border: Put a small border around the image. ("border")
- Location: Determines the horizontal placement of the image on the page. ("right", "left", "center" or "none".) (The default is "right" for thumbnails.)
- Alignment: Vertically aligns the image with respect to adjacent text. ("baseline", "middle", "sub", "super", "text-top", "text-bottom", "top", or "bottom".) The default is "middle".
- Size: Scales the image to be no greater than the given width and/or height, keeping its aspect ratio. ("Widthpx" or "xHeightpx" or "WidthxHeightpx".) Scaling up (i.e. stretching the image to a greater size) is disabled when the image is 'framed'.
- Caption: Specifies the image's caption. This is visible only if "frame" or "thumb" attribute is used. (Insert your own caption here.)

The wikitext for the image below is:

[[File:0528Memescience.jpg|thumb|center|baseline|500px|Scientific method, meme-style<ref>Steps of Scientific Method - Meme version | Meme Overload | Know Your Meme http://knowyourmeme.com/photos/308739-meme-overload (accessed Jan. 21, 2013).</ref>]]

Section 8. Wikitext Cheatsheet

(adapted from http://en.wikipedia.org/wiki/Help:Cheatsheet for use in the Chem 109 wiki.)

Works anywhere in the text		
Description	You type	You get
Italics, bold, and both	`''italics'', '''bold''', and '''''both'''''`	*italics*, **bold**, and ***both***
Link to another page	`[[aldehyde]]` `[[aldehyde]]s`	aldehyde aldehydes
Red Link *Red links in articles help by showing desired pages that need to be created or redirected.*	`[[something missing]]`	something missing

References
Sources in the article will appear where <references /> is put, typically under the "References" section at the bottom of the page.
	`Hello,<ref>Library of Congress</ref>`
	`World.<ref>http://www.w3.org/</ref>`
	
	`== References ==`
	`<references />`
		Hello,[1] World.[2]
		References:
		1. ↑ Library of Congress
		2. ↑ http://www.w3.org/

Signature (for edits on Talk pages) *Sign your contributions when posting to a talk page.*	`~~~~` *do not sign in an article, only sign talk pages*	Username (talk) 14:43, 21 June 2013 (UTC)
Plain website	`http://www.wikipedia.org`	http://www.wikipedia.org
Link a website	`[http://www.wikipedia.org]`	[1]
Link and name a website	`[http://www.wikipedia.org Wikipedia]`	Wikipedia
Show an image	`[[File:Wiki.png|thumb|Caption]]`	 Caption

Description	You type	You get
Redirect to another page *Redirects must be placed at the start of the first line*	`#REDIRECT [[Target page]]`	Target page
Redirect to a section of another page	`#REDIRECT [[`Target page#anchorName`]]`	Target page#anchorName

Section headings
A Table of Contents will automatically be generated when four headings are added to an article
	`==Level 2==`
	`===Level 3===`
	`====Level 4====`
	`=====Level 5=====`
	`======Level 6======`
	
	Do not use =Level 1= *as it is for page titles*
		[edit]Level 2
		[edit]**Level 3**
		[edit]**Level 4**
		[edit]**Level 5**
		[edit]**Level 6**

Nonindexed headers *Left out of Table of Contents*	`; Header name` *has a leading semicolon* ";" *in front*	**Header name** *Will not appear in Table of Contents*

Bulleted list	`* One`
	`* Two`
	`** Two point one`
	`* Three`
		▪ One
		▪ Two
		  ▪ Two point one
		▪ Three

Numbered list	`# One`
	`# Two`
	`## Two point one`
	`# Three`
		1. One
		2. Two
		  1. Two point one
		3. Three

Indenting text	`no indent (normal)`
	`:first indent`
	`::second indent`
	`:::third indent`
		no indent (normal)
		  first indent
		  second indent
		  third indent

Section 9. Frequently Asked Questions (FAQs)

How do I put in new headings if I accidentally delete them?

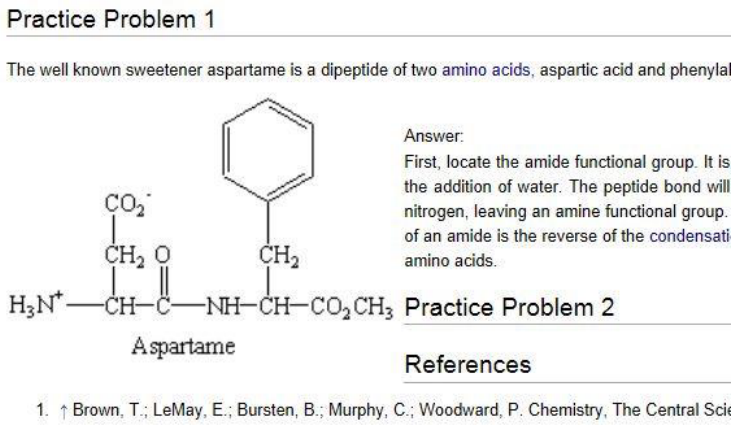
To put in a new heading, you need to use the double equal signs wikitext:
Ex. **== How do I add in headings? ==**

See the "Section headings" on the “Wikitext Cheatsheet” (Section 8) for more information.

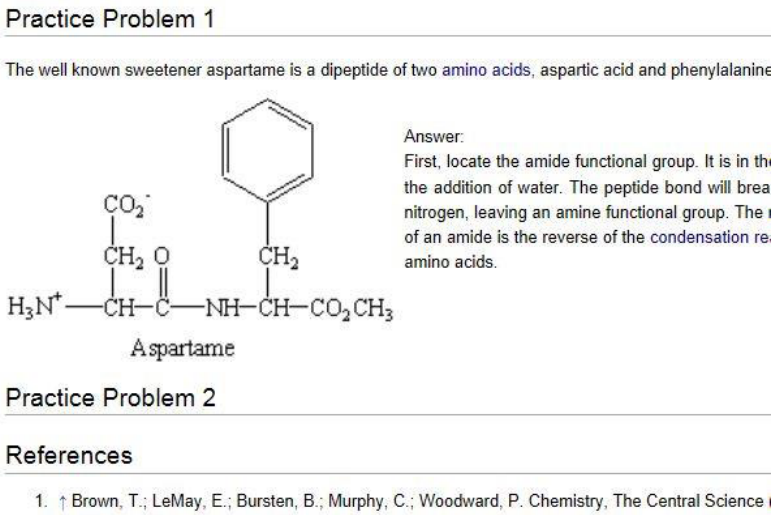
How do I clean up my page- it's a mess!

If your figures are not lining up underneath the headings properly, you can use the **{{clear}}** template to insert whitespace. To use the "Clear" template, simply type in **{{clear}}** underneath your entry.

Without using **{{clear}}**:



With **{{clear}}** template: (text added on line before **== Practice Problem 2 ==)**



How do I draw chemical structures?

If you would like to draw chemical structures, you need to download structure drawing software on your computer. MarvinSketch is a free, easy to use java application that anyone can download. See Section 10 for more details.

You need to register for a ChemAxon account in order to download the software. Here are step-by-step instructions for downloading MarvinSketch:

1) Register for a username at https://www.chemaxon.com/forum/profile.php?mode=register&agreed=true.

The company is the University of Wisconsin-Madison. ChemAxon will then send you an email (this may take a few minutes) which you will need to activate your account. Until you activate your account by email, you will not be able to download anything.

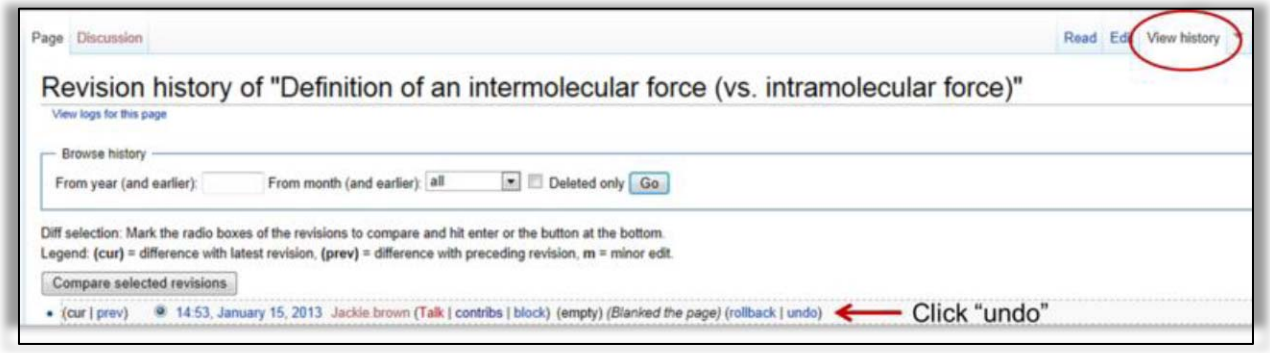
2) Once you have a username, go to http://www.chemaxon.com/download/marvin/for-end-users/.

Click “I Accept the License Agreement” and download the appropriate installer.

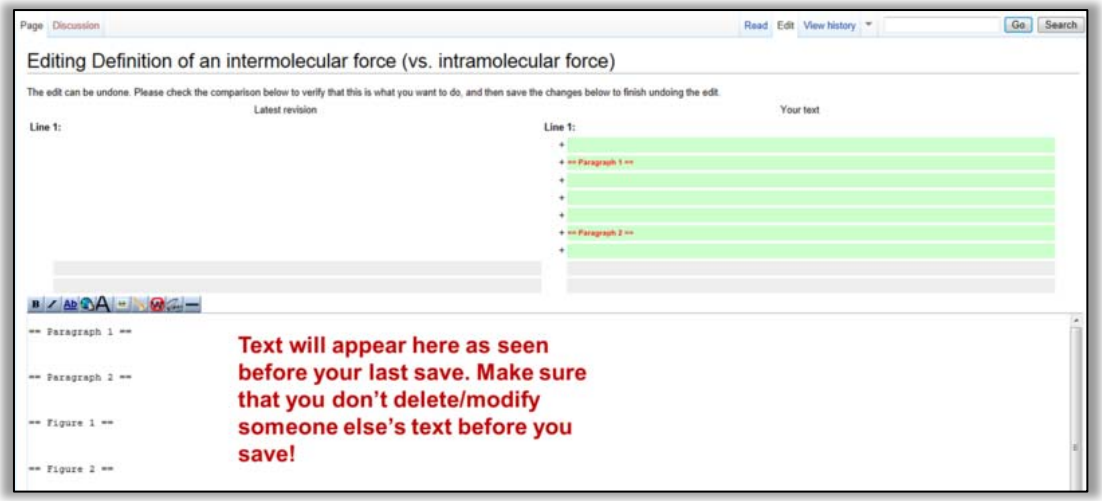
3) Follow the step-by-step instructions of the installer. When it is completely downloaded, you should have access to MarvinSketch.

I accidentally deleted someone else's contribution! How do I undo it?

If you accidentally changed someone else's text, you can undo your last edit by clicking the "View history" tab in the upper right corner.



Clicking will get you back to the previous version of wikitext. Next, click on the "undo" link on your last edit. This will undo that change and bring you back to a screen similar to the "Show preview" window. You can see (in column format) what changes were made, and you can continue editing.



Once you reach this screen, you can either save it or continue editing.

How do I link to an existing page without using the exact page name?

If you want to link to an existing page, but the page title doesn't exactly match what you need to say, then it is possible to redirect a new (empty) page to an existing page. For example, if I want to say "ammonia is a type of amine", and link to the "amines" page, I can't link to the amines page until there is a "dummy" amine page.

Here's what you do:

1) In your wikitext, make the page you wish (**[[relatedpagename]]**) by using the double bracket notation. (This would be a new page titled "amine".)

2) On the newly created page ("amine" in this example), insert the following wikitext: **#REDIRECT [[existingpagename]]** (in this case, the existing page would be "amines".)

3) Save the page. When you link to the new, related page in your future wikitext, it should now redirect to the existing page. ("Amine" will redirect to "Amines".)

Can I use color in my wikitext? How?

Yes, you can change the color of your text and tables, but it would be appreciated by all users if color is used for emphasis only. Using a lot of different colors (or one really obnoxious one) is a distraction. Please use colors in moderation. You can find a very thorough guide to using colors on Wikipedia (http://en.wikipedia.org/wiki/Help:Using_colours).

Section 10. MarvinSketch: A Tool for Drawing Chemical Structures

What is MarvinSketch?

MarvinSketch is a chemical structure drawing program that allows you to easily create organic structures and save them as images.[7] It is provided by ChemAxon free of charge. Use of MarvinSketch is not mandatory in Chem 109, but if you would like to be able to create chemical structures (especially organic structures), it is a very useful tool. A more comprehensive user guide can be found at:

http://www.chemaxon.com/marvin/help/sketch/sketch-index.html

Why is MarvinSketch useful?

MarvinSketch allows you to make your own chemical structures in a way that is legible. Chemists use programs like MarvinSketch (or very similar software) nearly every day, and chemical structure drawing programs are universally used to publish chemical research. By using MarvinSketch, you will become familiar with how chemical drawing software works, which will be quite useful if you decide to pursue a career in chemistry or biochemistry.

Downloading the MarvinSketch program

If you would like to use MarvinSketch, you need to register for a ChemAxon account in order to download the software. Here are step-by-step instructions for downloading MarvinSketch:

1) Register for a username at https://www.chemaxon.com/forum/profile.php?mode=register&agreed=true.

The company is the University of Wisconsin-Madison. ChemAxon will then send you an email (this may take a few minutes) which you will need to activate your account. Until you activate your account by email, you will not be able to download anything.

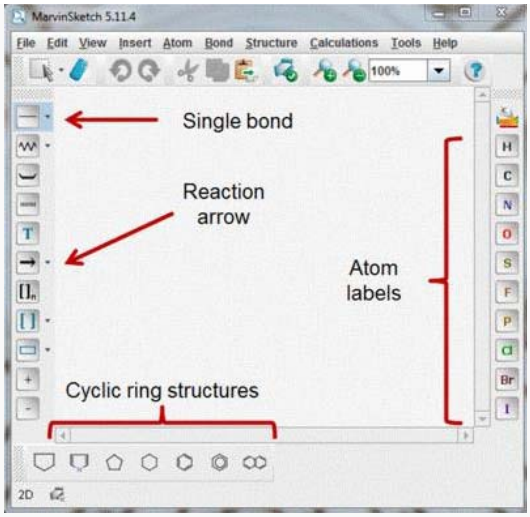
2) Once you have a username, go to http://www.chemaxon.com/download/marvin/for-end-users/.

Click “I Accept the License Agreement” and download the appropriate installer.

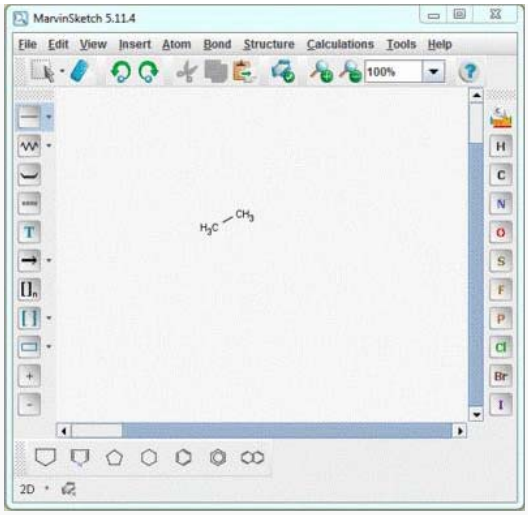
3) Follow the step-by-step instructions of the installer. When it is completely downloaded, you should have access to MarvinSketch.

Drawing Figures on MarvinSketch

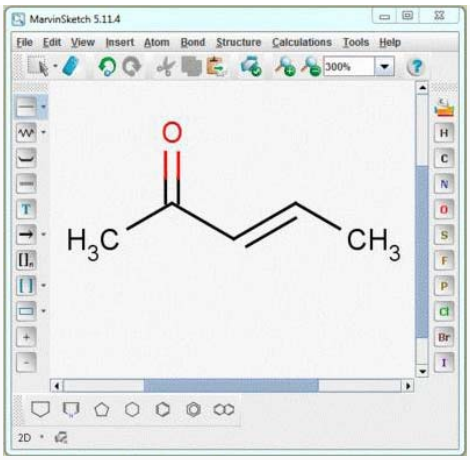
Once you have downloaded MarvinSketch, open the MarvinSketch program, where you will find a blank canvas to draw on:



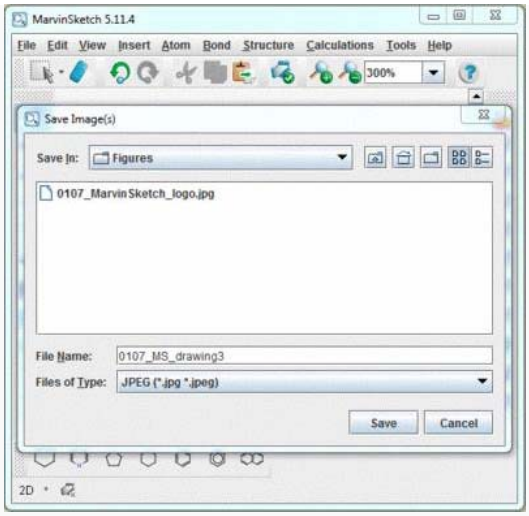
Click on the **single bond button**. Once selected, click anywhere on the canvas to draw a single bond (the default atom is carbon). You can also use the dropdown menu on the single bond button to access double and triple bonds.

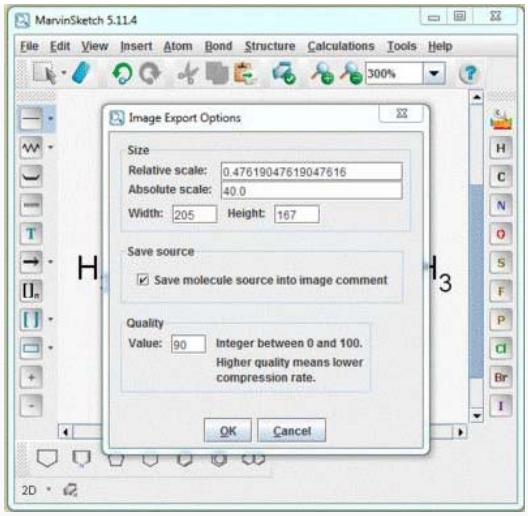


Use the bond drawing buttons to draw your molecule of interest. If you want add to a double bond, use the double bond button (in the scroll down menu on the single bond button) or click on the single bond that you want to turn into a double bond. To change the atom label, click on the atom of interest (on the right side of the screen) and then click on the target atom to change it. Once you are satisfied with your drawing, use the zoom button (top of the screen) to **zoom in so that the molecule structure takes up most of the space on the canvas**:



To **save your drawing**, select File ⇒ Save As Image. Save the drawing as a **.jpg, .png, or .gif file** using the "DDMM Description of file" notation. In order to have an appropriately sized image, **set the absolute scale to 40** and leave the other parameters alone. Press "OK" to save your image.





Once you have a file saved to your computer, **upload the file to the wiki**. Your file is now ready to be placed into the wiki content. (See Section 7, "Adding Images to the Wiki", for more information.)

Section 11. User Page Assignment: Getting Initiated with the ChemWiki

The goal of this first assignment is to familiarize yourself with using the ChemWiki (and your classmates!). On your user page, answer the following questions by making a new heading for each question. Please answer these questions in complete sentences:

1. What is your name and what group are you in? What are the names of the other people in your team? Link to their user pages and link to your group's page. (You will need to know their usernames before you do this exercise, so make sure that you exchange usernames before you begin.)

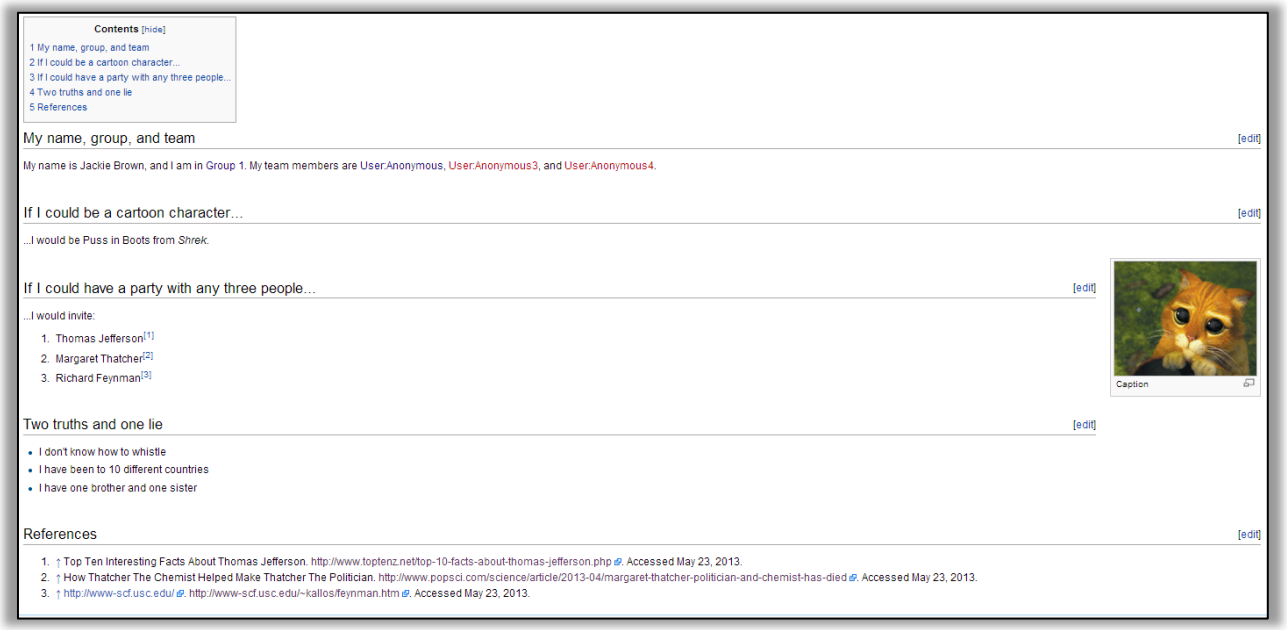
2. If you could be a cartoon character, who would you be and why? *Italicize* the name of the cartoon/comic/movie that your character is from and include a picture of this character on your page.

3. If you could have a party with any three people, dead or alive, who would you invite? List these people in a numbered list and provide references that explain who they are.

4. Write down two truths and one lie, but don't say which each one is. Write this list in a bulleted list.

5. Once you have finished parts 1-4, read the user pages of the other people in your group. (You will need to know their username.) On each person's talk page, write which item that they wrote for question number 4 that you think is a lie.

Your finished page should look similar to this page:



Contents [hide]

1 My name, group, and team
2 If I could be a cartoon character...
3 If I could have a party with any three people...
4 Two truths and one lie
5 References

My name, group, and team [edit]

My name is Jackie Brown, and I am in Group 1. My team members are User:Anonymous, User:Anonymous3, and User:Anonymous4.

If I could be a cartoon character... [edit]

...I would be Puss in Boots from *Shrek*.

If I could have a party with any three people... [edit]

...I would invite:

1. Thomas Jefferson[1]
2. Margaret Thatcher[2]
3. Richard Feynman[3]

Two truths and one lie [edit]

- I don't know how to whistle
- I have been to 10 different countries
- I have one brother and one sister

References [edit]

1. ↑ Top Ten Interesting Facts About Thomas Jefferson. http://www.toptenz.net/top-10-facts-about-thomas-jefferson.php. Accessed May 23, 2013.
2. ↑ How Thatcher The Chemist Helped Make Thatcher The Politician. http://www.popsci.com/science/article/2013-04/margaret-thatcher-politician-and-chemist-has-died. Accessed May 23, 2013.
3. ↑ http://www-scf.usc.edu/. http://www-scf.usc.edu/~kallos/feynman.htm. Accessed May 23, 2013.

Section 12. Traditional Report Requirements

If you are assigned to a "traditional report", you will write a report about a pre-assigned topic and turn in a hardcopy to your TA one week prior to the exam. A traditional report consists of no more than 5 pages of text (excluding references) and has all three types of entries outlined in the "Wiki Contribution Guidelines" (see Section 6 above for examples). Each report must fulfill all of the criteria below in order to be considered for full credit:

- Clear, concise text that thoroughly explains the concept at hand.
- At least 4 embedded figures (with source citations)
- At least 4 original practice problems, including answer keys to each problem.
- External references (listed at the bottom of the page under "References") to where the original information came from. References should be cited in ACS-style format.

A report that does not cite its sources will not receive credit.

Your TA will grade your report based on the quality of your description of your topic, the quality of your external references, and the content accuracy.

If you have any questions regarding the ChemWiki, feel free to contact Jackie at jackie.brown@chem.wisc.edu.

Good luck! ☺

References:

[1] Dean of Students Office | Division of Student Life http://students.wisc.edu/doso/students.html (Accessed Jan. 21, 2013).
[2] Barry, D.; Barstow, D.; Glater, J.D.; Liptak, A.; Steinberg, J. Correcting the Record; Times Reporter Who Resigned Leaves Long Trail of Deception. "The New York Times" [Online], **2003** http://www.nytimes.com/2003/05/11/us/correcting-the-record-times-reporter-who-resigned-leaves-long-trail-of-deception.html?src=pm (Accessed Jan 19, 2013).
[3] Moore, J.W., Stanitski, C., Jurs, P.C. Chemistry: The Molecular Science, 2nd ed.; Brooks-Cole: Belmont, CA, 2005; p 332.
[4] Moore, J.W., Stanitski, C., Jurs, P.C. Chemistry: The Molecular Science, 2nd ed.; Brooks-Cole: Belmont, CA, 2005; p 332.
[5] From Gen Chem to Org Chem, Pt. 7 – Lewis Structures. http://masterorganicchemistry.com/2010/08/14/from-gen-chem-to-org-chem-pt-7-lewis-structures/ (Accessed Jan 21, 2013).
[6] Carbohydrates, Proteins, and Fats: Overview of Nutrition: Merck Manual Home Edition. http://www.merckmanuals.com/home/disorders_of_nutrition/overview_of_nutrition/carbohydrates_proteins_and_fats.html. (Accessed Jan 11, 2013).
[7] Jmol + MS | MarvinSketch + Jmol Interface Home http://www.metallacycle.com/uiji/home.php (Accessed Jan. 21, 2013).

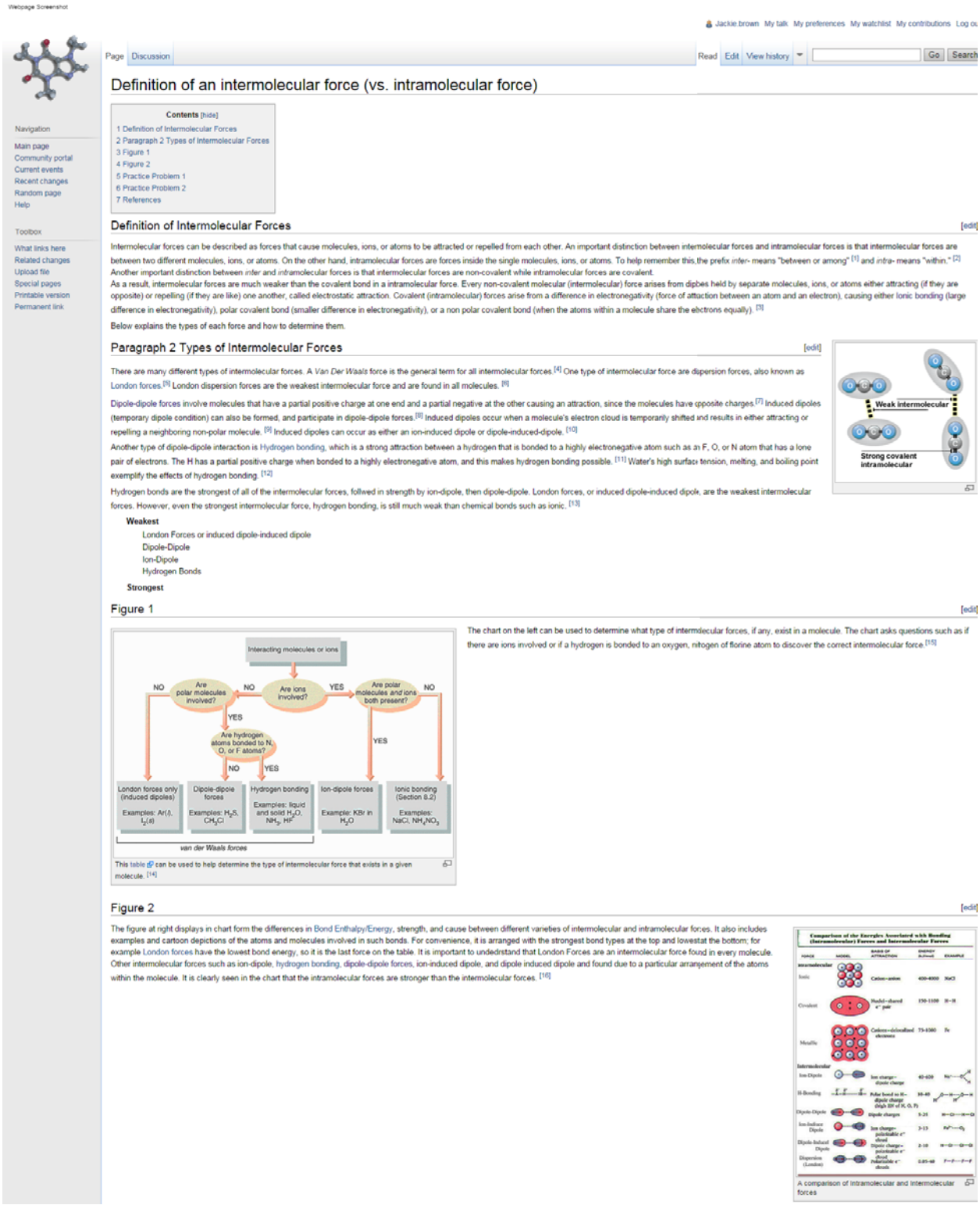
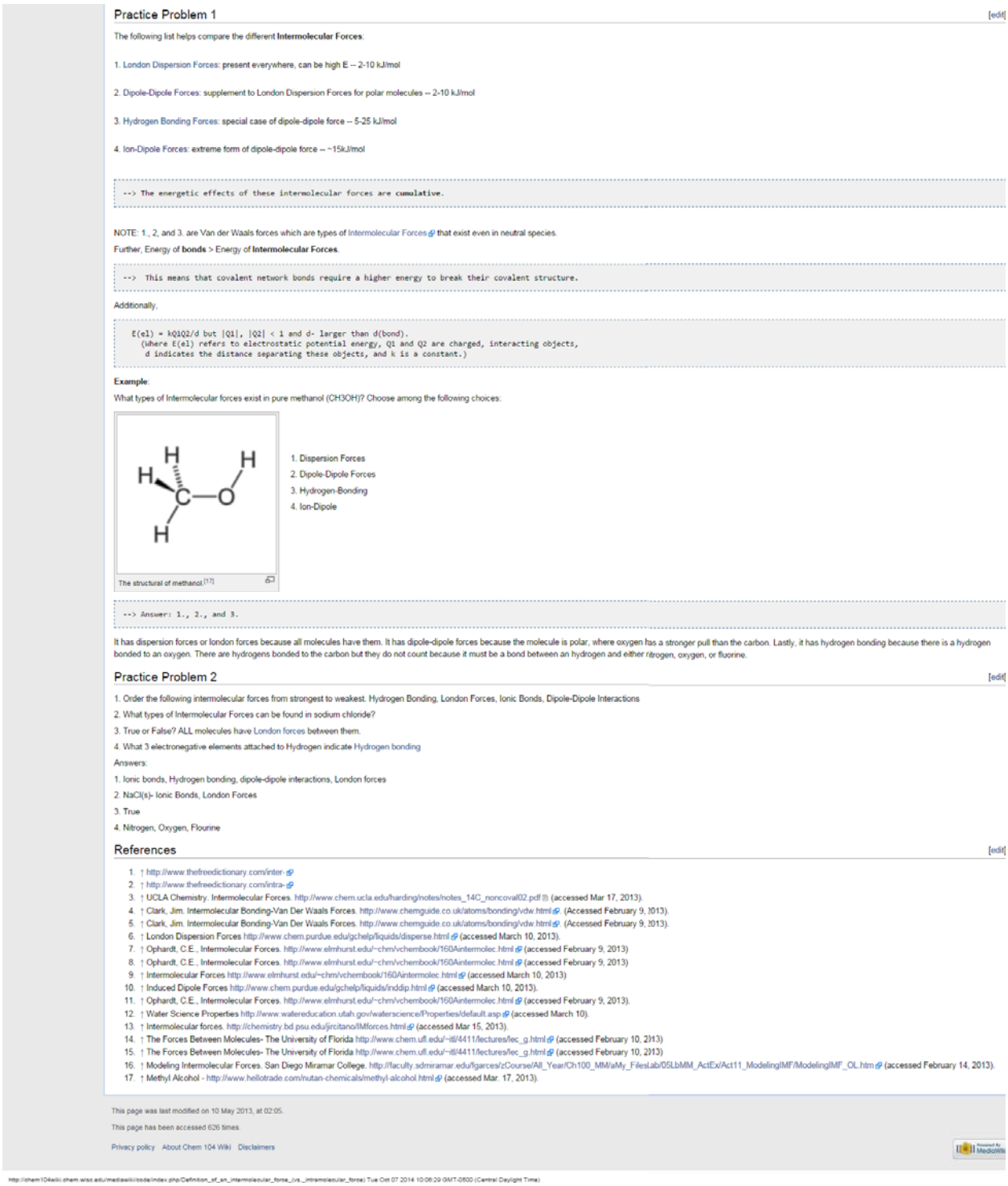


Figure C.1. Screenshot of student page on "Definition of an Intermolecular Force", Study I (Chem 104, Spring 2013).



Practice Problem 1 [edit]

The following list helps compare the different **Intermolecular Forces**:

1. London Dispersion Forces: present everywhere, can be high E -- 2-10 kJ/mol
2. Dipole-Dipole Forces: supplement to London Dispersion Forces for polar molecules -- 2-10 kJ/mol
3. Hydrogen Bonding Forces: special case of dipole-dipole force -- 5-25 kJ/mol
4. Ion-Dipole Forces: extreme form of dipole-dipole force -- ~15kJ/mol

```
--> The energetic effects of these intermolecular forces are cumulative.
```

NOTE: 1., 2, and 3. are Van der Waals forces which are types of Intermolecular Forces that exist even in neutral species.

Further, Energy of **bonds** > Energy of **Intermolecular Forces**.

```
-->  This means that covalent network bonds require a higher energy to break their covalent structure.
```

Additionally,

```
E(el) = kQ1Q2/d but |Q1|, |Q2| < 1 and d- larger than d(bond).
  (where E(el) refers to electrostatic potential energy, Q1 and Q2 are charged, interacting objects,
   d indicates the distance separating these objects, and k is a constant.)
```

Example:

What types of Intermolecular forces exist in pure methanol (CH3OH)? Choose among the following choices:

The structural of methanol.[17]

1. Dispersion Forces
2. Dipole-Dipole Forces
3. Hydrogen-Bonding
4. Ion-Dipole

```
--> Answer: 1., 2., and 3.
```

It has dispersion forces or london forces because all molecules have them. It has dipole-dipole forces because the molecule is polar, where oxygen has a stronger pull than the carbon. Lastly, it has hydrogen bonding because there is a hydrogen bonded to an oxygen. There are hydrogens bonded to the carbon but they do not count because it must be a bond between an hydrogen and either nitrogen, oxygen, or fluorine.

Practice Problem 2 [edit]

1. Order the following intermolecular forces from strongest to weakest. Hydrogen Bonding, London Forces, Ionic Bonds, Dipole-Dipole Interactions
2. What types of Intermolecular Forces can be found in sodium chloride?
3. True or False? ALL molecules have London forces between them.
4. What 3 electronegative elements attached to Hydrogen indicate Hydrogen bonding

Answers:

1. Ionic bonds, Hydrogen bonding, dipole-dipole interactions, London forces
2. NaCl(s)- Ionic Bonds, London Forces
3. True
4. Nitrogen, Oxygen, Flourine

References [edit]

1. ↑ http://www.thefreedictionary.com/inter-
2. ↑ http://www.thefreedictionary.com/intra-
3. ↑ UCLA Chemistry. Intermolecular Forces. http://www.chem.ucla.edu/harding/notes/notes_14C_noncoval02.pdf (accessed Mar 17, 2013).
4. ↑ Clark, Jim. Intermolecular Bonding-Van Der Waals Forces. http://www.chemguide.co.uk/atoms/bonding/vdw.html. (Accessed February 9, 2013).
5. ↑ Clark, Jim. Intermolecular Bonding-Van Der Waals Forces. http://www.chemguide.co.uk/atoms/bonding/vdw.html. (Accessed February 9, 2013).
6. ↑ London Dispersion Forces http://www.chem.purdue.edu/gchelp/liquids/disperse.html (accessed March 10, 2013).
7. ↑ Ophardt, C.E., Intermolecular Forces. http://www.elmhurst.edu/~chm/vchembook/160Aintermolec.html (accessed February 9, 2013)
8. ↑ Ophardt, C.E., Intermolecular Forces. http://www.elmhurst.edu/~chm/vchembook/160Aintermolec.html (accessed February 9, 2013)
9. ↑ Intermolecular Forces http://www.elmhurst.edu/~chm/vchembook/160Aintermolec.html (accessed March 10, 2013)
10. ↑ Induced Dipole Forces http://www.chem.purdue.edu/gchelp/liquids/inddip.html (accessed March 10, 2013).
11. ↑ Ophardt, C.E., Intermolecular Forces. http://www.elmhurst.edu/~chm/vchembook/160Aintermolec.html (accessed February 9, 2013).
12. ↑ Water Science Properties http://www.watereducation.utah.gov/waterscience/Properties/default.asp (accessed March 10).
13. ↑ Intermolecular forces. http://chemistry.bd.psu.edu/jircitano/IMforces.html (accessed Mar 15, 2013).
14. ↑ The Forces Between Molecules- The University of Florida http://www.chem.ufl.edu/~itl/4411/lectures/lec_g.html (accessed February 10, 2013)
15. ↑ The Forces Between Molecules- The University of Florida http://www.chem.ufl.edu/~itl/4411/lectures/lec_g.html (accessed February 10, 2013)
16. ↑ Modeling Intermolecular Forces. San Diego Miramar College. http://faculty.sdmiramar.edu/fgarces/zCourse/All_Year/Ch100_MM/aMy_FilesLab/05LbMM_ActEx/Act11_ModelingIMF/ModelingIMF_OL.htm (accessed February 14, 2013).
17. ↑ Methyl Alcohol - http://www.hellotrade.com/nutan-chemicals/methyl-alcohol.html (accessed Mar. 17, 2013).

Figure C.2. Continued screenshot of student page on "Definition of an Intermolecular Force", Study I (Chem 104, Spring 2013).

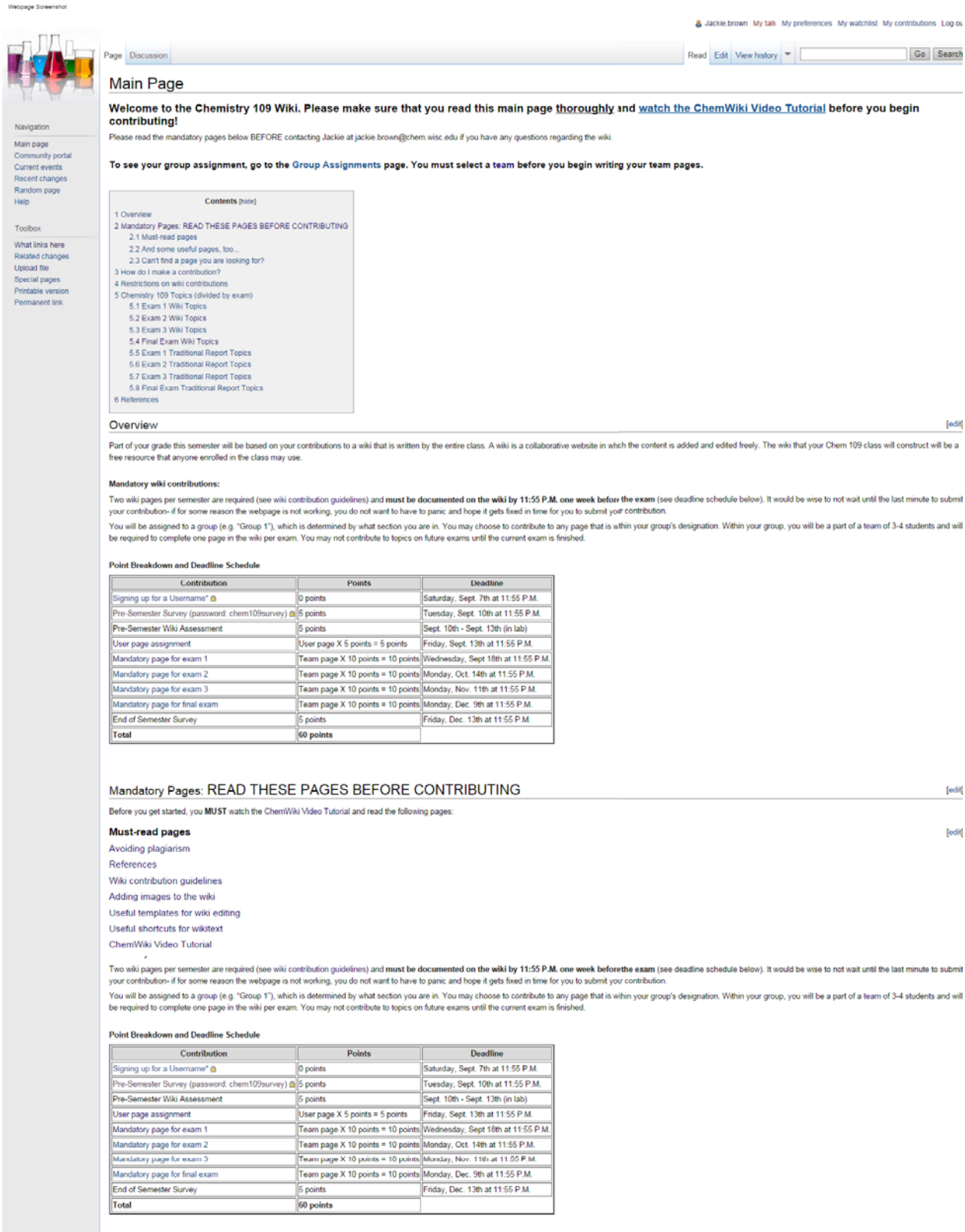


Figure C.3. Screenshot of main page, Study II (Chem 109, Fall 2013).

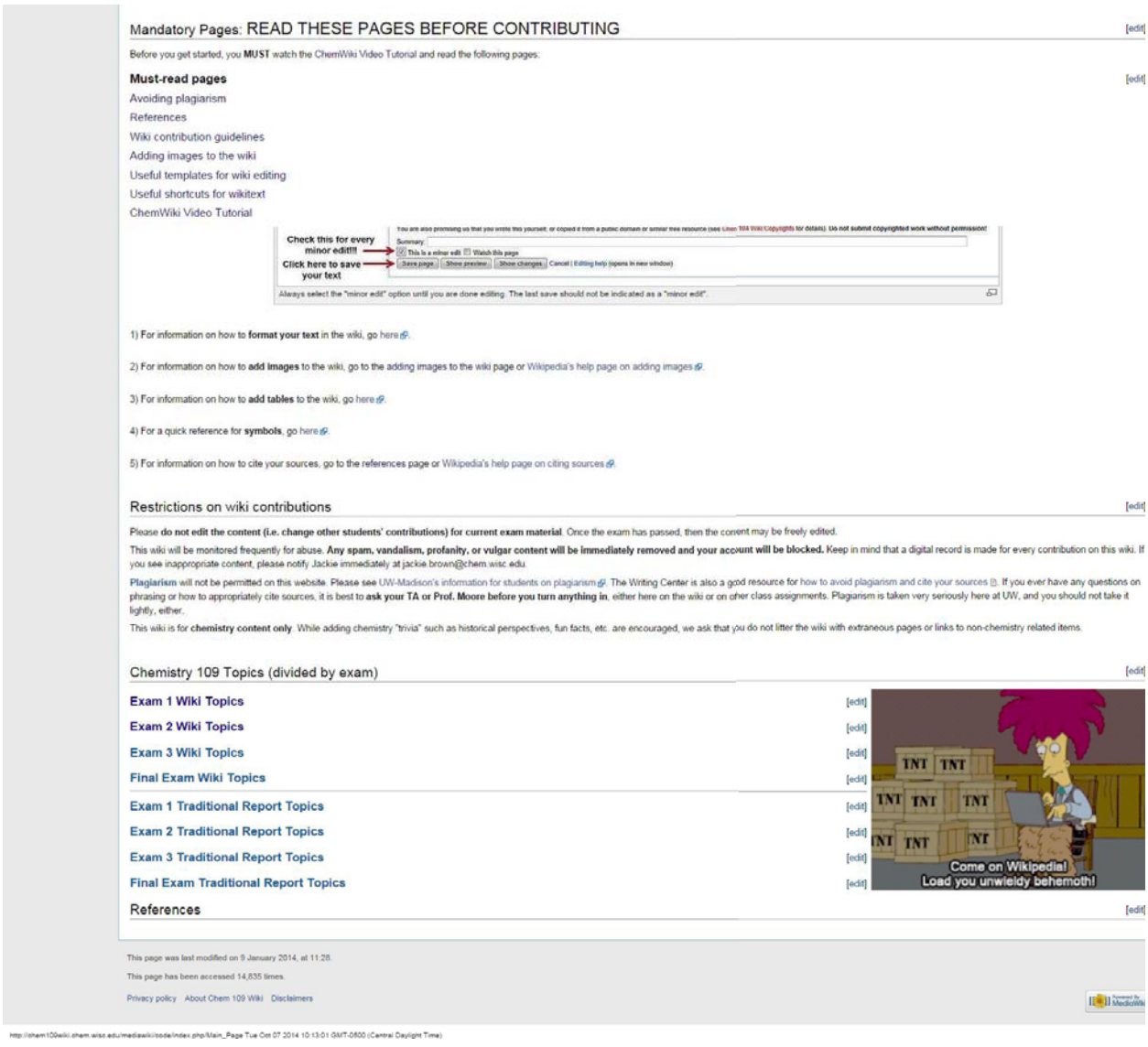


Figure C.4. Continued screenshot of main page, Study II (Chem 109, Fall 2013).

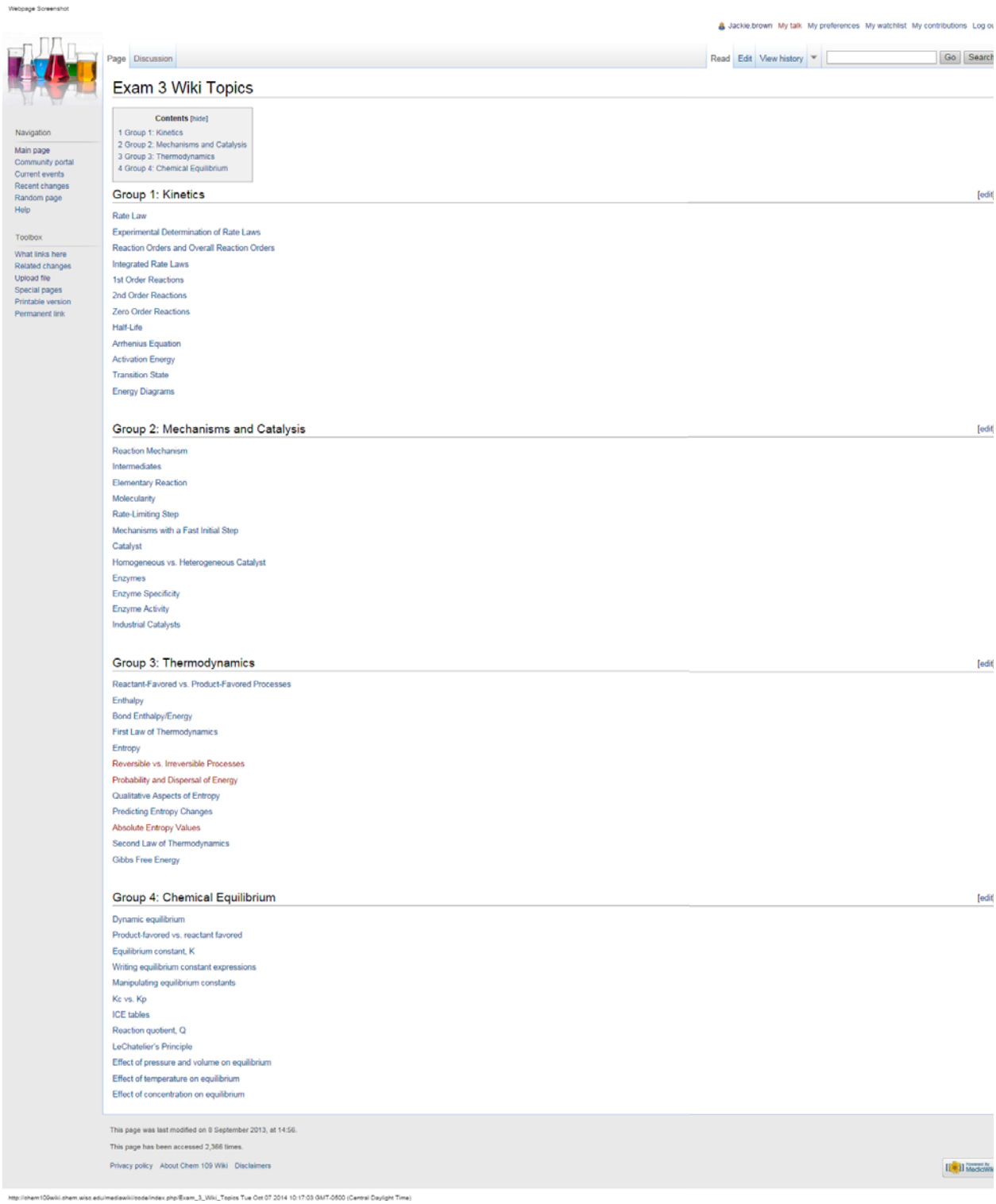


Figure C.5. Screenshot of "Exam 3 Wiki Topics", Study II (Chem 109, Fall 2013). Students in study II were instructed to select a topic page under their designated group heading. Blue topics indicate the page has been edited; red topic pages were not edited.

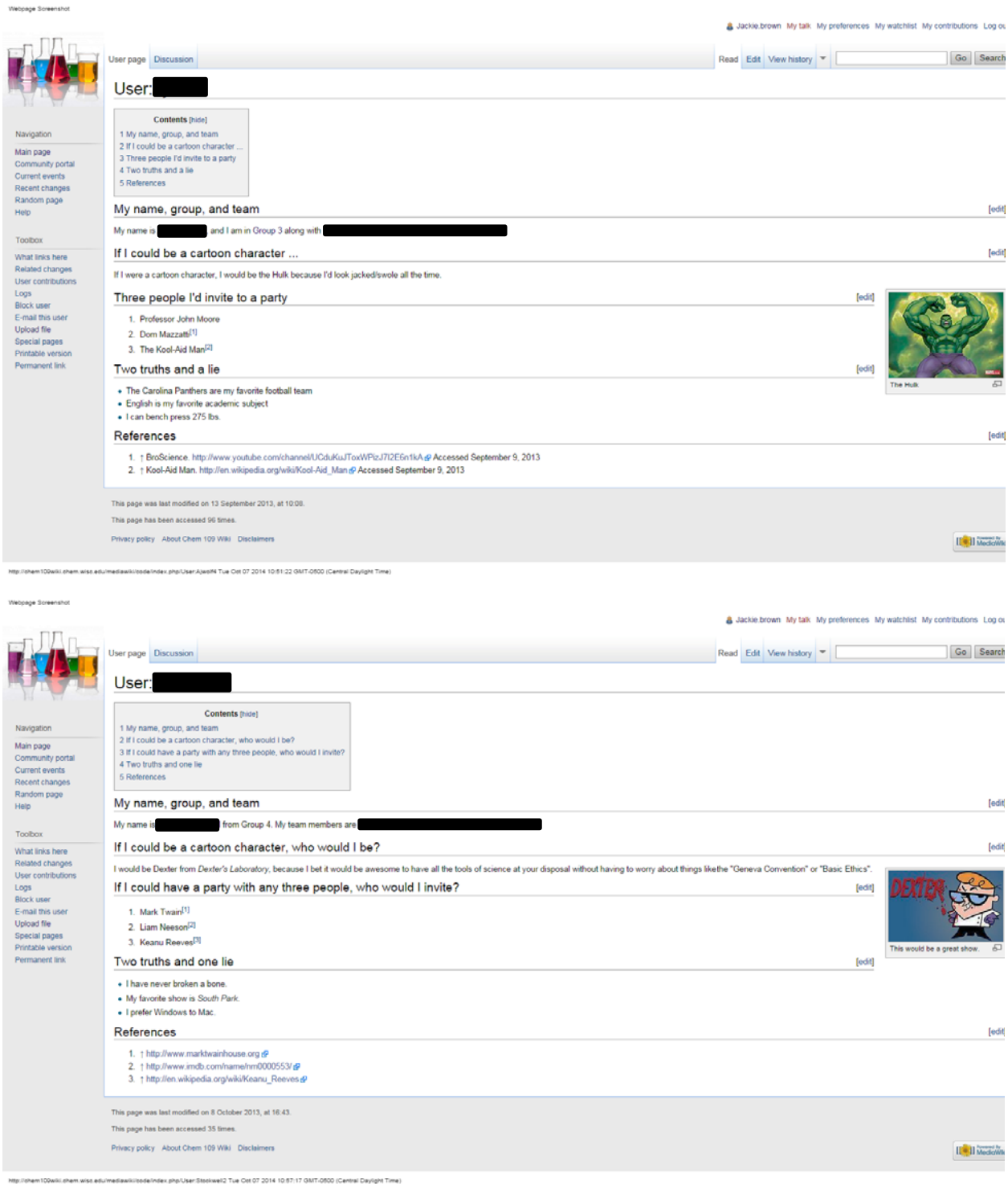


Figure C.6. Screenshots of student user pages, Study II (Chem 109, Fall 2013).

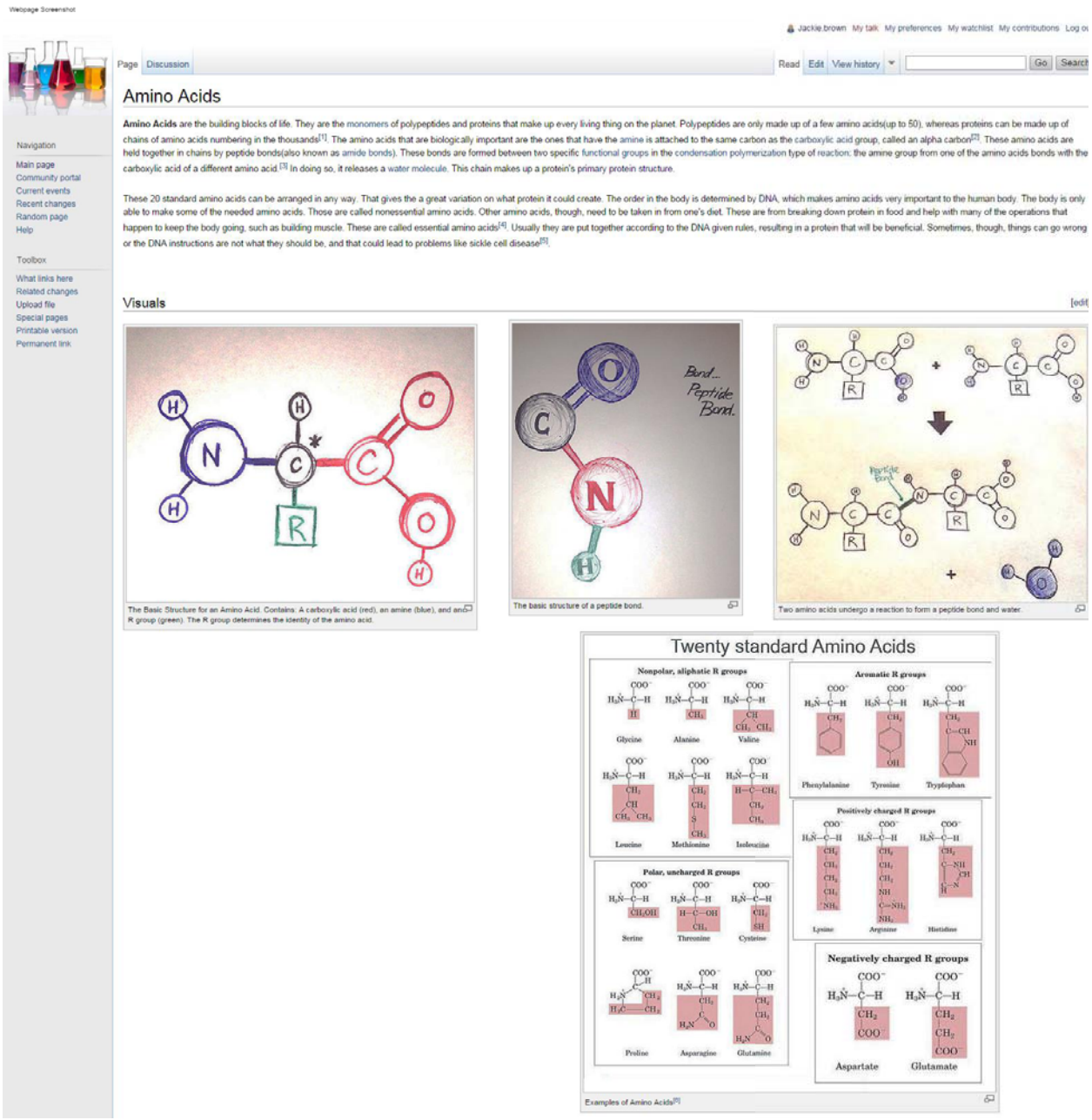
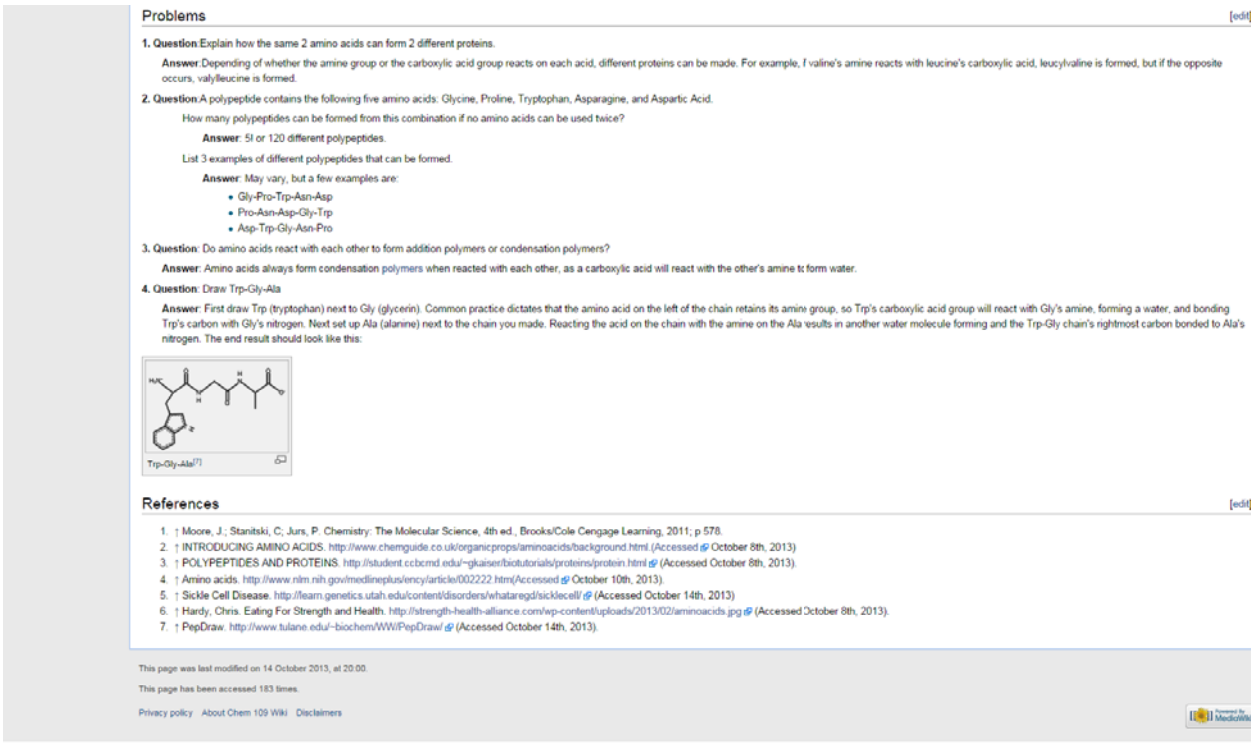


Figure C.7. Screenshot of student page on "Amino Acids", Study II (Chem 109, Fall 2013).



Problems

1. Question: Explain how the same 2 amino acids can form 2 different proteins.

Answer: Depending of whether the amine group or the carboxylic acid group reacts on each acid, different proteins can be made. For example, if valine's amine reacts with leucine's carboxylic acid, leucylvaline is formed, but if the opposite occurs, valylleucine is formed.

2. Question: A polypeptide contains the following five amino acids: Glycine, Proline, Tryptophan, Asparagine, and Aspartic Acid.

How many polypeptides can be formed from this combination if no amino acids can be used twice?

Answer: 5! or 120 different polypeptides.

List 3 examples of different polypeptides that can be formed.

Answer: May vary, but a few examples are:

- Gly-Pro-Trp-Asn-Asp
- Pro-Asn-Asp-Gly-Trp
- Asp-Trp-Gly-Asn-Pro

3. Question: Do amino acids react with each other to form addition polymers or condensation polymers?

Answer: Amino acids always form condensation polymers when reacted with each other, as a carboxylic acid will react with the other's amine to form water.

4. Question: Draw Trp-Gly-Ala

Answer: First draw Trp (tryptophan) next to Gly (glycerin). Common practice dictates that the amino acid on the left of the chain retains its amine group, so Trp's carboxylic acid group will react with Gly's amine, forming a water, and bonding Trp's carbon with Gly's nitrogen. Next set up Ala (alanine) next to the chain you made. Reacting the acid on the chain with the amine on the Ala results in another water molecule forming and the Trp-Gly chain's rightmost carbon bonded to Ala's nitrogen. The end result should look like this:

Trp-Gly-Ala[?]

References

1. ↑ Moore, J.; Stanitski, C; Jurs, P. Chemistry: The Molecular Science, 4th ed., Brooks/Cole Cengage Learning, 2011; p 578.
2. ↑ INTRODUCING AMINO ACIDS. http://www.chemguide.co.uk/organicprops/aminoacids/background.html (Accessed October 8th, 2013)
3. ↑ POLYPEPTIDES AND PROTEINS. http://student.ccbcmd.edu/~gkaiser/biotutorials/proteins/protein.html (Accessed October 8th, 2013).
4. ↑ Amino acids. http://www.nlm.nih.gov/medlineplus/ency/article/002222.htm(Accessed October 10th, 2013).
5. ↑ Sickle Cell Disease. http://learn.genetics.utah.edu/content/disorders/whataregd/sicklecell/ (Accessed October 14th, 2013)
6. ↑ Hardy, Chris. Eating For Strength and Health. http://strength-health-alliance.com/wp-content/uploads/2013/02/aminoacids.jpg (Accessed October 8th, 2013).
7. ↑ PepDraw. http://www.tulane.edu/~biochem/WW/PepDraw/ (Accessed October 14th, 2013).

This page was last modified on 14 October 2013, at 20:00.

This page has been accessed 183 times.

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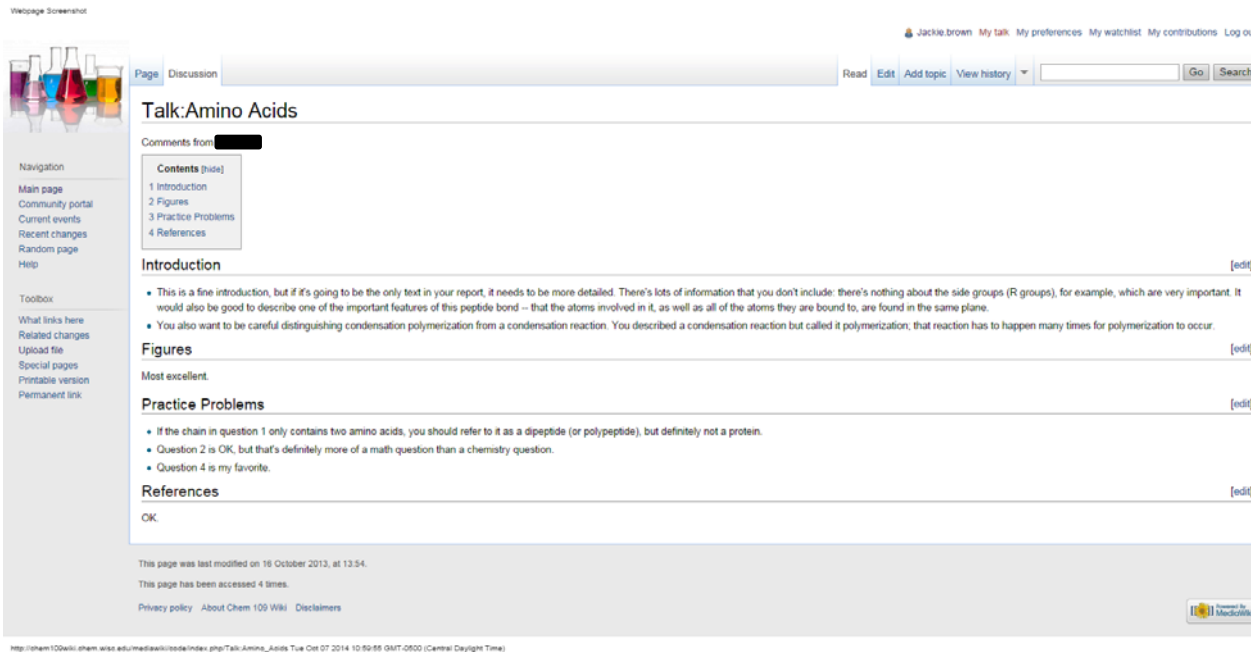
http://chem109wiki.chem.wisc.edu/mediawiki/index.php/Amino_Acids Tue Oct 07 2014 10:41:08 GMT-0500 (Central Daylight Time)

Figure C.8. Continued screenshot of student page on "Amino Acids", Study II (Chem 109, Fall 2013).



Webpage Screenshot

Jackie.brown My talk My preferences My watchlist My contributions Log o

Page Discussion Read Edit Add topic View history Go Search

Talk:Amino Acids

Comments from [redacted]

Navigation

Main page
Community portal
Current events
Recent changes
Random page
Help

Toolbox

What links here
Related changes
Upload file
Special pages
Printable version
Permanent link

Contents [hide]

1 Introduction
2 Figures
3 Practice Problems
4 References

Introduction

- This is a fine introduction, but if it's going to be the only text in your report, it needs to be more detailed. There's lots of information that you don't include: there's nothing about the side groups (R groups), for example, which are very important. It would also be good to describe one of the important features of this peptide bond -- that the atoms involved in it, as well as all of the atoms they are bound to, are found in the same plane.
- You also want to be careful distinguishing condensation polymerization from a condensation reaction. You described a condensation reaction but called it polymerization; that reaction has to happen many times for polymerization to occur.

Figures

Most excellent.

Practice Problems

- If the chain in question 1 only contains two amino acids, you should refer to it as a dipeptide (or polypeptide), but definitely not a protein.
- Question 2 is OK, but that's definitely more of a math question than a chemistry question.
- Question 4 is my favorite.

References

OK.

This page was last modified on 16 October 2013, at 13:54.

This page has been accessed 4 times.

Privacy policy About Chem 109 Wiki Disclaimers

http://chem109wiki.chem.wisc.edu/mediawiki/index.php/Talk:Amino_Acids Tue Oct 07 2014 10:59:55 GMT-0500 (Central Daylight Time)

Figure C.9. Teaching assistant feedback on "Amino Acids", Study II (Chem 109, Fall 2013).

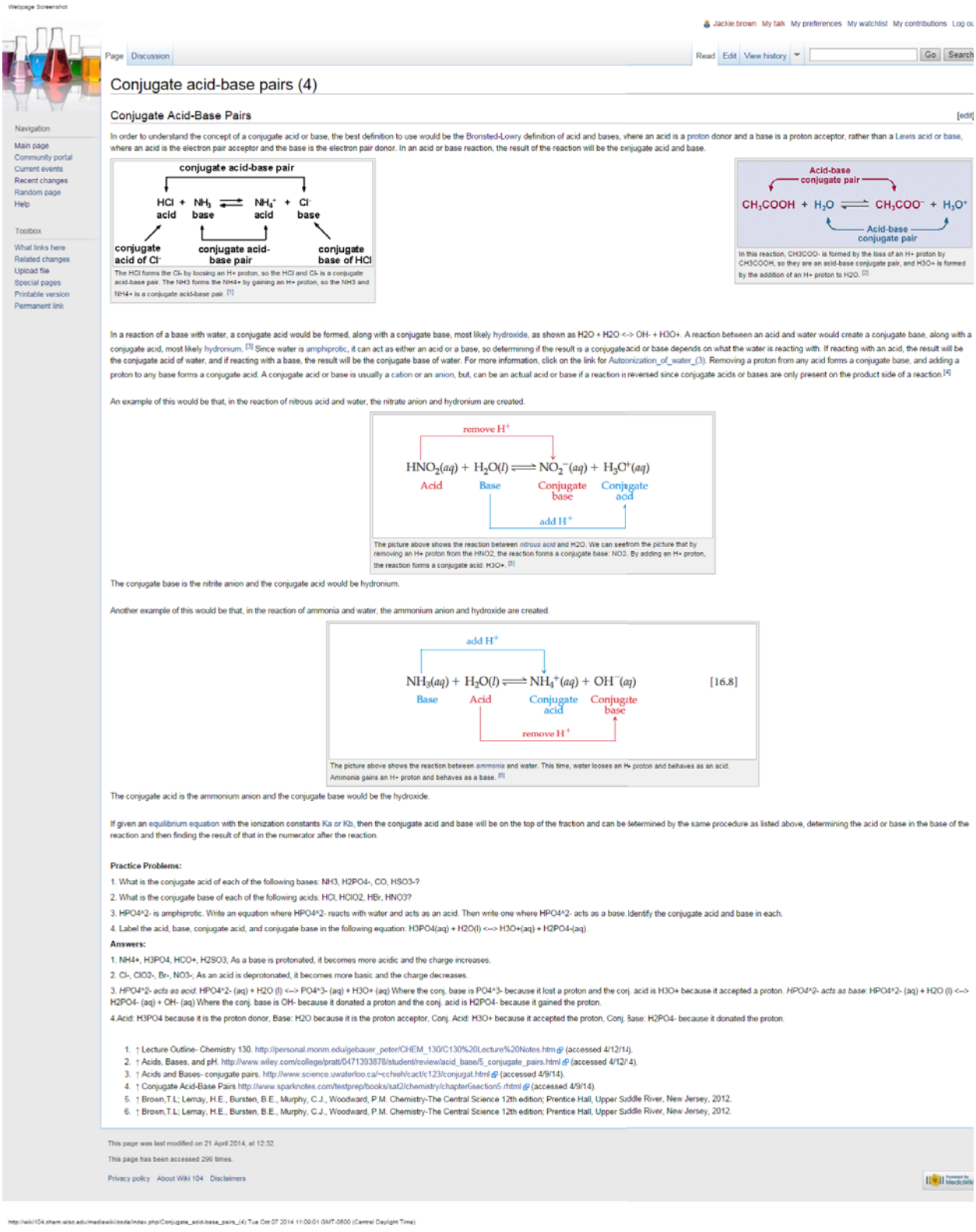


Figure C.10. Screenshot of student page on "Conjugate Acid-Base Pairs", Study III (Chem 104, Spring 2014).

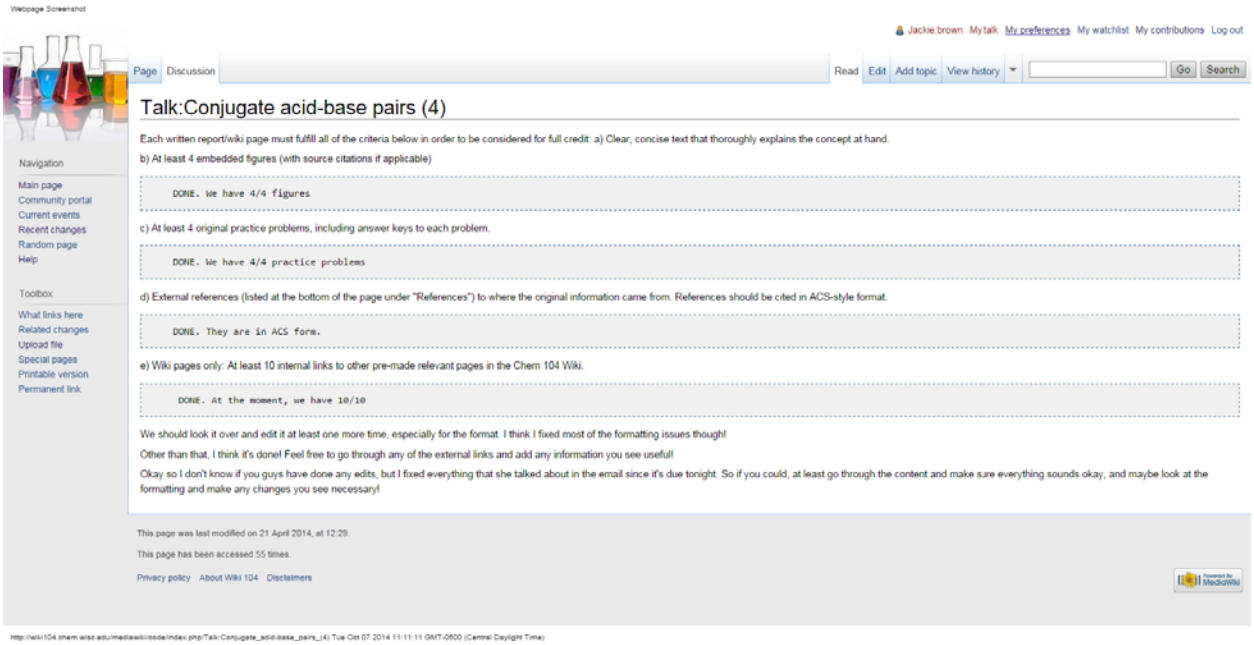


Figure C.11. Example of students using Talk page to discuss ChemWiki page, Study III (Chem 104, Spring 2014).

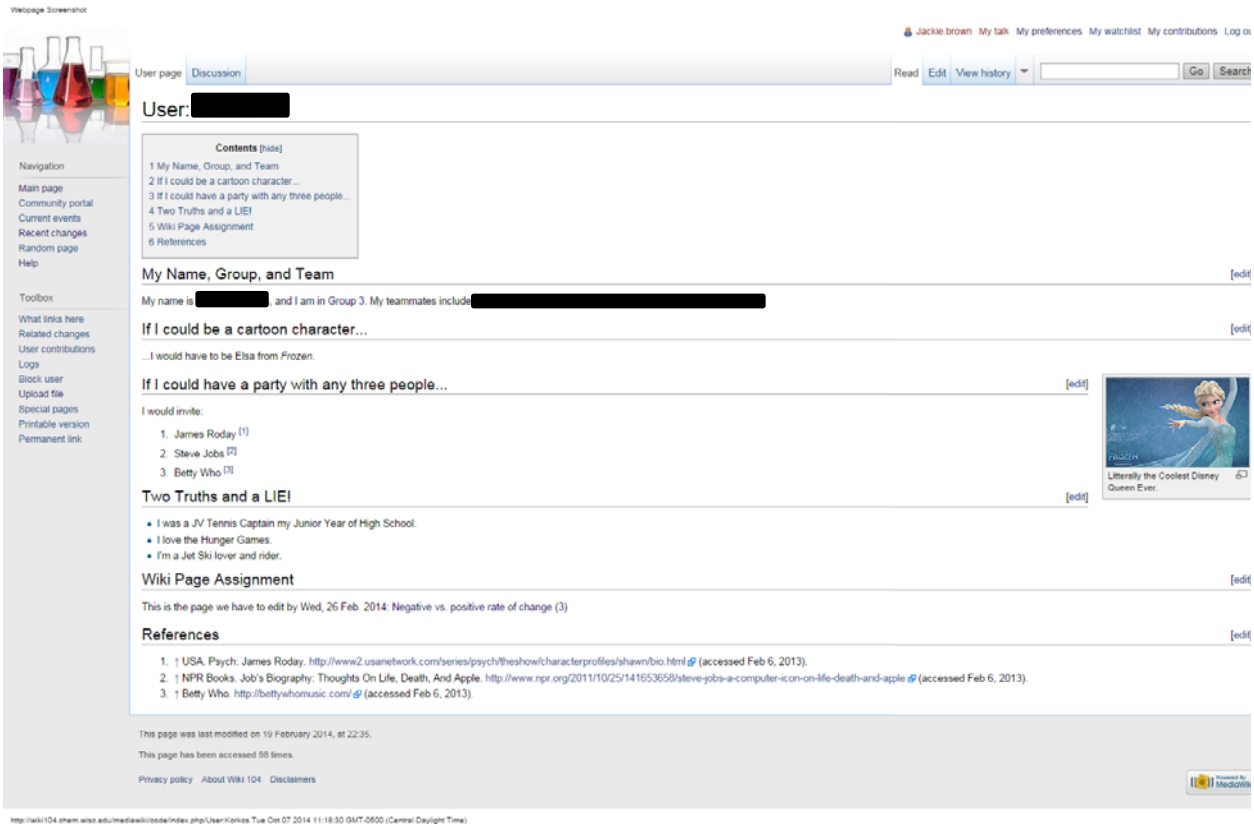


Figure C.12. Screenshot of student user page, Study III (Chem 104, Spring 2014).

Section				General Intro Content	Body Paragraph Content	Figures	Practice Problems	References	Accuracy	Format/Grammar/Spelling	Total Percent	Point Factor	
	109		Percentage	5	10	20	20	15	20	10	÷ 100	2.5	
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Section				General Intro Content	Body Paragraph Content	Figures	Practice Problems	Internal Links	External References	Accuracy	Format/Grammar/Spelling	Individual Contribution	Total Percent	Point Factor		Score to Recover	Score Recovered
	104	Wiki Page	Percentage	5	10	15	15	10	10	15	10	10	100	3.75			
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Section				General Intro Content	Body Paragraph Content	Figures	Practice Problems	External References	Accuracy	Format/Grammar/Spelling	Total Percent	Point Factor		Score to Recover	Score Recovered
	104	Written Report	Percentage	5	20	15	15	20	15	10	100	3.75			
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											0	0		11	
											0	0		11	
			Possible Marks:	0	1	2	3	4			Class Average				

Appendix D: Pretest and Pretest Instructions and Posttests

Appendix D contains all of the pretests and posttests utilized in this study. Teaching assistants administered the pretests and were given explicit pretest instructions. These instructions are also included in Appendix D. The final exams for study I and study II included questions from an ACS Exams Institute exam. These questions are confidential, and final exams for study I and study II are therefore not included. The pretests and posttests included in Appendix D are:

Study I: Chem 104, Spring 2013

- Pretest
- Exam 1
- Exam 2
- Exam 3

Study II: Chem 109, Fall 2013

- Pretest
- Exam 1
- Exam 2
- Exam 3

Study III: Chem 104, Spring 2014

- Pretest
- Exam 2
- Exam 4
- Final Exam

Instructions for the Pre-Semester Assessment

Thank you for taking the time to administer this assessment. The goal is to have a baseline for the students' knowledge on the concepts they will learn this semester. It is important that each student takes this assessment and completes every question, regardless of if they fully know how to answer it. Please give the students 40 minutes to complete this assessment, and make sure that they fill out their scantron sheet completely.

Order of events:

1) Hand out scantron sheets (and pencils if necessary) and have the students fill out their name and identification number. The identification number is their 10-digit campus ID number.

2) Before handing out the assessments, tell the students the following 3 things:

- **You need to turn in your scantron sheet AND the assessment**.
- The material on this assessment is on concepts that you will learn this semester; you may not know the answers to all of the questions, and that's OK- just fill out the entire assessment to the best of your ability.
- You will get full credit **if you answer all 24 questions; you will receive partial credit if you leave questions blank.** If you do not know how to answer a question, give it your best guess.

3) While they are taking the assessment, please go around the class and record who has each assessment in the table below.

4) After 40 minutes has elapsed, collect the scantron sheets, assessments, and any pencils you lent out. **Check that each scantron sheet has the name and identification number filled out completely**.

5) Make sure that all of the assessments have been turned in by checking them off in the table below. If you are missing an assessment, you should have the names recorded of each person; please get it back from them.

5) Place all of the scantron sheets, assessments, and pencils in the envelope, close it, and drop it off at my office in room 1305C.

It is of utmost importance that none of these copies go out of the testing room. Please, *please*, PLEASE make sure that you have every single copy that was assigned to you returned.

#	Checked out to	☑ in	#	Checked out to	☑ in
00625			00638		
00626			00639		
00627			00640		
00628			00641		
00629			00642		
00630			00643		
00631			00644		
00632			00645		
00633			00646		
00634			00647		
00635			00648		
00636					
00637					

Chem 109 Pre-Semester Assessment

This pre-semester assessment consists of 24 questions. You will be given 40 minutes to complete these problems. Course credit will be awarded based on your completion of this assessment. Please answer all questions on this assessment to the best of your ability and bubble your answers on the scantron sheet provided. **You must answer all 24 questions in order to receive full credit.**

1. 1.0 L of octane, C_8H_{18}, is reacted with oxygen gas to produce CO_2 and water. How many moles of CO_2 are produced in this reaction? The density of octane is 0.703 g/mL.

   A. 5.26 moles B. 6.17 moles C. 49.4 moles D. 30.8 moles E. 12.2 moles

2. What is the percent yield of the reaction in question 1 if 900 grams of water are produced?

   A. 86.8% B. 72.4% C. 88.9% D. 90.0%

   E. There is not enough information to determine percent yield.

3. If 5.0 grams of $MgCl_2$ are dissolved in 2.0 L of water, what is the molarity of chloride ion in this solution?

   A. 0.083 M
   B. 0.052 M
   C. 0.11 M
   D. 0.22 M
   E. 0.034 M

4. Which of statement or statements are *incorrect*?

   A. Electromagnetic radiation has both wave- and particle-like properties.
   B. The photoelectric effect can be used to explain why atoms produce a line emission spectrum.
   C. Every atom has a characteristic line emission spectrum.
   D. Heisenberg's Uncertainty Principle states that it is possible to know both the exact position and exact momentum of an electron at any given time.
   E. B and D are incorrect.

5. A possible set of quantum numbers for a *valence* electron of chlorine is:

   A. $n = 1, l = 1, m_l = 0, m_s = +1/2$
   B. $n = 2, l = 1, m_l = 0, m_s = -1/2$
   C. $n = 3, l = 0, m_l = 1, m_s = +1/2$
   D. $n = 3, l = 1, m_l = 1, m_s = -1/2$
   E. None of these sets of quantum numbers are possible.

6. Which atom or ion has the electron configuration $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8 4s^2$?

A. Ca B. Ni C. Fe D. Zn^{2+} E. Zn

7. Which bond is the most polar bond?

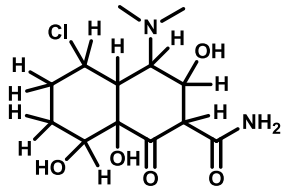
A. F–F B. H–O C. N–O D. C–N E. H–F

8. What is the formal charge on sulfur in the molecule SO_2?

A. -2 B. -1 C. 0 D. +1 E. +2

9. What are the electronic and molecular geometries of ozone, O_3?

A. Electronic = tetrahedral; Molecular = trigonal pyramidal
B. Electronic = trigonal planar; Molecular = trigonal planar
C. Electronic = linear; Molecular = linear
D. Electronic = tetrahedral; Molecular = bent
E. Electronic = trigonal planar; Molecular = bent



A

Consider the structure of molecule A above for questions 10-12.

10. Which letter below includes all of the functional groups present in molecule A?

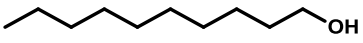
A. Alcohol and amine
B. Alcohol and amide
C. Alcohol, amide, and amine
D. Alcohol, amine, ester
E. None of these answers is correct.

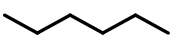
11. In which solvent do you expect molecule A to be the most soluble?

A. Tetrahydrofuran, 

B. Acetone, 

C. Ethanol, 

B. D. 1-decanol, 

E. Hexane, 

12. How many secondary alcohols are present in molecule A?

A. 0 B. 1 C. 2 D. 3 E. 4

13. The units of k for a certain reaction rate constant are $M^{-3}s^{-1}$. What is the overall order of the reaction?

A. Second order B. Third order C. Fourth order D. Fifth order
E. More information is needed to determine the overall order of the reaction.

14. Under certain conditions, the reaction below was observed to proceed at a rate of 0.0375 M/s. What is the value (including the sign) of $\Delta[C]/\Delta t$?

$$A + 2\,B \rightarrow 3C$$

A. 0.0375 M/s B. -0.0375 M/s C. 0.113 M/s D. -0.113 M/s E. 0.0125 M/s

15. Chlorination of 2-pentene is first order in 2-pentene and first order in Cl_2 and has an activation energy of 55 kJ/mol. Which change or changes will decrease the rate of reaction?

$$H_3CCH{=}CHCH_2CH_3(g) + Cl_2(l) \rightarrow CH_3CHClCHClCH_2CH_3(l)$$

A. Increasing the concentration of Cl_2
B. Increasing the temperature
C. Adding a catalyst such as UV light
D. Both A and C decrease the rate
E. None of these changes decrease the rate.

16. Which statement is or statements are *incorrect*?

A. A catalyst speeds up a chemical reaction by changing the mechanism
B. A catalyst is not altered by the reaction and therefore does not participate in the reaction
C. A catalyst lowers the energy of the products and the reactants
D. B and C are incorrect
E. None of these statements is incorrect.

17. This mechanism has been proposed for the reaction of nitrogen dioxide with carbon monoxide:

$$NO_2 + NO_2 \xrightarrow{k_1} NO_3 + NO$$

$$NO_3 + CO \underset{k_{-2}}{\overset{k_2}{\rightleftharpoons}} NO_2 + CO_2$$

where $k_2 >> k_1$

Derive the rate law for the proposed mechanism; the correct rate law is:

A. rate = $k_1[NO_2]$ B. rate = $k_1[NO_2]^2$ C. rate = $\frac{k_1 k_2 [NO_2]^2}{k_{-2}[NO]}$

D. rate = $k_2[NO_3][CO]$ E. rate = $k_1[NO_2][CO]$

18. Which statement is *correct*?

A. The portion of the enzyme that the substrate binds to is called the inhibitor site.
B. Enzymes are not as effective as metallic catalysts.
C. All enzymes are more efficient when the temperature is raised.
D. The efficiency of an enzyme may decrease when an inhibitor is present.
E. The second step of an enzyme-catalyzed reaction is the binding of the substrate to the enzyme to form the active site.

19. Which solution is most acidic?

A. 1.0 M KOC_6H_5	$K_a(HOC_6H_5) = 1.3 \times 10^{-10}$
B. 1.0 M CsF	$K_a(HF) = 6.8 \times 10^{-4}$
C. 1.0 M NaClO	$K_a(HClO) = 6.8 \times 10^{-8}$
D. 1.0 M KCH_3COO	$K_a(CH_3COOH) = 1.8 \times 10^{-5}$
E. 1.0 M KBrO	$K_a(HBrO) = 2.5 \times 10^{-9}$

20. Which salt gives a solution with a pH of 7 or less when dissolved in water at 25 °C?

A. $NaNO_2$	$K_a(HNO_2) = 4.5 \times 10^{-4}$
B. NH_4BrO	$K_a(NH_4^+) = 5.6 \times 10^{-10}$
C. NaBr	$K_a(HBrO) = 2.5 \times 10^{-9}$
D. NH_4CH_3COO	$K_a(CH_3COOH) = 1.8 \times 10^{-5}$
E. Both C and D	

21. Calculate the pH of a 0.045 M aqueous solution of $Ca(OH)_2$. The correct pH is

A. 1.05 B. 12.95 C. 1.347 D. 12.65 E. 13.46

22. Consider the reaction below:

$$[Al(H_2O)_6]^{3+}(aq) + H_2O(l) \rightarrow [Al(H_2O)_5OH]^{2+}(aq) + H_3O^+(aq)$$

What is the role of water ($H_2O(l)$) in this reaction?

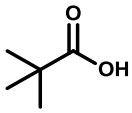
A. Bronsted-Lowry base B. Lewis base C. Lewis acid
D. Arrhenius acid E. A and B

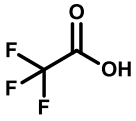
23. What type of bonding does the compound $[Co(H_2O)_6]SO_4$ contain?

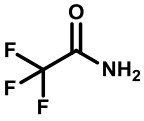
A. Covalent
B. Coordinate covalent
C. Ionic
D. Dipole-dipole
E. A, B and C

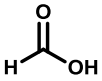
24. Which compound is the strongest acid?

A. Acetic acid, 

B. Pivalic acid, 

C. Trifluoroacetic acid, 

D. Trifluoroacetamide, 

E. Formic acid, 

Periodic Table of the Elements

1 H 1.008																	2 He 4.00
3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.20	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.0	45 Rh 102.9	46 Pd 106.4	47 Ag 107.8	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.7	52 Te 127.6	53 I 126.9	54 Xe 131.2
55 Cs 132.9	56 Ba 137.3	57 La 138.9	72 Hf 178.5	73 Ta 180.1	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr 223.0	88 Ra 226.0	89 Ac 227.0	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 Ds (281)	111 Rg (272)	112 Uub (285)	113 Uut (284)	114 Uuq (289)	115 Uup (288)	116 Uuh (292)		

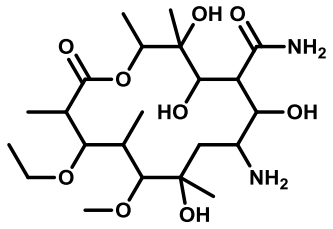
58 Ce 140.1	59 Pr 141.0	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 153.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
90 Th 232.4	91 Pa 231.4	92 U 238.0	93 Np (237)	94 Pu (240)	95 Am (243)	96 Cm (247)	97 Bk (248)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (257)	102 No (259)	103 Lr (262)

Chem 104 Pre-Semester Assessment

This pre-semester assessment consists of two components:

- this booklet containing 24 multiple choice questions
- one scantron form

1. **Do not separate the pages of the booklet.**
2. The scantron form is machine-scored and **must be filled out using a #2 PENCIL**.
3. PRINT your last name, first name and middle initial (MI) on the scantron form, then fill in the circles corresponding to the letters in your name. Write your 10-digit student ID number under Identification Number, and fill in the circles. **Circles must be filled in completely.**
4. **ANSWERS TO THE MULTIPLE CHOICE QUESTIONS MUST BE FILLED IN ON THE SCANTRON FORM.** Circles must be filled in completely in order to be scored. Do not make any stray marks on the form. If you decide to change an answer on the scantron form, make sure to completely erase your previous answer. Each question has one correct answer. Questions with two answers will receive zero credit. **All 24 questions must be answered in order to receive full credit.**
5. You have up to 40 minutes to complete this assessment.
6. You may write anywhere on this booklet or use page 6 for scratch paper.
7. After you have finished the assessment, **turn in both the booklet and the scantron form.**



A

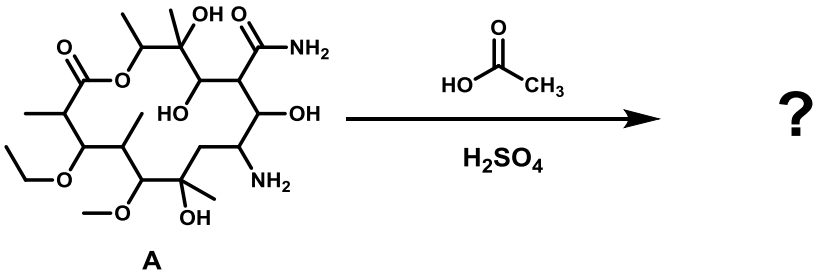
Consider the structure of molecule A above for questions 1-4.

1. Which letter below includes **ALL** of the functional groups present in molecule A?
   A. Alcohol and ester
   B. Alcohol and amide
   C. Alcohol, amide, and amine
   D. Alcohol, amine, ester
   E. None of these answers is correct.

2. How many secondary alcohols are present in molecule A?

   A. 0 B. 1 C. 2 D. 3 E. 4

3. Molecule A is combined with acetic acid and sulfuric acid in the reaction below:



How many esters will be in the resulting product? Assume no hydrolysis occurs.

A. 0 B. 1 C. 2 D. 3 E. 4

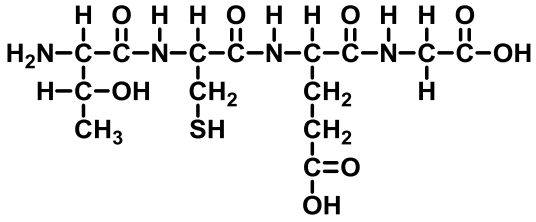
4. Molecule A is reacted with $KMnO_4$. How many alcohols will be oxidized?

A. 0 B. 1 C. 2 D. 3 E. 4

5. Rank the following compounds from **highest to lowest** boiling point:

A. 1-butanol > 1-decanol > acetone > 1-pentene
B. acetone > 1-pentene > 1-butanol > 1-decanol
C. 1-pentene > acetone > 1-butanol > 1-decanol
D. 1-butanol > 1-decanol > 1-pentene > acetone
E. 1-decanol > 1-butanol > acetone > 1-pentene

6. How many amino acids were used to make the polypeptide below?



A. 1 B. 2 C. 3 D. 4 E. 5

7. The units of k for a certain reaction rate constant are $M^{-3}s^{-1}$. What is the overall order of the reaction?

A. Second order B. Third order C. Fourth order D. Fifth order

E. More information is needed to determine the overall order of the reaction.

8. Under certain conditions, the reaction below was observed to proceed at a rate of 0.0375 M/s. What is the value (including the sign) of $\Delta[C]/\Delta t$?

$$A + 2\,B \rightarrow 3C$$

A. 0.0375 M/s B. –0.0375 M/s C. 0.113 M/s D. –0.113 M/s E. 0.0125 M/s

9. Chlorination of 2-pentene is first order in 2-pentene and first order in Cl_2 and has an activation energy of 55 kJ/mol. Which change or changes will **decrease** the rate of reaction?

$$H_3CCH{=}CHCH_2CH_3(g) + Cl_2(l) \rightarrow CH_3CHClCHClCH_2CH_3(l)$$

A. Increasing the concentration of Cl_2
B. Increasing the temperature
C. Adding a catalyst such as UV light
D. Both A and C decrease the rate
E. None of these changes decreases the rate.

10. Which statement or statements are **incorrect**?
    A. A catalyst speeds up a chemical reaction by changing the mechanism.
    B. A catalyst is not altered by the reaction and therefore does not participate in the reaction.
    C. A catalyst lowers the energy of the products and the reactants.
    D. B and C are incorrect.
    E. None of these statements is incorrect.

11. The mechanism below has been proposed for the reaction of nitrogen dioxide with carbon monoxide:

$$NO_2 + NO_2 \xrightarrow{k_1} NO_3 + NO \quad \textbf{slow}$$

$$NO_3 + CO \underset{k_{-2}}{\overset{k_2}{\rightleftharpoons}} NO_2 + CO_2 \quad \textbf{fast}$$

The rate law for this mechanism is:

A. rate = $k_1[NO_2]$ B. rate = $k_1[NO_2]^2$ C. rate = $\frac{k_1k_2[NO_2]^2}{k_{-2}[NO]}$

D. rate = $k_2[NO_3][CO]$ E. rate = $k_1[NO_2][CO]$

12. Which statement is **correct** about the mechanism in question 11?
    A. NO_3 is a catalyst. B. NO is an intermediate. C. NO_3 is an intermediate.
    D. CO is an intermediate. E. CO is a catalyst.

13. Which statement is **correct**?
    A. The entropy of 1 mole of $Cl_2(g)$ is greater than the entropy of 1 mole of 1-chloropentane, $C_5H_{11}Cl(g)$ at the same temperature and pressure.
    B. The second law of thermodynamics states that the entropy of the universe increases for any spontaneous process.
    C. The enthalpy change for the reaction $2\ NH_3(aq) + Ag^+(aq) \rightarrow [Ag(NH_3)_2]^+(aq)$ is defined as ΔH_f° for ammonia.
    D. The first law of thermodynamics states that the total energy of the universe increases for any spontaneous process.
    E. B and D are both correct.

14. When you dissolve NaCl in a glass of water at room temperature, you notice that the glass becomes cold. Which statement or statements is **correct**?
    A. The dissolution of NaCl is exothermic.
    B. The dissolution of NaCl results in an increase in entropy.
    C. The dissolution of NaCl is non-spontaneous.
    D. The entropy of both the universe and the surroundings increase.
    E. B and D are both correct.

15. The sublimation of solid CO_2 to gaseous CO_2 has a ΔH value of 26.1 kJ/mol at 200 K. Which statement is **correct**?
    A. This process is always spontaneous.
    B. This process is never spontaneous.
    C. This process is spontaneous at low temperatures.
    D. This process is spontaneous at high temperatures.
    E. None of these statements is correct.

16. Which solution has the **lowest** pH?

A. 1.0 M KOC_6H_5	$K_a(HOC_6H_5) = 1.3 \times 10^{-10}$
B. 1.0 M CsF	$K_a(HF) = 6.8 \times 10^{-4}$
C. 1.0 M NaClO	$K_a(HClO) = 6.8 \times 10^{-8}$
D. 1.0 M KCH_3COO	$K_a(CH_3COOH) = 1.8 \times 10^{-5}$
E. 1.0 M KBrO	$K_a(HBrO) = 2.5 \times 10^{-9}$

17. What is the pH of a 100.0 mL solution consisting of 0.0100 M HClO and 0.0300 M NaClO? $K_a(HClO) = 6.8 \times 10^{-8}$.
    A. 6.16
    B. 6.89
    C. 7.09
    D. 7.64
    E. 8.06

18. Which solution will produce a buffer with a pH < 7?

A.	0.1 M HCN/0.1 M NaCN	$K_a(HCN) = 3.3 \times 10^{-10}$
B.	0.1 M H_2CO_3/0.1 M $NaHCO_3$	$K_a(H_2CO_3) = 4.3 \times 10^{-7}$
C.	0.1 M NH_4Cl/0.1 M NH_3	$K_a(NH_4^+) = 5.6 \times 10^{-10}$
D.	0.1 M CH_3NH_2/0.1 M CH_3NH_3Cl	$K_a(CH_3NH_3^+) = 2.0 \times 10^{-11}$
E.	0.1 M HNO_3/0.1 M $NaNO_3$	$K_a(HNO_3) = 20$

19. Which species **does not** have a conjugate acid?
    A. H_2
    B. NH_3
    C. ClO_4^-
    D. O^{2-}
    E. HSO_4^-

Refer to the ionization constants below when answering question 20.

$K_a(HNO_2) = 4.5 \times 10^{-4}$ $K_a(NH_4^+) = 5.6 \times 10^{-10}$
$K_a(HBrO) = 2.5 \times 10^{-9}$ $K_a(CH_3COOH) = 1.8 \times 10^{-5}$

20. Which salt gives a solution with a pH ≤ 7 when dissolved in water at 25 °C?
    A. $NaNO_2$
    B. NH_4BrO
    C. NaBr
    D. NH_4CH_3COO
    E. Both C and D

21. The pH of a 0.045 M solution of $Ca(OH)_2$ is:
    A. 1.05 B. 12.95 C. 1.347 D. 12.65 E. 13.46

22. What is the oxidation number of S in SO_4^{2-}?
    A. –6 B. –7 C.–8 D. +6 E. +7

Questions 23 and 24 refer to the balanced reaction below:

$$8\ H^+(aq) + Cr_2O_7^{2-}(aq) + 3\ SO_3^{2-}(aq) \rightarrow 2\ Cr^{3+}(aq) + 3\ SO_4^{2-}(aq) + 4\ H_2O(aq)$$

23. How many electrons are transferred in the above reaction?
    A. 3 B. 4 C. 5 D. 6 E. 12

24. What is the oxidizing agent in the above reaction?
    A. $Cr_2O_7^{2-}$ B. SO_3^{2-} C. Cr^{3+} D. SO_4^{2-} E. H_2O

Periodic Table of the Elements

1 H 1.008																	2 He 4.00
3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.20	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.0	45 Rh 102.9	46 Pd 106.4	47 Ag 107.8	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.7	52 Te 127.6	53 I 126.9	54 Xe 131.2
55 Cs 132.9	56 Ba 137.3	57 La 138.9	72 Hf 178.5	73 Ta 180.1	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr 223.0	88 Ra 226.0	89 Ac 227.0	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 Ds (281)	111 Rg (272)	112 Uub (285)	113 Uut (284)	114 Uuq (289)	115 Uup (288)	116 Uuh (292)		

58 Ce 140.1	59 Pr 141.0	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 153.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
90 Th 232.4	91 Pa 231.4	92 U 238.0	93 Np (237)	94 Pu (240)	95 Am (243)	96 Cm (247)	97 Bk (248)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (257)	102 No (259)	103 Lr (262)

Scratch paper (do not remove from booklet):

DO NOT REMOVE THIS SHEET UNTIL EXAM IS GRADED.

Please legibly print your 10-digit student ID number: _____

Please answer the following three questions my marking with a check:

1) Which part of the wiki did you **actually contribute to**? **Check all that apply**.

_____ Intermolecular Forces _____ Organic Structures: Hydrocarbons _____ Organic Reactions

_____ Organic Structures: Functional Groups and Polymers _____ DNA and Proteins

_____ Lipids, Carbohydrates, and Polysaccharides

2) What was the name of the page you edited? Please print legibly:

_____

3) Which part(s) of the wiki did you **read or use to study**? **Check all that apply.**

_____ Intermolecular Forces _____ Organic Structures: Hydrocarbons _____ Organic Reactions

_____ Organic Structures: Functional Groups and Polymers _____ DNA and Proteins

_____ Lipids, Carbohydrates, and Polysaccharides _____ I did not use the wiki to study.

LEAVE THIS PORTION OF THE COVERSHEET BLANK AND PROCEED TO NEXT PAGE.

1. _____	6. _____	10. _____	13. _____
2. _____	7. _____	11. _____	14. _____
3. _____	8. _____	12. _____	15. _____
4. _____	9. ____		
5. _____			

FOR TA USE ONLY.

DO NOT WRITE HERE.

Page	**Score**
2-5 (multiple-choice)	**_____/ 45**
6	**_____/ 21**
7	**_____/ 18**
8	**_____/ 12**
Total	**_____/ 90**

Chemistry 104, Lecture 3 **Name _____**
Professor John Moore
Spring 2013; Exam I **Section_____TA_____**

Form B (Blue)

INSTRUCTIONS

1. This exam consists of two cover sheets and 7 pages of questions (pages 2-8). There is also a separate handout with formulas, useful constants, some structures, and a periodic table. If a page is missing, let your TA know.

2. Answer the questions on the top cover sheet. PRINT your name NOW at the top of ALL pages.

3. Be sure to show all your work on open-ended questions and be certain that all your explanations are given as complete sentences.

4. Many questions are multiple-choice; circle the answer to each multiple-choice question inside the test and transfer your answers to the spaces provided below. A penalty of 3 points will be assessed if this is not done.

5. Communicating in any way with anyone else, or accessing information from any source other than your 3x5" card during the exam will be considered to be one form of cheating.

Honor Code: *By the definition of academic integrity, the exam I am handing in is solely my own work and truthfully represents work I have done.*

_____
Signature

Answers: Multiple-Choice Questions Here

1. ____	6. ____	10. ____	15. ____
2. ____	7. ____	11. ____	14. ____
3. ____	8. ____	12. ____	15. ____
4. ____	9. ____		
5. ____			

Page	Score
2-5 (multiple-choice)	_____/ 45
6	_____/ 15
7	_____/ 15
8	_____/ 15
Total	_____/ 90

Name_____

Multiple-Choice Questions. (45 points; 3 points each) There is **one best response** to each question. Read all responses, choose the best one, circle it on this page, and write the letter corresponding to that response in the appropriate space on page one of the exam.

1. Which molecule could be an alkene?

A. C_7H_{14} C. C_5H_{12} E. C_6H_{14}

B. C_4H_{10} D. C_3H_8

2. Which molecule is capable of having geometric isomerism?

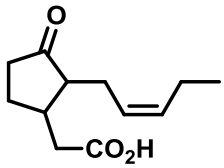
A. C_4H_{10} C. C_3H_7Br E. C_7H_{12}

B. C_2H_6 D. $C_4H_8Cl_2$

3. During the combustion of 1,4-pentadiene, 4 moles of water are produced. How many moles of O_2 were consumed during this reaction?

A. 7 B.5 C. 4 D. 3 E.1

Consider the structure of jasmonic acid, shown below, for questions 4-5.



Jasmonic acid

4. Which functional groups are present in jasmonic acid?

A. Carbonyl, ester, alkyne

B. Alkene, carbonyl, ketone

C. Alkene, carbonyl, carboxylic acid

D. Ketone, carboxylic acid, and alkene

E. Ketone and ester

F. Alkene, ester, ketone

5. What kind of intermolecular forces are present in jasmonic acid?

A. Hydrogen bonding

B. Dipole-dipole forces

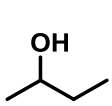
C. London dispersion forces

D. Hydrogen bonding and London dispersion forces

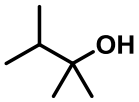
E. Hydrogen bonding, dipole-dipole forces, and London dispersion forces

Name_____

Consider these structures as you answer questions 6-7.



1



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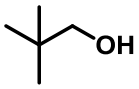

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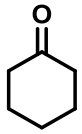

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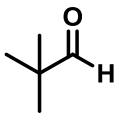


5

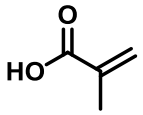
6. Which compound has (or compounds have) a chiral carbon atom?

A. 1 C. 3 E. 5 G. 1 and 3
B. 2 D. 4 F. 1 and 2 H. none of these compounds are chiral

7. Which compounds can be oxidized with aqueous $KMnO_4$?

A. 1 and 2 C. 1, 2, and 3 E. 1, 2, 3, 4, and 5
B. 1 and 3 D. 1, 3, and 5 F. none of these compounds reacts with $KMnO_4$

Consider compound 6 for questions 8-9



6

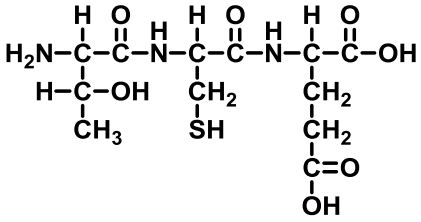
8. What type of polymerization could this compound possibly undergo?

A. Addition polymerization
B. Condensation polymerization
C. Condensation and addition polymerization
D. This structure cannot undergo polymerization

9. Compound 6 was combined with NaOH. In which solvent would you expect this mixture to be most soluble?

A. 1-Octanol C. Water E. Pentane
B. Diethyl ether D. Hexane

Name_____



10. Consider the peptide sequence shown above. Which statement is *incorrect*?

A. This peptide sequence can form disulfide bridges

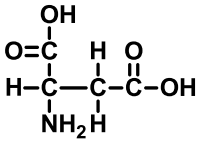
B. The peptide chain was formed by a condensation reaction

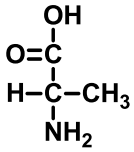
C. The peptide chain is composed of three amino acids

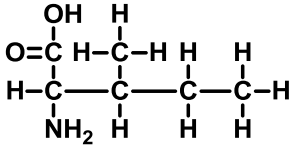
D. The name of this peptide sequence is Thr-Cys-Glu

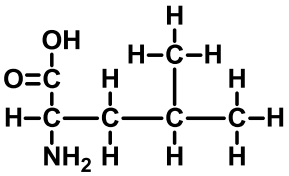
E. This peptide sequence has hydrophobic side chains

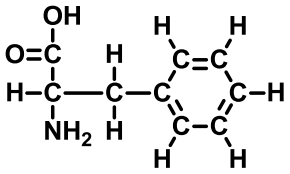
11. Which amino acid would be the most likely to be found on the surface of a globular protein?

A. Aspartic acid 

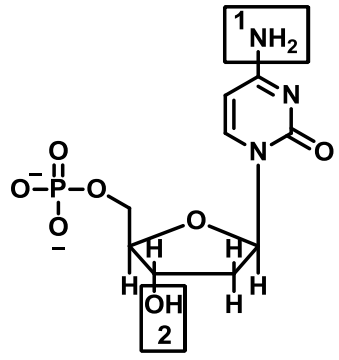
B. Alanine 

C. Isoleucine 

D. Leucine 

F. Phenylalanine 

12. Consider the structure shown at the right. Which statement is *incorrect*?



A. This structure is capable of hydrogen bonding

B. This structure could be part of a DNA molecule

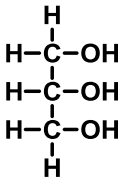
C. This structure contains a sugar and a nitrogenous base

D. This structure contains a phosphate ester and a nitrogenous base

E. This structure can polymerize with DNA bases when the amine group labeled 1 reacts with the hydroxyl group labeled 2

Name_____

Consider these structures and their numbers when answering questions 13-14



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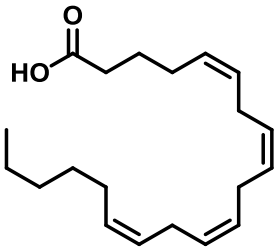

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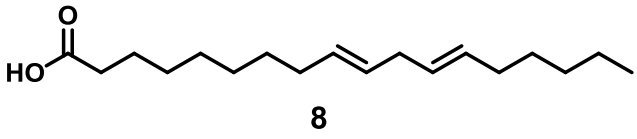

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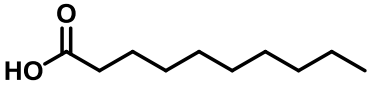
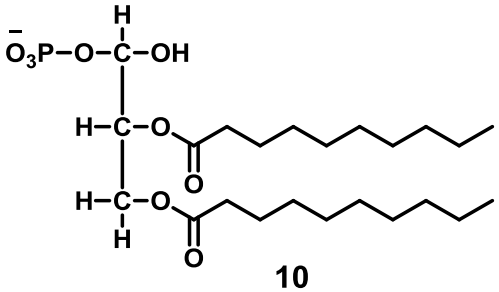


9



10

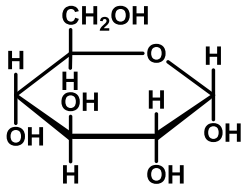
13. Which compound is a triglyceride?

A.10	C. 8	E. 6
B. 9	D. 7	F. None of these compounds is a triglyceride

14. Which compound (or compounds) is a fatty acid?

A. 9	C. 7 and 8	E. 10
B. 7, 8 and 9	D. 6	F. None of these compounds is a fatty acid

Consider the structure of compound 11 when answering question 15.



11

15. Which statement about compound 11 is *incorrect*?

A. Compound 11 is optically active (has optical isomers)

B. Compound 11 is water soluble

C. Compound 11 has a β-anomeric carbon

D. Compound 11 can undergo polymerization

E. Compound 11 is a monosaccharide

Name_____

Part B OPEN-ENDED QUESTIONS. Answer these questions in the space provided. SHOW YOUR WORK AND WRITE EXPLANATIONS IN FULL SENTENCES.

16. (7 points) The structure of DNA involves base pairing and is able to replicate very accurately.

(a) (4 pts) Describe the overall structure of DNA, including the polymer backbone and the role of base pairing.

(b) (3 pts) Explain why the bases pair in DNA and how base pairing contributes to accurate replication of the molecule when cells divide.

17. (8 pts) Draw the structure of a single molecule that could form a condensation polymer (not a copolymer). The molecule should have three carbon atoms and appropriate functional groups so that a polymer can form. Draw two repeating units of the polymer that could be synthesized from your monomer.

18. (6 points) Fabric softeners work by coating the surface of fabrics with a very thin layer of surfactant. This coating is made possible by an interaction between the surfactant and fabric. What kind of interaction is this? Is the interaction stronger or weaker than dipole-dipole forces?

Name_____

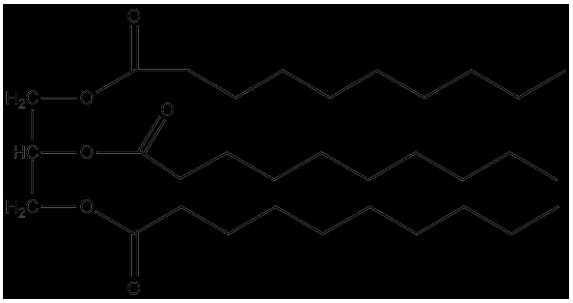
19. (9 points) For each chemical reaction described below, write structures of reactants (if needed) and product or products. It there would be no reaction, write N.R.

(a) Catalytic cracking of hexadecane, $C_{16}H_{34}$.

$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$ n

(b) Condensation of salicylic acid with acetic anhydride

(c) Formation of soap by saponification (basic hydrolysis) of a saturated fat.



+ n

Name_____

20. (15 points) More than one compound exists with the formula C_4H_8.

(a) (8 pts) You have samples of two different compounds C_4H_8. Both are liquids at the temperature of the experiment. $Br_2(\ell)$ is added to each sample. For compound A, the resulting solution is brown. For compound B, the resulting solution is colorless. Draw possible structures for compounds A and B. Explain how you decided what these structures are.

Compound A Compound B

(b) (7 pts) A sample of the product of the reaction of bromine with compound B is analyzed further and found to contain two chiral carbon atoms. Does this change the conclusion about the structure of compound B you gave in part (a)? What is the structure of compound B?

DO NOT REMOVE THIS SHEET UNTIL EXAM IS GRADED.

Please legibly print your 10-digit student ID number: _____

Please answer the following four questions by marking with a check:

1. Which part of the wiki were you **assigned to contribute to**? Check **only one** concept.

___ Rate Laws ___ Integrated Rate Laws ___ Mechanisms and Catalysis ____ Applications of Catalysis

___ Equilibrium States ___ Non-Equilibrium States

2. Which part of the wiki did you **contribute to (i.e. write an original entry)**? **Check all that apply**.

___ Rate Laws ____ Integrated Rate Laws ____ Mechanisms and Catalysis ____ Applications of Catalysis

___ Equilibrium States ____ Non-Equilibrium States

3. Which part(s) of the wiki did you **read or use to study**? **Check all that apply.**

___ Rate Laws ___ Integrated Rate Laws ____ Mechanisms and Catalysis ___ Applications of Catalysis

___ Equilibrium States ___ Non-Equilibrium States ___ I did not read or use the wiki.

4. Which part(s) of the wiki did you **edit**? **Check all that apply.**

___ Intermolecular Forces ___ Organic Structures: Hydrocarbons ___ Organic Reactions

___ Organic Structures: Functional Groups and Polymers ____ DNA and Proteins

___ Lipids, Carbohydrates, and Polysaccharides

LEAVE THIS PORTION OF THE COVERSHEET BLANK.

1. _____	7. _____	11. _____	For TA use only
2. _____	8. _____	12. _____	
3. _____	9. _____	13. _____	
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5. _____		15. _____	
6. _____	**DO NOT WRITE HERE.**		

Page	**Score**
3-5 (multiple-choice)	**_____/ 45**
6	**_____/ 12**
7	**_____/ 21**
8	**_____/ 12**
Total	**_____/ 90**

Name_____

Chemistry 104, Lecture 3 **Section**_____**TA**_____
Professor John Moore
Spring 2013; Exam 2

Form A (Pink)

INSTRUCTIONS

1. This exam consists of two cover sheets and 6 pages of questions (pages 3-8). There is also a separate handout with formulas, useful constants, some structures, and a periodic table. If a page is missing, let your TA know.

2. Answer the questions on the top cover sheet. PRINT your name NOW at the top of ALL pages.

3. On open-ended questions, show all your work, write legibly, and use complete sentences for all explanations.

4. Many questions are multiple-choice; circle the answer to each multiple-choice question inside the test and transfer your answers to the spaces provided below. A penalty of 3 points will be assessed if this is not done.

5. Communicating in any way with anyone else, or accessing information from any source other than your 3x5" card during the exam will be considered to be one form of cheating.

Honor Code: *By the definition of academic integrity, the exam I am handing in is solely my own work and truthfully represents work I have done.*

_____
Signature

Answer Multiple-Choice Questions Here

1. _____	7. _____	11. _____
2. _____	8. _____	12. _____
3. _____	9. _____	13. _____
4. _____	10. ____	14. _____
5. _____		15. _____
6. _____		

Page	**Score**
3-5 (multiple-choice)	_____**/ 45**
6	_____**/ 12**
7	_____**/ 21**
8	_____**/ 12**
Total	_____**/ 90**

Multiple-Choice Questions. (45 points; 3 points each) There is **one best response** to each question. Read all responses, choose the best one, circle it on this page, and write the letter corresponding to that response in the appropriate space on page one of the exam.

1. A reaction is first order in A and second order in B. If the concentrations of both A and B are halved, what happens to the reaction rate?

A. The reaction rate stays the same.

B. The reaction rate decreases to one half the original rate.

C. The reaction rate increases to twice the original rate.

D. The reaction rate decreases to one quarter the original rate.

E. The reaction rate decreases to one eighth the original rate.

2. The units of k for a certain reaction rate constant are $M^{-3}s^{-1}$. What is the overall order of the reaction?

A. Second order B. Third order C. Fourth order D. Fifth order

E. More information is needed to determine the overall order of the reaction.

3. Under certain conditions, the reaction below was observed to proceed at a rate of 0.0245 M/s. What is the value (including sign) of $\Delta[A]/\Delta t$?

2 A + 4 B n 3 C

A. 0.0245 M/s B. -0.0245 M/s C. 0.0490 M/s D. -0.0490 M/s E. 0.000625 M/s

4. The decomposition of cyclobutane is a first order reaction. At a certain temperature, 0.40 mol cyclobutane is placed in a 2.0-L reaction vessel and left to decompose; the rate constant is 0.0051 s^{-1}. Calculate the concentration of cyclobutane after 137 seconds.

A. 0.18 M B. 0.099 M C. 0.20 M D. 0.010 M E. 0.020 M

5. Hydrogenation of 1-butyne is first order in 1-butyne and first order in H_2. Which change(s) increase the rate of reaction?

$$HC{\equiv}CCH_2CH_3(g) + 2\,H_2(g) \rightarrow CH_3CH_2CH_2CH_3$$

A. Increasing the partial pressure of H_2 B. Increasing the temperature

C. Adding a catalyst such as Pd D. Both A and C increase the rate

E. A, B, and C all increase the rate

6. Which statement or statements are correct?

A. A catalyst speeds up a chemical reaction by changing the mechanism

B. A catalyst is not altered by the reaction and therefore does not participate in the reaction

C. A catalyst lowers the activation energy

D. A and C are correct

E. A, B, and C are correct

7. This mechanism has been proposed for the decomposition of hydrogen peroxide, H_2O_2.

$$H_2O_{2\,(aq)} + I^-_{(aq)} \xrightarrow{k_1} H_2O_{(l)} + IO^-_{(aq)} \quad \text{(slow)}$$

$$H_2O_{2\,(aq)} + IO^-_{(aq)} \underset{k_{-2}}{\overset{k_2}{\rightleftharpoons}} H_2O_{(l)} + I^-_{(aq)} + O_{2\,(g)} \quad \text{(fast)}$$

Which statement is *incorrect*?

A. I^- and IO^- are both intermediates in the overall reaction

B. The overall reaction is 2 $H_2O_2(aq)$ → 2 $H_2O(l)$ + $O_2(g)$

C. H_2O_2 is a reactant in the overall reaction

D. I^- is a catalyst in the overall reaction

E. O_2 is a product in the overall reaction

8. Derive the rate law for the proposed mechanism in question 7; the correct rate law is

A. rate = $k_1[H_2O_2]$

B. rate = $k_1[H_2O_2][I^-]$

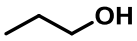
C. $\text{rate} = \dfrac{k_1[H_2O_2][I^-]}{k_{-1}[H_2O]}$

D. $\text{rate} = \dfrac{k_1 k_2[H_2O_2]^2[I^-]}{k_{-1}[H_2O]}$

E. rate = $k_2[H_2O_2][IO^-]$

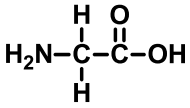
9. Nitrogenase is an enzyme that binds N_2 and converts it to NH_3 (E_a = 420 kJ/mol). Which molecule would you predict to be a competitive inhibitor of nitrogenase?

A. Hexane, 

B. Propanol, 

C. NaCl

D. O_2

E. Glycine, 

10. Which statement about heterogeneous catalysts is *incorrect*?

A. Heterogeneous catalysts are common in industrial catalysis because they are easy to separate from the products when a reaction is over.

B. Reactions with heterogeneous catalysts take place on the surface of the catalyst.

C. Catalytic converters in cars are used to convert hydrocarbons, CO, and NO to more environmentally benign products

D. Pd, Pt, and Rh are common heterogeneous metal catalysts.

E. A heterogeneous catalyst cannot react with a substrate because it is not in the same phase as the substrate.

11. Which statement is incorrect?

A. The portion of an enzyme that the substrate binds to is called the active site.

B. Enzymes are much more effective than metallic catalysts

C. All enzymes are more efficient when the temperature is raised.

D. The efficiency of an enzyme may decrease when an inhibitor is present.

E. The first step of many enzyme-catalyzed reactions is binding of the substrate to the enzyme to form an enzyme-substrate complex.

Consider this equilibrium reaction for questions 12-15:

$H_2(g) + Br_2(g) \rightleftharpoons 2\ HBr(g)$ $\quad K_c = 58$ at 425 °C; $\quad \Delta H = -185$ kJ/mol

12. Which of these statements is *incorrect*?

A. At 425 °C, K_p is 58 for the reaction above.

B. At 425 °C, K_c is 0.017 for the reverse reaction, $2\ HBr(g) \rightleftharpoons H_2(g) + Br_2(g)$

C. At 425 °C, K_c is 3.4×10^3 for the reaction $2\ H_2(g) + 2\ Br_2(g) \rightleftharpoons 4\ HBr(g)$

D. Once equilibrium is established, the rate of the forward reaction is the same as the rate of the reverse reaction

E. The reaction above is reactant-favored.

13. What change in conditions for the system above causes the equilibrium to shift to the reactants?

A. Adding more H_2

B. Increasing the volume of the reaction vessel

C. Adding a catalyst

D. Increasing the temperature

E. Decreasing the temperature

14. What happens if the equilibrium mixture is heated to 800 °C?

A. K_c increases

B. K_c decreases

C. K_c stays the same

D. The equilibrium shifts toward products

E. There is no change

15. Into an empty 5.0 L container, 0.45 moles of H_2, 0.65 moles of Br_2, and 4.5 moles of HBr are added at 425 °C. Which direction must the reaction shift to reach equilibrium?

A. The reaction shifts toward reactants

B. The reaction shifts toward products

C. The reaction is at equilibrium

D. More information is needed to determine the direction the reaction will proceed.

Part B OPEN-ENDED QUESTIONS. Answer these questions in the space provided. SHOW YOUR WORK AND WRITE EXPLANATIONS IN FULL SENTENCES.

16. (12 pts) This question refers to the equilibrium reaction

$$H_2(g) + Br_2(g) \rightleftharpoons 2\ HBr(g) \quad K_c = 58 \text{ at } 425\ ^\circ C$$

If 0.11 mol H_2 and 0.11 mol Br_2 are placed in an empty 1.0 L container, with no HBr initially present, calculate the concentration of HBr(g) when the reaction reaches equilibrium.

.

17. (9 points) Write a correct equilibrium constant expression (K_p or K_c) for each reaction.

(a) $2\ HgO(s) \rightleftharpoons 2\ Hg(\ell) + O_2(g)$

$K_c =$

(b) $2\ N_2O_5(g) \rightleftharpoons 4\ NO_2(g) + O_2(g)$

$K_p =$

(c) $2\ H^+(aq) + CaCO_3(s) \rightleftharpoons H_2CO_3(aq) + Ca^{2+}(aq)$

$K_c =$

18. (12 points) Based on the data given for the reaction below, determine the order with respect to each reactant, write the rate law, and calculate the rate constant. Make certain that the rate constant is expressed with the proper units.

$CO(g) + NO_2(g) \rightleftharpoons CO_2(g) + NO(g)$

Initial Rate (mol L^{-1} h^{-1})	Initial [CO] (mol/L)	Initial [NO_2] (mol/L)
2.5×10^{-4}	3.5×10^{-5}	1.7×10^{-8}
5.1×10^{-4}	7.0×10^{-5}	1.7×10^{-8}
5.0×10^{-4}	3.5×10^{-5}	3.4×10^{-8}

19. (12 points) In both the Fenton Kinetics lab and the Crystal Violet lab you prepared a Beer's law graph.

(a) (2 pts) What is plotted on each axis in a Beer's law graph? Label the axes in the graph at the right.

(b) (4 pts) Draw a series of data points that would be collected in a successful Beer's law experiment.

(c) (2 pts) What does the slope of a Beer's law graph tell you? Explain. Include in your explanation symbols to represent absorbance and other quantities involved in Beer's law.

(d) (4 pts) Explain briefly and clearly the purpose of the Beer's law graph in both experiments. Why was it necessary to make a Beer's law graph before kinetic data could be analyzed?

20. (6 points) This equilibrium reaction was demonstrated in lecture:

$$Cr_2O_7^{2-}(aq) + 2\ OH^-(aq) \rightleftharpoons 2\ CrO_4^{2-}(aq) + H_2O(\ell)$$

(a) (3 pts) When a small volume of concentrated NaOH(aq) was added to a solution containing dichromate ions, the color remained orange. Did the equilibrium shift? Explain. Include in your explanation a description of the predominant chromium-containing species in the solution before and after the addition of NaOH(aq).

(b) (3 pts) Describe clearly the appearance of the solution before and after a significant quantity of NaOH(aq) is added to a dichromate solution.

Exam 3: DO NOT REMOVE THIS SHEET UNTIL EXAM IS GRADED.

Please legibly print your 10-digit student ID number: _____

Please answer the following four questions by marking with a check:

1. Which part of the wiki were you **assigned to contribute to**? Check **only one** concept.

____ Intro to Acids and Bases ____ Aqueous Acidic and Basic Solutions

____ Buffers and Lewis Acids and Bases ____ Titrations

_____ Enthalpy and Entropy _____ Gibbs Free Energy

2. Which part of the wiki did you contribute to (i.e. write an original entry)? Check all that apply.

____ Intro to Acids and Bases ____ Aqueous Acidic and Basic Solutions

____ Buffers and Lewis Acids and Bases ____ Titrations

_____ Enthalpy and Entropy _____ Gibbs Free Energy

3. What page did you **contribute to (i.e. write an original entry)**? Write the page name here:

_____

4. Which part(s) of the wiki did you **read or use to study**? **Check all that apply.**

____ Intro to Acids and Bases ____ Aqueous Acidic and Basic Solutions

____ Buffers and Lewis Acids and Bases ____ Titrations _____ Enthalpy and Entropy

_____ Gibbs Free Energy ____ I did not read or use the wiki to study.

LEAVE THIS PORTION OF THE COVERSHEET BLANK.

1. _____	7. _____	13. _____	For TA use only
2. _____	8. _____	14. _____	
3. _____	9. _____	15. _____	
4. _____	10. ____		
5. _____	11. ____		**DO NOT WRITE HERE.**
6. _____	12. ____		

Page	**Score**
3-5 (multiple-choice)	**_____/ 45**
6	**_____/ 10**
7	**_____/ 16**
8	**_____/ 14**
9	**_____/ 05**
Total	**_____/ 90**

Name_____

Chemistry 104, Lecture 3 **Section**_____**TA**_____
Professor John Moore
Spring 2013; Exam 3

Form A (Pink)

INSTRUCTIONS

1. This exam consists of two cover sheets and 7 pages of questions (pages 3-9). There is also a separate handout with formulas, useful constants, some structures, a table of acid-base ionization constants, and a periodic table. If a page is missing, let your TA know.

2. Answer the questions on the top cover sheet. PRINT your name NOW at the top of ALL pages.

3. On open-ended questions, show all your work, write legibly, and use complete sentences for all explanations.

4. Many questions are multiple-choice; circle the answer to each multiple-choice question inside the test and transfer your answers to the spaces provided below. A penalty of 3 points will be assessed if this is not done.

5. Communicating in any way with anyone else, or accessing information from any source other than your 3x5" card during the exam will be considered to be one form of cheating.

Honor Code: *By the definition of academic integrity, the exam I am handing in is solely my own work and truthfully represents work I have done.*

_____
Signature

Answer Multiple-Choice Questions Here

1. _____	7. _____	13. _____
2. _____	8. _____	14. _____
3. _____	9. _____	15. _____
4. _____	10. _____	
5. _____	11. _____	
6. _____	12. _____	

Page	**Score**
3-5 (multiple-choice)	**_____/ 45**
6	**_____/ 10**
7	**_____/ 16**
8	**_____/ 14**
9	**_____/ 05**
Total	**_____/ 90**

Name_____

Multiple-Choice Questions. (45 points; 3 points each) There is **one best response** to each question. Read all responses, choose the best one, circle it on this page, and write the letter corresponding to that response in the appropriate space on page one of the exam.

1. Hydrogen fluoride, HF, can be classified as a

A. Brønsted-Lowry acid.

B. Arrhenius acid.

C. Weak acid.

D. A and B are both correct.

E. All three (A, B, and C) are correct.

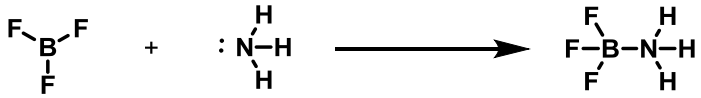
2. Which compound does *not* completely ionize in water?

A. HNO_2 B. HBr C. HCl D. NaOH E. $Sr(OH)_2$

3. Which species does *not* have a conjugate acid?

A. HSO_4^- B. O^{2-} C. ClO_4^- D. NH_3 E. H_2

4. Consider the reaction below when answering question 4.



What is the role of ammonia (NH_3) in this reaction?

A. Lewis acid B. Lewis base C. Brønsted-Lowry acid

D. Brønsted-Lowry base E. Arrhenius base

5. Calculate the pH of a 100.0-mL solution consisting of 0.0100-M HClO and 0.0300-M NaClO. The correct pH is

A. 6.16 B. 6.89 C. 7.09 D. 7.64 E. 8.06

6. Which aqueous solution is an acidic buffer? Concentrations of all substances are 0.10 M. T = 298 K.

A. HCN and NaCN $K_a(HCN) = 3.3 \times 10^{-10}$

B. H_2CO_3 and $NaHCO_3$ $K_a(H_2CO_3) = 4.3 \times 10^{-7}$

C. NH_4Cl and NH_3 $K_a(NH_4^+) = 5.6 \times 10^{-10}$

D. CH_3NH_2 and CH_3NH_3Cl $K_a(CH_3NH_3^+) = 2.0 \times 10^{-11}$

E. HNO_3 and $NaNO_3$ $K_a(HNO_3) = 20$

Name_____

7. Which statement is *incorrect*?

A. The second law of thermodynamics states that the entropy of the universe is constantly increasing.

B. Breaking a bond is always endothermic; forming a bond is always exothermic.

C. The first law of thermodynamics states that the total energy of the universe is constant.

D. The entropy of 1 mol $H_2(g)$ is greater than the entropy of 1 mol butane, $C_4H_{10}(g)$ at the same temperature.

E. The enthalpy change for the reaction

3/2 $H_2(g)$ + 1/2 $N_2(g)$ n $NH_3(g)$ is defined as $\Delta H_f°$ for ammonia.

Use these data to answer questions 8 and 9:

Species	$\Delta H_f°$ (kJ/mol)	$S°$ (J/ moljK)
$NO_2(g)$	33.18	240.06
NO(g)	90.25	210.761
$O_2(g)$	0	205.138

8. Calculate $\Delta H°$ for the reaction 2 NO(g) + O_2(g) n 2NO_2(g) The correct result is

A. – 114.1 kJ/mol B. – 57.07 kJ/mol C. – 146.5 kJ/mol

D. 57.07 kJ/mol E. 114.1 kJ/mol

9. Calculate $\Delta S°$ for the reaction 2 NO(g) + O_2(g) n 2NO_2(g) The correct result is

A. 175.8 J/moljK B. 146.5 J/moljK C. – 57.07 J/moljK

D. – 146.5 J/moljK E. – 175.8 J/moljK

For the reaction N_2(g) + 3 H_2(g) n 2 NH_3(g) $\Delta H° = -92.22$ kJ/mol; $\Delta S° = -198.762$ J/ moljK

10. Calculate ΔG° at 25 °C for the ammonia synthesis reaction above. Is the reaction reactant-favored or product-favored at 25 °C?

A. 59.13 kJ/mol; product-favored.

B. – 32.99 kJ/mol; product-favored.

C. – 87.25 kJ/mol; product-favored.

D. 59.13 kJ/mol; reactant-favored.

E. – 32.99 kJ/mol; reactant-favored

F. – 87.25 kJ/mol; reactant-favored.

11. At which temperatures is the reaction in question 10 non-spontaneous?

A. > 324.6 K B. > 464.0 K C. > 0.46 K D. < 324.6 K E. < 464.0 K F. < 0.46 K

G. This reaction is spontaneous at all temperatures

12. Calculate the pH of a 0.020-M aqueous solution of $Ba(OH)_2$. The correct pH is

A. 1.40 B. 1.70 C. 12.30 D. 12.60 E. 10.60

Name_____

13. Which solution is most basic?

A. 0.10 M NaF $K_a(HF) = 6.8 \times 10^{-4}$

B. 0.10 M $NaCH_3COO$ $K_a(CH_3COOH) = 1.8 \times 10^{-5}$

C. 0.10 M NaBrO $K_a(HBrO) = 2.5 \times 10^{-9}$

D. 0.10 M KClO $K_a(HClO) = 6.8 \times 10^{-8}$

E. 0.10 M NaH_2PO_4 $K_a(H_3PO_4) = 7.2 \times 10^{-3}$

14. Which salt gives an acidic solution when dissolved in water at 25 °C?

A. KNO_2 B. LiCl C. NH_4F D. NH_4Cl E. Both C and D are acidic

15. Which of these statements about the titration of a weak acid by a strong base is correct?

A. The equivalence point cannot be determined using an indicator.

B. The pH at the equivalence point is 7.00 at 25 °C.

C. The solution is buffered before the equivalence point.

D. The solution is buffered both before and after the equivalence point.

E. Methyl orange (pH color range 3.1-4.4) would be a better indicator for this titration than thymol blue (8.0-9.6).

Name_____

Part B OPEN-ENDED QUESTIONS. Answer these questions in the space provided. SHOW YOUR WORK AND WRITE EXPLANATIONS IN FULL SENTENCES.

16. (10 pts) Calculate the mass of ammonium chloride that must be added to 500.0 mL of a 0.100-M solution of aqueous ammonia to make a buffer with a pH of 9.15.
[Possibly useful information: $K_a(NH_4^+) = 5.6 \times 10^{-10}$ and $M(NH_4Cl) = 53.49$ g/mol]

.

Name_____

17. (16 points) For each aqueous solution indicate whether the conductivity is high or low and whether the pH is low, neutral, or high by circling a choice. Explain your choices in each case.

(a) 0.20 M NaCl

Conductivity: high low

pH: low neutral high

Explanation:

(b) 0.20 M NH_3

Conductivity: high low

pH: low neutral high

Explanation:

(c) 0.20 M NaCN

Conductivity: high low

pH: low neutral high

Explanation:

(d) 0.20 M $(NH_4)_3PO_4$

Conductivity: high low

pH: low neutral high

Explanation:

Name_____

18. (14 points) A student determines the titration curve for the titration of 50.0 mL of 0.10-M weak base with 0.10-M strong acid. Both acid and base are monoprotic. The pK_a for the conjugate acid of the weak base is 9.25. The pOH of the weak base solution before the titration starts is 2.95. The pH at the equivalence point of the titration is 5.28.

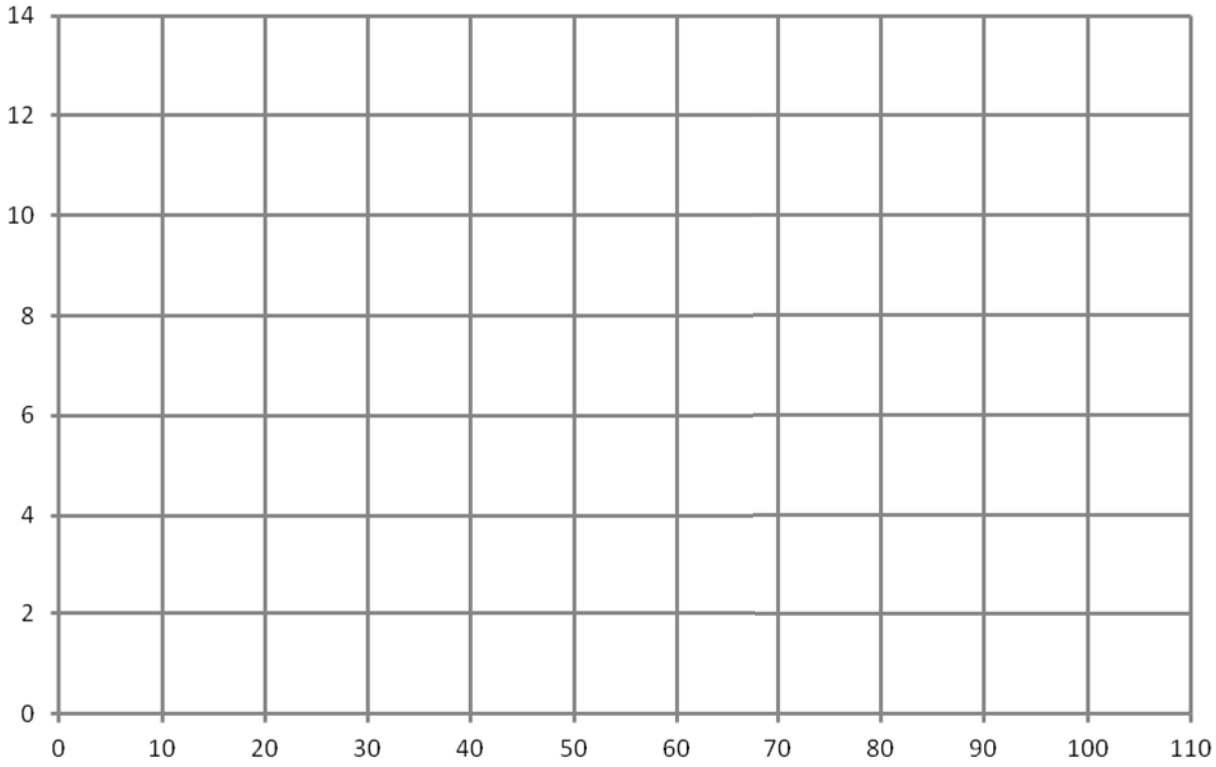
(a) (2 pts) Without doing any calculations, sketch the titration curve on the axes below. Be as accurate as you can with regard to both the vertical and horizontal placement of the curve.

(b) (2 pts) Label each axis on the graph.

(c) Label each of these points on the curve, using the Roman numeral given below (i.e. i, ii).

(i) (2 pts) The equivalence point
(ii) (2 pts) The point where pH = pK_a
(iii) (2 pts) A point where the pH is determined by the concentration of strong acid in the solution
(iv) (2 pts) A region where there is a buffer solution

(d) (2 pts) From these indicators, choose the most appropriate indicator for the titration: phenolphthalein (pH 8.0 to 10.0); bromothymol blue (pH 6.0 to 8.0); methyl red (pH 4.2 to 6.0). Explain your choice.



Chemistry 109
Lectures 1 and 2, Fall 2013
Exam 1

Name _____

Section_____**TA**_____

INSTRUCTIONS

1. This exam consists of 11 pages. You will also receive a separate packet with a page of formulas, a page with useful constants, and a periodic table. If anything is missing, ask your TA for a complete exam. **Do not separate this page from the rest of the exam.**

2. PRINT your name NOW in the spaces at the top of ALL pages.

3. **Answer all questions in this exam booklet. For multiple-choice questions, circle the answers in this booklet and then transfer your answers to the mark-sense form. On open-ended questions show all work and give all explanations as complete sentences.**

4. **On the grading chart at the bottom of this page, CIRCLE the numbers of the questions you would like to be graded. Check that you have circled the correct number of questions for Parts B (3) and C (1). A penalty of 5 points will be assessed if this is not done.**

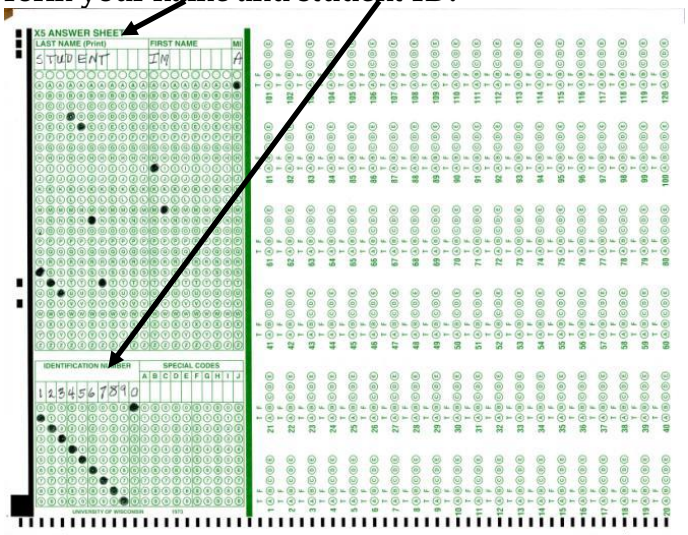
5. You will have 80 minutes to work on the exam; you should be able to complete the exam in less than 75 minutes. Check your work after completing the exam.

Honor Code: *By the definition of academic integrity, the exam I am handing in is solely my own work and truthfully represents work I have done.*

_____
Signature

Exam Part	Quest.	Pts	Score
Part A (Mult-Choice)	1-6	18	
Part B (Circle 3)	7	19	
	8	19	
	9	19	
	10	19	
	11	19	
Part C (Circle 1)	12	25	
	13	25	
Parts B and C		82	
TOTAL	--	100	

Multiple Choice: Record your answers on the separate mark-sense form. Make certain that you encode on the mark-sense form your name and student ID.



Name_____

PART A. (18 points) **Multiple-Choice QUESTIONS**. Circle the correct answer to each question on this exam and then use a pencil to transfer your answer to each question to the mark-sense form provided. Be sure to mark your name and student ID on the mark-sense form.

1. Which statement or statements is *incorrect*?

A. Electromagnetic radiation has both wave- and particle-like properties.
B. The photoelectric effect can be used to explain why atoms produce a line emission spectrum.
C. Every atom has a characteristic line emission spectrum.
D. Heisenberg's Uncertainty Principle states that it is impossible to know both the exact position and exact momentum of an electron at any given time.
E. All of these statements are correct.

2. If 5.0 grams of $BaCl_2$ are dissolved in 4.0 L of water, what is the molarity of chloride ion in this solution?

A. 0.048 M
B. 0.052 M
C. 0.012 M
D. 0.0073 M
E. 0.0060 M

3. Which atom or ion has the electron configuration $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 5s^0$?

A. Ni
B. Sr
C. Pd
D. Cd
E. Cd^{2+}

4. 3.00 L of benzene, C_6H_6, is reacted with oxygen gas to produce CO_2 and water. How many moles of CO_2 are produced in this reaction? The density of benzene is 0.8765 g/mL.

A. 202 moles
B. 263 moles
C. 0.202 moles
D. 101 moles
E. 33.7 moles

5. What is the percent yield of the reaction in question 4 if 1425 grams of water are produced?

A. 19.6%
B. 25.4%
C. 78.4%
D. 60.2%
E. There is not enough information to determine percent yield.

6. A possible set of quantum numbers for a *valence* electron of selenium is:

A. $n = 2, l = 0, m_l = 0, m_s = +1/2$
B. $n = 2, l = 1, m_l = 0, m_s = -1/2$
C. $n = 3, l = 0, m_l = 0, m_s = +1/2$
D. $n = 4, l = 0, m_l = 1, m_s = -1/2$
E. $n = 4, l = 1, m_l = -1, m_s = -1/2$

Name_____

Part B (57 points) **COMPETENCY QUESTIONS** Answer THREE of the following FIVE questions in the space provided. SHOW YOUR WORK AND WRITE EXPLANATIONS IN FULL SENTENCES.

7. (19 points) This question explores electron configurations and chemical formulas.

a) (4 pts) Use the periodic table to predict the electron configuration for indium (In). You may use the noble-gas abbreviation.

Electron configuration for indium: _____

b) (2 pts) How many valence electrons does indium have?

c) (4 pts) Write the formulas of indium chloride and indium oxide below. Explain why you chose the number of indium ions and chloride or oxide ions you put in each formula.

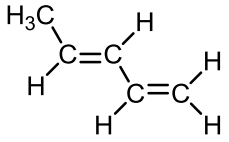
c) (3 pts) Are you surprised to learn that indium forms a chloride with a formula analogous to the formula of sodium chloride? Write the formula for this indium chloride here and explain why you were or were not surprised about this formula.

d) (3 pts) Indium forms two different oxides. Predict the formulas for both oxides and explain why you chose these formulas.

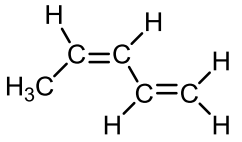
e) (3 pts) Based on the fact that it forms more than a single oxide, it is clear that indium exhibits variable valence. Name and give the chemical symbol for another metal that exhibits variable valence. Explain why you chose that metal.

Name_____

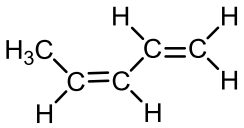
8. (19 points) This question explores the structures of covalent molecular compounds, isomerism, and properties of compounds with particular structures. Consider these structures (I) – (IV):



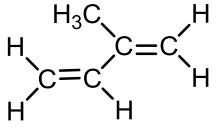
(I)



(II)



(III)



(IV)

a) (5 pts) Consider the compound that consists of molecules that have each structure. For which structures does the corresponding compound have exactly the same physical properties? (melting point, boiling point, density)? Explain.

b) (5 pts) Which of these structures is/are trans isomers? Explain.

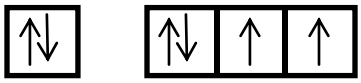
c) (5 pts) Which of these structures is/are not capable of cis-trans isomerism? Explain.

d) (4 pts) Draw a Lewis diagram for a structural (constitutional) isomer of structure IV that is not structure I, II, or III.

Name_____

9. (19 points) This question explores atomic electron configurations. Write the name and symbol for the atom or ion with the valence electron orbital diagram or electron configuration in each case:

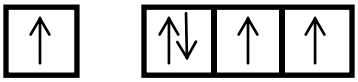
a. (4 pts) A ground-state atom:



3s 3p

Name: _____ Symbol: ____

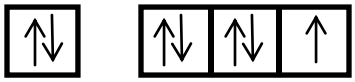
b. (4 pts) An atom in an excited state (assume the $n = 1$ shell is completely filled with electrons)



2s 2p

Name: _____ Symbol: ____

c. (4 pts) A ground state ion with a charge of -1.



4s 4p

Name: _____ Symbol: ____

d. (4 pts) An excited state of this element has the electron configuration: $[Kr]5s^2 4d^6 5p^2 6s^1$

Name: _____ Symbol: ____

e. (3 pts) The ground state electron configuration contains three unpaired 6p electrons.

Name: _____ Symbol: ____

Name_____

10. (19 points) This question explores properties that vary periodically. Write a clear, concise explanation for each observation described below.

a. (5 pts) The second ionization energy of potassium (energy required to remove a second electron) is 3069 kJ/mol whereas the first ionization energy of potassium is 419 kJ/mol

b. (5 pts) The radius of a strontium ion (132 pm) is much smaller than the radius of a strontium atom (215 pm) whereas the radius of a sulfide ion (170 pm) is much larger than the radius of a sulfur atom (104 pm).

c) (5 pts) The first ionization energy of phosphorus is 1060 kJ/mol and the first ionization energy of sulfur is 999 kJ/mol.

d) (4 pts) Barium usually forms ionic compounds.

Name_____

11. (19 points) This question explores the particle nature of electromagnetic radiation. One type of sunburn occurs because of exposure to UV light of wavelength 325 nm.

a) (5 pts) Calculate the energy of a photon of this wavelength.

b) (5 pts) Calculate the energy of a mole of these photons.

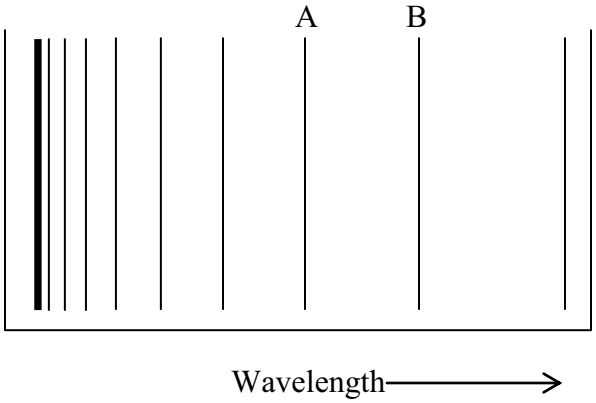
c) (5 pts) Pulsed lasers can produce bursts of radiation with a specific total energy. How many photons are in a 1.00 mJ burst of this radiation?

d) (4 pts) If the 325 nm radiation provides exactly enough energy to break a specific chemical bond X–Y in the skin, calculate the energy in kJ/mol required to separate atom X from atom Y so that they are no longer bonded.

Name_____

Part C (25 points) **MASTERY QUESTIONS** Answer ONE of the following two questions in the space provided. SHOW ALL YOUR WORK AND WRITE EXPLANATIONS IN COMPLETE SENTENCES.

12. (25 points) This question explores emission spectra and the Bohr theory. The Bohr theory can be used to interpret the spectra of one-electron ions as well as the spectrum of a hydrogen atom. (A one-electron ion is any ion that contains only a single electron; for example, He^+ is a one-electron ion.) The figure below represents part of the gas-phase emission spectrum for a one-electron ion. All lines involve electronic transitions from excited states to the $n = 3$ state.



a) (5 pts) The Bohr theory does not predict the spectrum of He accurately, but it does predict the spectrum of He^+. Explain clearly but concisely the difference between He and He^+ that causes the Bohr theory not to work for He.

b) (5 pts) The Bohr-theory formula for the energy levels of a one-electron ion (and a hydrogen atom) is $E = (-2.179 \times 10^{-18}\ \text{J})(Z^2/n^2)$, where Z represents the atomic number. Explain clearly and concisely why Z is involved in the formula.

c) (7 pts) Determine the quantum numbers of the excited states associated with the electronic transitions that produce lines A and B. Explain how you arrived at your answer.

Line A quantum number _____ Line B quantum number _____

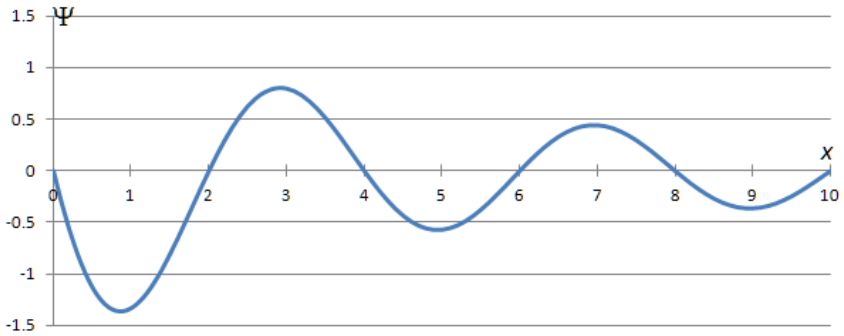
This question continues on the next page.

Name_____

d) (8 pts) If the wavelength of line B is 142.5 nm, determine the name of the element from which the one-electron ion was formed. Show your mathematical work completely and clearly.

Name_____

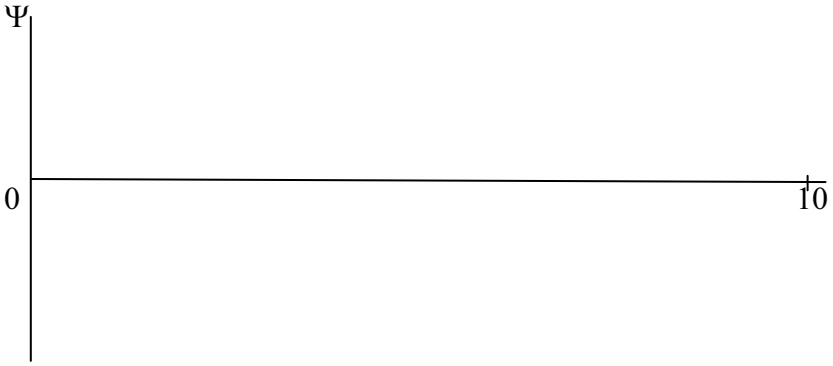
13. (25 points) This question deals with the wave theory of matter, the properties of wave functions, and how the wave theory applies to covalent bonding. The wave function, Ψ, of an electron in an arbitrary chemical system is shown below. Assume that the system is one-dimensional and extends from $x = 0$ to $x = 10$.



a) (4 pts) At what value of x is the probability of finding the electron greatest? Explain your choice.

b) (3 pts) How many nodes does the wave function have? Define *node*.

c) (3 pts) On the axes below, draw a wave function for this chemical system that would *not* be allowed by the quantum rules for wave functions.



d) (3 pts) The system in the diagram at the beginning of this question is similar to, but not identical to a particle in a box. For the system given, what would happen to the energy levels if the one-dimensional system extended from $x = 0$ to $x = 20$? Explain briefly.

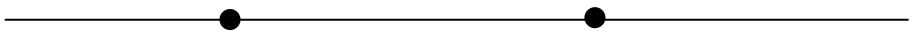
This question continues on the next page.

Name_____

e) (12 pts) Explain clearly and concisely how interference between waves is related to formation of chemical bonds.

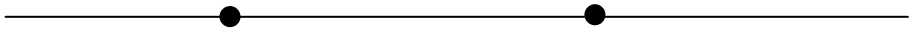
i) (4 pts)Describe in words the formation of a bonding molecular orbital (MO) when two H atoms form a bond. Explain clearly why the atoms are held together.

ii) (2 pts) Make a boundary-surface diagram showing what the bonding MO looks like. Nuclei of the two H atoms are shown below.



iii) (4 pts) Describe in words the formation of an antibonding MO involving two H atoms. Include an explanation of why this MO is higher in energy than the bonding MO.

iv) (2 pts) Make a boundary-surface diagram showing what the antibonding MO looks like. Nuclei of the two H atoms are shown below.



Chemistry 109
Lectures 1 and 2, Fall 2013
Exam 2

Name _____

Section_____**TA**_____

INSTRUCTIONS

1. This exam consists of 12 pages. You will also receive a separate packet with formulas, constants, other useful information, and a periodic table. If anything is missing, ask your TA for a complete exam. **Do not separate this page from the rest of the exam.**

2. PRINT your name NOW in the spaces at the top of ALL pages.

3. **Answer all questions in this exam booklet. For multiple-choice questions, circle the answers in this booklet and then transfer your answers to the mark-sense form. On open-ended questions show all work and give all explanations as complete sentences.**

4. **On the grading chart at the bottom of this page, CIRCLE the numbers of the questions you would like to be graded. Check that you have circled the correct number of questions for Parts B (3) and C (1). A penalty of 5 points will be assessed if this is not done.**

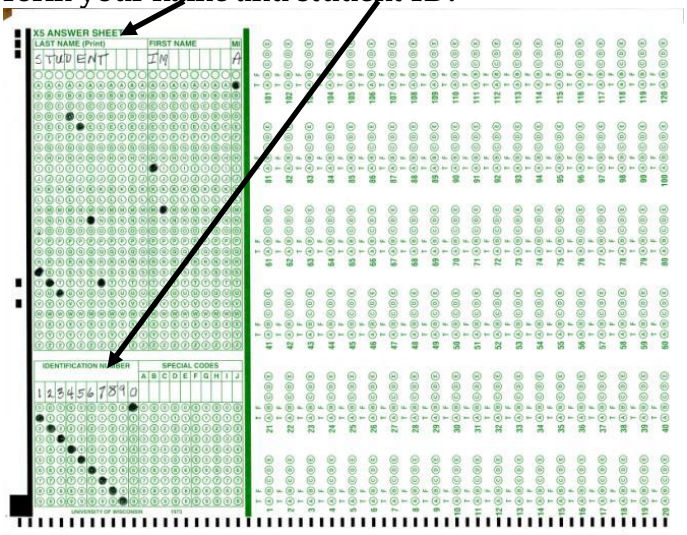
5. You will have 80 minutes to work on the exam; you should be able to complete the exam in less than 75 minutes. Check your work after completing the exam.

Honor Code: *By the definition of academic integrity, the exam I am handing in is solely my own work and truthfully represents work I have done. I will not communicate with anyone in any way about this exam until after 9 PM Monday, October 21.*

_____
Signature

Exam Part	Quest.	Pts	Score
Part A (Mult-Choice)	**1-6**	**18**	
Part B (Circle 3)	**7**	**19**	
	8	**19**	
	9	**19**	
	10	**19**	
	11	**19**	
Part C (Circle 1)	**12**	**25**	
	13	**25**	
Parts B and C		**82**	
TOTAL	**--**	**100**	

Multiple Choice: Record your answers on the separate mark-sense form. Make certain that you encode on the mark-sense form your name and student ID.



Name_____

PART A. (18 points) **Multiple-Choice QUESTIONS**. Circle the correct answer to each question on this exam and then use a pencil to transfer your answer to each question to the mark-sense form provided. Be sure to mark your name and student ID on the mark-sense form.

1. Which bond is the least polar bond?

A. Li-C B. H–O C. Na–N D. C–N E. H–F

2. What are the formal charges on nitrogen in the molecule HN_3? (The order of the charges listed does not matter.)

A. 0,0, and 0 B. -1, 0, and +1 C. 0, -1 and 0 D. 0, -1, and +2

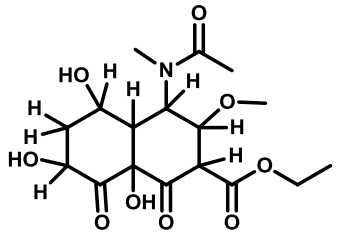
E. -2, 0, and +2

3. What are the electronic and molecular geometries of SO_2?

A. Electronic = tetrahedral; Molecular = triangular pyramidal
B. Electronic = triangular planar; Molecular = triangular planar
C. Electronic = linear; Molecular = linear
D. Electronic = tetrahedral; Molecular = bent
E. Electronic = triangular planar; Molecular = bent

Name_____

Consider the structure of molecule A for questions 4-6.



A

4. Which letter below includes all of the functional groups present in molecule A?

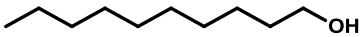
A. Alcohol, amine and amide
B. Alcohol, ketone, amine, ether
C. Alcohol, carboxylic acid, amine, ether
D. Alcohol, ketone, amide, ether
E. None of these (A through D) includes all functional groups in molecule A.

5. In which solvent do you expect molecule A to be the most soluble?

A. Ethanol, 

B. Acetone, 

C. Tetrahydrofuran, 

D. 1-decanol, 

E. Hexane, 

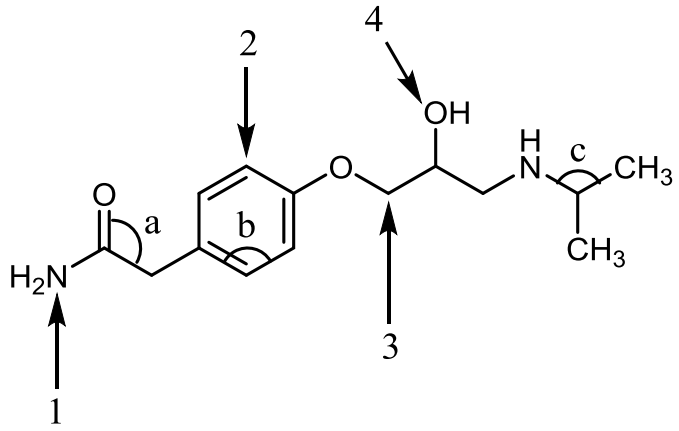
6. How many secondary alcohols are present in molecule A?

A. 0 B. 1 C. 2 D. 3 E. 4

Name_____

Part B (57 points) **COMPETENCY QUESTIONS** Answer THREE of the following five questions in the space provided. SHOW YOUR WORK AND WRITE EXPLANATIONS IN FULL SENTENCES.

7. (19 points) This question is about chemical bonding and functional groups. The organic molecule with the structure below is Atenolol, a drug used to treat hypertension.



a. (5 pts) On the structure above circle all the functional groups and name them.

b. (8 pts) Provide the hybridization of the numbered atoms (1-4) and the angles for the bonds indicated (a-c)

Orbital hybridization: 1 ____ 2 _____ 3 _____ 4 _____

Bond angles: a _____ b _____ c _____

c. (2 pts) Mark using an asterisk (*) each chiral carbon atom in the structure above.

d. (2 pts) How many carbon-carbon sigma bonds are in this molecule? _____

e. (2 pts) How many pi bonds are in this molecule? _____

Name_____

8. (19 points) This question is about chemical kinetics and rate laws. The decomposition of ethanol (C_2H_5OH) on an alumina (Al_2O_3) surface

$$C_2H_5OH(g) \rightarrow C_2H_4(g) + H_2O(g)$$

was studied at 600 K. Concentration versus time data were collected for this reaction and a plot of $[C_2H_5OH]$ versus time resulted in a straight line with a slope of -4.00×10^{-5} mol L^{-1} s^{-1}. For each part of the question show your work or reasoning clearly.

a. (3 pts) Determine the rate law for this reaction.

b. (3 pts) Determine the integrated rate law for this reaction.

c. (3 pts) Determine the value of the rate constant for this reaction.

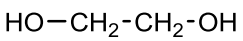
d. (5 pts) Suppose the initial concentration of C_2H_5OH is 1.25×10^{-2} M. Calculate the time required for all the C_2H_5OH to decompose.

e. (2 pts) Based on the description at the beginning of this question, is this reaction homogeneous or heterogeneous? Explain how you know.

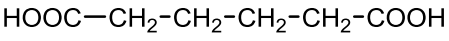
f. (3 pts) Describe a way that the rate of this reaction can be increased that does not involve changing the temperature.

Name_____

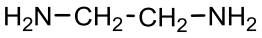
9. (19 points) This question is about polymers. Consider these monomers:



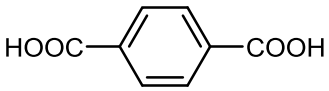
Ethylene glycol



Adipic acid



1,2-Diamino-ethane



Terephtalic acid

a. (5 pts) Draw the structure of two repeating units of the copolymer formed with ethylene glycol and adipic acid.

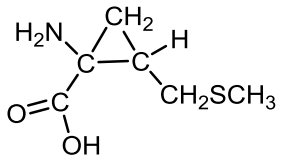
b. (5 pts) Draw the structure of two repeating units of the copolymer formed with 1,2-diamino-ethane and terephtalic acid.

c. (5 pts) Which of the polymers above (a or b) is the toughest and strongest? Explain.

d. (4 pts) Draw the structure of a diamine you could use instead of 1,2-diamino-ethane to increase the rigidity of the polymer in part c. Explain why your diamine would increase rigidity.

Name_____

10. (19 points) This question is about amino acids and peptides. Chemists at Texas A&M University reported the synthesis of a non-naturally occurring amino acid with this structure:



a. (3 pts) To which naturally occurring amino acid is this compound most similar?

b. (4 pts) Indicate all chiral carbon atoms in this synthetic amino acid by placing an asterisk (*) next to them on the structure above.

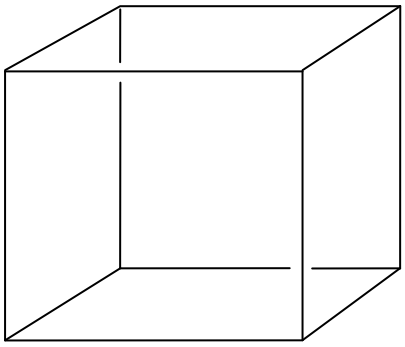
c. (6 pts) A tetrapeptide Phe-Met-Arg-Phe is synthesized in the brains of rats involved in addiction studies. Draw the chemical structure of this tetrapeptide, but substitute the synthetic amino acid above for the original amino acid it is most similar to.

d. (6 pts) In the tetrapeptide you drew in part c, there are groups of six atoms that all must be in the same plane. Identify one of these groups by drawing a box around it. Explain why all six atoms must lie in the same plane (a diagram or structure would be helpful).

Name_____

11. (19 pts) This question is about solid-state structures. Consider the body-centered cubic (bcc) crystal structure and the face-centered cubic (fcc) crystal structure. Answer these questions.

a. (3 pts) Draw a picture of the fcc unit cell in the space to the right of this sentence. Draw the atoms as circles about this size. ◯



b. (3 pts) Determine the net number of atoms that lie within the fcc unit cell. Explain how you arrived at that number.

Number of atoms: _____

c. (6 pts) Sodium has a body-centered cubic crystal structure. The radius of a sodium atom is 191 pm. Calculate the volume of a sodium unit cell. Express your result in pm^3.

d. (2 pts) One of the two structures, bcc or fcc, is a closest-packed structure. Which one?

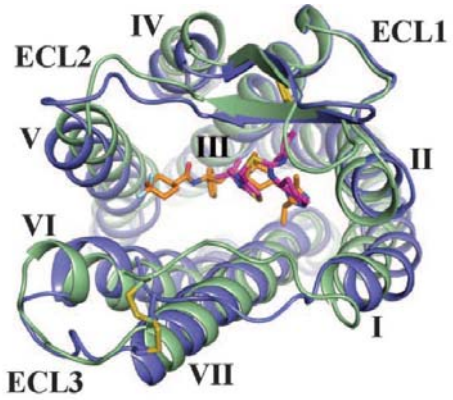
e. (5 pts) At different temperatures, iron is known to exist in both fcc and bcc crystal structures. At 912 °C iron undergoes a solid-state phase transition from one structure to the other. At 900 °C the density of iron is smaller than at 920 °C. Determine the crystal structure of iron at 900 °C and at 920 °C. Explain how you know which structure is which.

Structure at 900 °C: _____ Structure at 920 °C: _____

Explanation:

Part C (25 points) **MASTERY QUESTIONS** Answer ONE of the next two questions in the space provided. SHOW ALL YOUR WORK AND WRITE EXPLANATIONS IN COMPLETE SENTENCES.

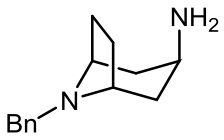
12. (25 points) This question is about biochemical structure and noncovalent forces. The three-dimensional structure, determined by X-ray crystallography, of CCR5, a protein that HIV uses to infect humans' cells, was published in the September 20, 2013 issue of *Science* magazine. This detailed structure, in which CCR5 is attached to the HIV drug Maraviroc, provides important clues about how HIV infections begin and how they might be stopped. The figure shows a top view from the extracellular side of the CCR5 receptor complexed with Maraviroc (shown in the middle in stick representation). The CCR5 receptor contains three extracellular loops ECL1-3 and seven transmembrane domains I-VII.



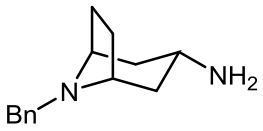
a. (2 pts) Name the main kind of secondary-structure in CCR5. _____

b. (5 pts) What type of noncovalent forces are responsible for the shape of the structural element in part a? Explain how these noncovalent forces are arranged by using a drawing. Be specific about which atoms of the protein chain are involved.

c. (4 pts) During the process of chemical synthesis of Maraviroc the two intermediates at the right are formed in a ratio of endo : exo = 1:10. The smaller percent of undesired endo material can be easily separated out at a later step in the process.



endo

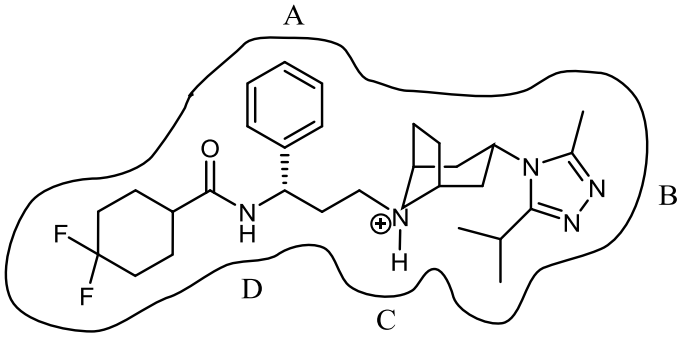


exo

This bicyclic organic fragment containing a N atom is called tropane. Based on your knowledge of cyclohexane conformations gained during lab, explain which of the tropane forms (endo or exo) is more energetically favored and why.

Name_____

d. (8 pts) The figure below shows Maraviroc interacting with CCR5. Letters A, B, C and D designate locations of amino acid side chains that are part of the CCR5 receptor and form intermolecular interactions with the drug molecule.



What amino acids would be suitable for participating in intermolecular interactions with the Maraviroc molecule? In the table below give the three-letter abbreviation for an example amino acid that could interact with each of positions A-D and specify the most important type of interaction it undergoes with the drug molecule. (*Hint: Carboxylic acids are ionized to carboxylate anions at physiologic pH.*)

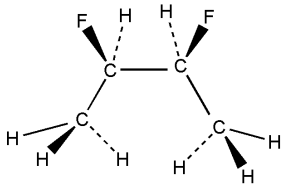
	Example of amino acid	Most important type of interaction
A		
B		
C		
D		

e. (6 pts) The X-ray crystal structure published in *Science* shows the interaction of two threonine (Thr) side chains from CCR5 with the same F atom in Maraviroc. Draw a clear picture showing how this interaction occurs and all the atoms/groups and electron lone pairs involved. Specify the type of noncovalent intermolecular interaction between the threonine side-chains and the F atom.

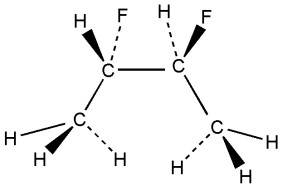
Name_____

13. (25 points) This question involves isomerism, chiral atoms, and drawing mirror image molecules.

a. (4 pts) In each structure identify all chiral carbon atoms by placing an asterisk (*) next to the symbol for each chiral carbon atom.



Structure A



Structure B

b. (3 pts) Are structures A and B constitutional isomers? Explain why or why not.

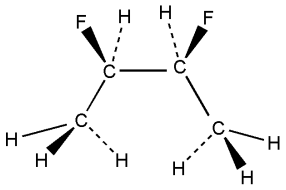
c. (3 pts) Are structures A and B geometric isomers? Explain why or why not.

d. (3 pts) Molecules represented by structures A and B are not enantiomers. Explain why not.

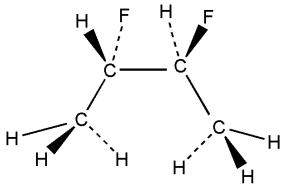
(question continues on next page)

Name_____

(structures are repeated from previous page for convenience in answering parts e and f)



Structure A



Structure B

e. (3 pts) Using lines, wedges, and dotted lines, draw the structure of the molecule that is a mirror image of structure A; label it structure C.

f. (3 pts) Draw the mirror image of structure B and label it structure D.

g. (3 pts) Describe the relationship between structures A and C and the relationship between structures B and D. (Enantiomers; both same structure; completely different structures.)

h. (3 pts) From your answers in part g, does molecule A have an enantiomer? Does molecule B have an enantiomer? Given that both molecules have chiral C atoms, is your answer to either of these questions surprising? Explain.

Chemistry 109
Lectures 1 and 2, Fall 2013
Exam 3

Name _____

Section_____**TA**_____

INSTRUCTIONS

1. This exam consists of 12 pages. You will also receive a separate packet with formulas, constants, other useful information, and a periodic table. If anything is missing, ask your TA for a complete exam. **Do not separate this page from the rest of the exam.**

2. PRINT your name NOW in the spaces at the top of ALL pages.

3. **Answer all questions in this exam booklet. For multiple-choice questions, circle the answers in this booklet and then transfer your answers to the mark-sense form. On open-ended questions show all work and give all explanations as complete sentences.**

4. **On the grading chart at the bottom of this page, CIRCLE the numbers of the questions you would like to be graded. Check that you have circled the correct number of questions for Parts B (3) and C (1). A penalty of 5 points will be assessed if this is not done.**

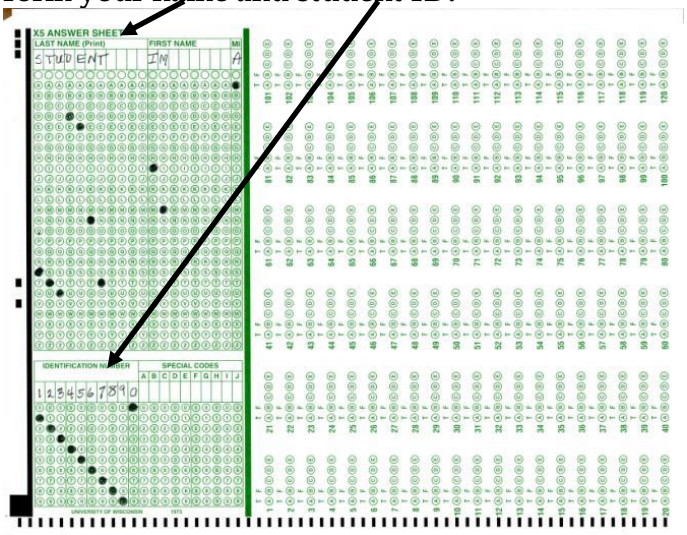
5. You will have 80 minutes to work on the exam; you should be able to complete the exam in less than 75 minutes. Check your work after completing the exam.

Honor Code: *By the definition of academic integrity, the exam I am handing in is solely my own work and truthfully represents work I have done. I will not communicate with anyone in any way about this exam until after 9 PM Monday, Nov. 18.*

_____
Signature

Exam Part	Quest.	Pts	Score
Part A (Mult-Choice)	**1-6**	**18**	
Part B (Circle 3)	**7**	**19**	
	8	**19**	
	9	**19**	
	10	**19**	
	11	**19**	
Part C (Circle 1)	**12**	**25**	
	13	**25**	
Parts B and C		**82**	
TOTAL	**--**	**100**	

Multiple Choice: Record your answers on the separate mark-sense form. Make certain that you encode on the mark-sense form your name and student ID.



Name_____

PART A. (18 points) **Multiple-Choice QUESTIONS**. Circle the correct answer to each question on this exam and then use a pencil to transfer your answer to each question to the mark-sense form provided. Be sure to mark your name and student ID on the mark-sense form.

1. The units of *k* for a certain reaction rate constant are $M^{-4}s^{-1}$. What is the overall order of the reaction?

A. Second order B. Third order C. Fourth order D. Fifth order

E. More information is needed to determine the overall order of the reaction.

2. Under certain conditions, the reaction below was observed to proceed at a rate of 0.0455 M/s. What is the value (including the sign) of Δ[C]/Δt?

$$2\ A + 3\ B \rightarrow 4\ C$$

A. – 0.182 M/s B. – 0.0455 M/s C. 0.182 M/s D. – 0.0114 M/s E. 0.0455 M/s

3. Bromination of 2-hexene is first order in 2-hexene and first order in Br_2 and has an activation energy of 47 kJ/mol. Which change or changes will decrease the rate of reaction?

$H_3CCH{=}CHCH_2CH_2CH_3(g) + Br_2(g) \rightarrow CH_3CHBrCHBrCH_2CH_2CH_3(g)$

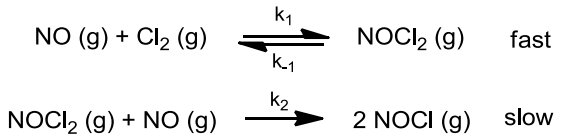
A. Decreasing the concentration of Br_2
B. Increasing the temperature
C. Increasing the concentration of $CH_3CHBrCHBrCH_2CH_2CH_3$
D. Both A and C decrease the rate
E. None of these changes decrease the rate.

4. Which statement is or statements are *correct*?

A. A catalyst speeds up a chemical reaction by changing the mechanism
B. A catalyst is not altered by the reaction and therefore does not participate in the reaction
C. A catalyst lowers the energy of the products and the reactants
D. A and C are correct
E. None of these statements is correct.

Name_____

5. This mechanism has been proposed for the reaction of nitrogen monoxide with chlorine gas:



Assuming that the first step in the mechanism is an equilibrium, derive the rate law for the mechanism; the correct rate law is:

A. rate = $k_2[NOCl_2][NO]$ B. rate = $k_1[NO][Cl_2]$ C. $\text{rate} = \frac{k_1 k_2 [NO][Cl_2]}{k_{-1}}$

D. $\text{rate} = \frac{k_1 k_2 [NO]^2 [Cl_2]}{k_{-1}}$ E. rate = $k_1[NO]^2[Cl_2]$

6. Which statement is *correct*?

A. The portion of the enzyme that the substrate binds to is called the inhibitor site.

B. Enzymes are not as effective as metallic catalysts.

C. All enzymes are more efficient when the temperature is raised.

D. The second step of an enzyme-catalyzed reaction is the binding of the substrate to the enzyme to form the active site.

E. All of these statements (A-D) are incorrect.

Name_____

Part B (57 points) **COMPETENCY QUESTIONS** Answer THREE of the following five questions in the space provided. SHOW YOUR WORK AND WRITE EXPLANATIONS IN FULL SENTENCES.

7. (19 points) This question is about thermodynamics. These two reactions produce acetic acid:

(1) $CH_4(g) + CO_2(g) \rightarrow CH_3COOH(l)$ $\Delta H° = -16.2$ kJ/mol

(2) $CH_3OH(g) + CO(g) \rightarrow CH_3COOH(l)$ $\Delta H° = -173.3$ kJ/mol

a. (6 pts) Calculate ΔG° for each reaction using the following thermodynamic data:

Compound	$\Delta H°_f$ (kJ/mol)	$\Delta G°_f$ (kJ/mol)	S° (J/mol·K)
$CH_4(g)$	-74.81	-50.72	186.264
$CO_2(g)$	-393.509	-394.359	213.74
$CH_3COOH(l)$	-484.5	-389.9	159.8
$CH_3OH(g)$	-200.66	-161.96	239.81
$CO(g)$	-110.525	-137.168	197.674

b. (4 pts) Which reaction would you choose as a commercial method for producing acetic acid at standard conditions? Explain.

c. (6 pts) At what temperature does the reaction in part b shift from product-favored to reactant-favored?

d. (3 pts) What assumptions did you make to determine the temperature in part c?

Name_____

8. (19 points) This question involves calculating equilibrium concentrations. At a temperature of 1297 K, the elements $H_2(g)$ and $Br_2(g)$ react to form HBr(g) and chemical equilibrium is established. The equilibrium constant $K_P = 1.6 \times 10^{-5}$.

a. (2 pts) Write the balanced equation for the equilibrium reaction.

b. (4 pts) Write the equilibrium-constant expression, K_c, for the reaction, including the value of the equilibrium constant.

c. (13 pts) If 1.0 mol $H_2(g)$ and 1.0 mol $Br_2(g)$ are sealed in a 10.0-L flask and heated to 1297 K, calculate the equilibrium concentrations of $H_2(g)$, $Br_2(g)$, and HBr(g). Show your work clearly.

$[H_2]$ = _____

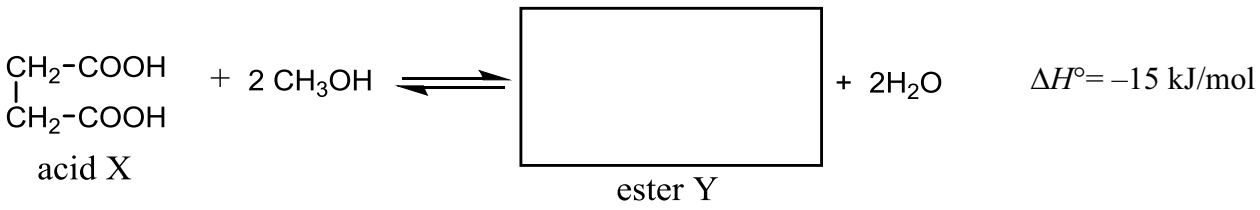
$[Br_2]$ = _____

[HBr] = _____

Name_____

9. (19 points) This question is about chemical equilibrium and reactions involving esters. Esters are often used as artificial flavorings and fragrances. Esters are usually prepared by reacting a carboxylic acid and an alcohol. Determining the equilibrium constant, K_c, for an esterification reaction is an important first step in ensuring an efficient preparation.

Acid **X** reacts with methanol to form ester **Y** according to this equation.



acid X

ester Y

To prepare ester Y, 0.25 mol of **X** and 0.34 mol of methanol were dissolved in tetrahydrofuran and allowed to reach equilibrium in the presence of a small amount of concentrated sulfuric acid. The equilibrium mixture contained 0.13 mol of ester **Y**.

a. (3 pts) Draw the structure of ester Y in the box above.

b. (3 pts) Using **X** to represent the acid and **Y** to represent the ester, write an expression for the equilibrium constant, K_c, for this reaction.

c. (6 pts) Calculate the number of moles of **X**, the number of moles of methanol, and the number of moles of water in the equilibrium mixture.

d. (4 pts) Calculate the value of K_c for this reaction. (The total volume of the reaction mixture at equilibrium is 1.00 L)

e. (3 pts) Explain the effect of increasing the temperature on the value of K_c

Name_____

10. (19 points) This question is about Beer's law and the Fenton Kinetics experiment. Beer's law is given mathematically as $A = \varepsilon \ell c$. You are studying the kinetics of the reaction of a dye with hydrogen peroxide, H_2O_2, in aqueous solution.

a. (6 pts) You are given a stock solution of a dye with a concentration of 1.00 mmol/L. The absorbance of this solution is approximately 2. You have a graduated pipet that can measure volumes up to 10.0 mL and several 10.0- mL volumetric flasks. Describe in detail how you would prepare the solutions for a Beer's law plot. Remember that it is difficult to accurately measure absorbance values above 1.0.

b. (6 pts) The slope of your Beer's law plot is 1.75 L/mmol. When you started a reaction of the dye with hydrogen peroxide (which decolorizes the dye) the absorbance was 0.974; after 10.0 s the absorbance had changed to 0.898. You know that in the 10.0-s period less than 2% of the reactant dye was converted to product. Calculate the initial rate of reaction; express your result in M s^{-1}.

c. (4 pts) Several other measurements of initial rates gave the results in this table.

Experiment Number	Initial [dye] (M)	Initial [H_2O_2] (M)	Initial rate (M s^{-1})
1	2.0×10^{-4}	2.0×10^{-4}	3.4×10^{-6}
2	2.0×10^{-4}	4.0×10^{-4}	6.9×10^{-6}
3	4.0×10^{-4}	4.0×10^{-4}	1.4×10^{-5}

Determine the order of reaction with respect to dye and with respect to H_2O_2.

Order with respect to dye: _____ Order with respect to H_2O_2: _____

d. (3 pts) Write the rate law (do not calculate the numerical value of the rate constant).

Name_____

11. (19 pts) This question is about equilibrium constants. Tin can be released from its oxide by reaction with CO according to Reaction I below.

I. $SnO_2(s) + 2\ CO(g) \rightleftharpoons Sn(s) + 2\ CO_2(g)$

a. (4 pts) Write the expression for the equilibrium constant K_c for Reaction I.

b. (6 pts) Calculate K_c at 500 K for Reaction I using data given below for Reactions II and III.

II. $SnO_2(s) + 2\ H_2(g) \rightleftharpoons Sn(s) + 2\ H_2O(g)$ $K_c = 8.12$ at 500 K

III. $H_2(g) + CO_2(g) \rightleftharpoons H_2O(g) + CO(g)$ $K_c = 0.771$ at 500 K

c. (2 pts) Calculate K_P at 500 K for Reaction I.

d. (4 pts) For each change below indicate whether the equilibrium (Reaction **I**) shifts and in which direction.

(i) CO(g) is added to the constant-volume system.

(ii) Sn(s) is added to the constant volume system.

e. (3 pts) K_c for reaction I is 0.122 at 298 K. Is reaction I exothermic or endothermic? Explain clearly how you decided.

Part C (25 points) **MASTERY QUESTIONS** Answer ONE of the next two questions in the space provided. SHOW ALL YOUR WORK AND WRITE EXPLANATIONS IN COMPLETE SENTENCES.

12. (25 points) This question is about enzyme kinetics. Enzyme catalyzed reactions are characterized by the formation of an enzyme-substrate complex (ES) in a fast reversible step. ES undergoes a second slower step to form products and regenerate the free enzyme. The equation below describes the rate of an enzymatic reaction:

$$v = \frac{k_2[E]_T[S]}{K_M + [S]}$$

where v is the reaction rate, $[E]_T$ is the total enzyme concentration, [S] is the substrate concentration and K_M is the Michaelis constant (K_M can be written using the rate constants in the two step mechanism as $K_M=(k_{-1}+k_2)/k_1$). V_{max} is the maximum rate of the reaction and can be calculated as $V_{max}=k_2[E]_T$

a. (3 pts) On the axes below draw a plot of reaction rate versus substrate concentration. Show V_{max} on your graph.

b. (3 pts) Determine the order in substrate of the enzyme-catalyzed reaction at very high substrate concentrations. Explain.

c. (3 pts) Determine the order in substrate at low substrate concentrations. Explain.

question continues on next page

Name_____

d. (6 pts) The rate of an enzymatic reaction is measured with three substrates. From the experiments, the K_M and k_2 values were determined for each substrate.

	Compound A	Compound B	Compound C
K_M (mM)	31	15	25
k_2 (s^{-1})	0.06	0.14	2.80

(i) Which compound A, B or C reacts with the highest rate at very high substrate concentration ([S]>>K_M)? (Assume all reactions have the same total enzyme concentration.) Explain.

(ii) Which compound A, B, or C reacts with the highest rate at low substrate concentrations ([S]<<K_M)? (Assume all reactions have the same total enzyme concentration.) Explain.

e. (4 pts) An enzyme has a V_{max} of 150 μmoles product formed per minute. The K_M for the major substrate of the enzyme is 1.5 mM. Calculate the reaction rate at a substrate concentration of 3.0 mM.

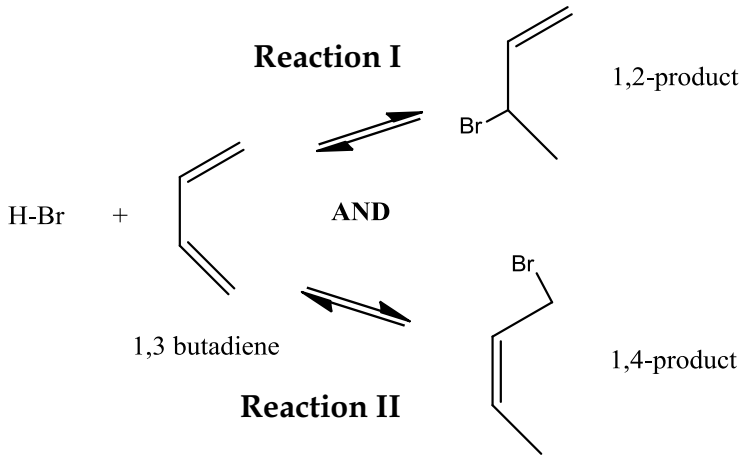
f. (3 pts) If the enzyme-catalyzed reaction is carried out with the substrate concentration initially 1000 times greater than the K_M, the amount of product formed after 9 minutes is 12 μmol. In a separate experiment one-third as much enzyme and twice as much substrate had been combined. How long would it take for the same amount of product (12 μmol) to be formed?

g. (3 pts) Under physiological conditions, the cellular concentration of most substrates is below the K_M for that substrate. Explain why you think this would be biochemically advantageous for the cell.

Name_____

13. (25 points) This question is about both kinetics and thermodynamics.

When1,3-butadiene reacts with HBr two different reactions occur and two different products are formed. These two reactions are shown at the right.



Reaction I forms a 1,2-product where H adds to the first C atom and Br adds to the second C atom in the butadiene chain. For **Reaction I** $\Delta G° = -243$ kJ/mol.

Reaction II forms a 1,4-product where H adds to the first C atom and Br adds to the fourth C atom in the butadiene chain. For **Reaction II** $\Delta G° = -353$ kJ/mol.

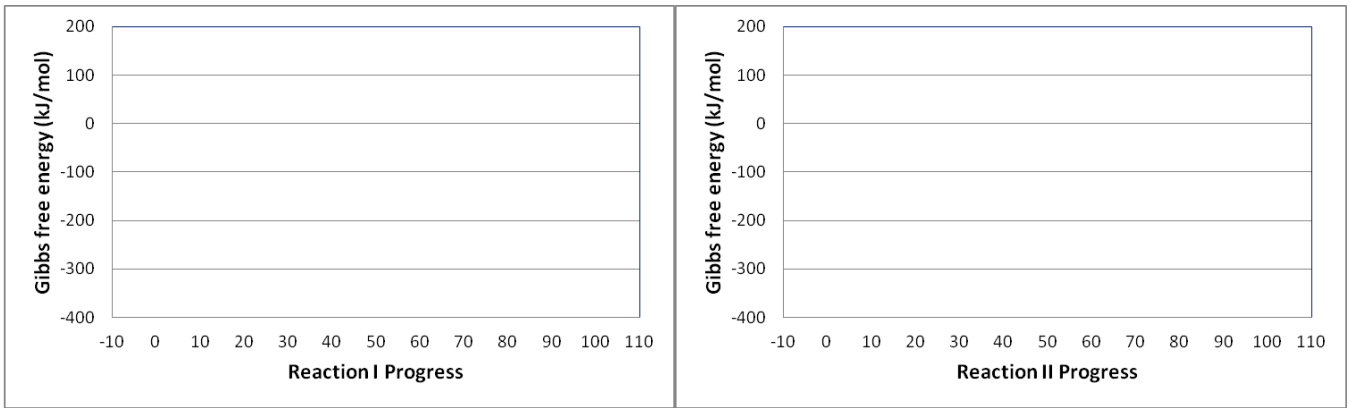
For both reactions the mechanism is similar; it involves these two steps. (All species are gases.)

Step 1 (slow): HBr + 1,3-butadiene n butadieneH^+ + Br^-

Step 2 (fast): butadieneH^+ + Br^- n 1,2-product or 1,4-product

Step 1 of the mechanism is the same for both reactions; it has $\Delta G° = 60$ kJ/mol.
For **Reaction I**, in *step 2* of the mechanism, the Gibbs free energy of activation is 41 kJ/mol.
For **Reaction II**, in *step 2* of the mechanism the Gibbs free energy of activation is 87 kJ/mol

a. (8 pts) Energy versus reaction progress diagrams can be drawn for Gibbs free energy as well as for potential energy. On the axes below, draw a graph of Gibbs free energy (*G*) versus reaction progress for Reaction I on the left and Reaction II on the right. Note that the scales on both axes are the same for the two diagrams. Your graphs should be roughly to scale on both axes, based on the data already given. Place the reactants, HBr + 1,3-butadiene, at zero Gibbs free energy.



b. (2 pts) Identify all intermediates in the reaction mechanism and write their formulas here.

question continues on next page

Name_____

c. (2 pts) Which reaction is slower at room temperature, Step 2 of Reaction I or Step 2 of Reaction II? Explain

d. (2 pts) For Reaction I, what is the sign of $\Delta S°$? Explain how you know.

e. (2 pts) For Reaction II, what is the sign of $\Delta S_{universe}$? Explain how you know.

f. (3 pts) Consider the reaction of the 1,2-product, $CH_3CHBrCH_2CH_3$ to form the 1,4-product, $CH_2BrCH_2CH_2CH_3$. Determine whether this reaction is product-favored or not and explain your choice.

g. (3 pts) When 1,3-butadiene reacts with HBr at low temperatures one obtains mostly 1,2-product. Explain clearly how this can happen. It will probably help to look at the G versus reaction progress diagrams you drew on the previous page and at your answers to some of the questions on this page.

h. (3 pts) When 1,3-butadiene reacts with HBr at high temperatures one obtains mostly 1,4-product. Explain clearly how this can happen. It will probably help to look at the G versus reaction progress diagrams you drew on the previous page and at your answers to some of the questions on this page.

CHEMISTRY 104-5
Dr. Zelewski
EXAM 2
Friday, March 7, 2014

Name _____

Sec _____ TA _____

INSTRUCTIONS:

1. **DO NOT SEPARATE THE PAGES OF THE EXAM.**
2. This exam consists of 7 pages, including this cover sheet. Constants are at the top of page 2 and a periodic table is on page 7. LOOK THROUGH THE EXAM NOW to make sure you have all 7 pages. **PRINT your name at the top of each page.**
3. **ANSWERS TO THE MULTIPLE CHOICE QUESTIONS MUST BE ENTERED ON THE SCANTRON FORM**. **Only the scantron form will be graded.** Circle your answer in the exam so you have a record of your answer.
4. The scantron form is machine-scored and **must be filled out using a #2 PENCIL**. PRINT your last name, first name and middle initial (MI) on the scantron form, then fill in the circles corresponding to the letters in your name. Write your student ID number under Identification Number, and fill in the circles. **Circles must be filled in completely.** If you decide to change an answer on the scantron form, make sure to completely erase your previous answer.
5. On questions other than multiple choice questions that involve calculations, you must clearly show all of the steps in the calculation. **NO CREDIT WILL GIVEN FOR NUMERICAL VALUES THAT DO NOT SHOW HOW THE NUMBER WAS DETERMINED.**
6. You have up to 50 minutes to complete the exam. Budget your time. First, look over the entire exam; plan your work; then begin.
7. Good luck!

II.	_____/6
III.	_____/8
IV.	_____/8
V.	_____/7
VI.	_____/7
SCORE	_____/36

Name _____

R = 8.314 J/K·mol	R = 0.08206 L·atm/K·mol	K = °C + 273

I. (39 points) Multiple choice. Each question is worth 3 points. There is **one** best response to each question. Circle your answer, then fill in the scantron form. **THE ANSWERS ON THE SCANTRON FORM ARE THE ONLY ANSWERS THAT WILL BE GRADED.**

1. The units of a rate constant, k, are $M^{-3}s^{-1}$. What is the overall order of the reaction?

   A. second order
   B. third order
   C. fourth order
   D. fifth order
   E. More information is needed to determine the overall order of the reaction.

2. Under certain conditions, the reaction, $A + 2\ B \rightarrow 3C$, below was observed to proceed at a rate of 0.0375 M/s. What is the value (including the sign) of $\Delta[C]/\Delta t$?

   A. 0.0375 M/s B. –0.0375 M/s C. 0.113 M/s D. –0.113 M/s E. 0.0125 M/s

3. Chlorination of 2-pentene is first order in 2-pentene and first order in Cl_2 and has an activation energy of 55 kJ/mol. Which change(s) will **decrease** the rate of reaction?

   $$H_3CCH{=}CHCH_2CH_3(g) + Cl_2(l) \rightarrow CH_3CHClCHClCH_2CH_3(l)$$

   A. Increasing the concentration of Cl_2.
   B. Increasing the temperature.
   C. Adding a catalyst such as UV light.
   D. Both increasing the concentration of Cl_2 and adding a catalyst will decrease the rate.
   E. None of these changes will decrease the rate.

4. The rate law for the reaction mechanism shown below is

   $$ICl + H_2 \xrightarrow{k_1} HI + HCl \quad \textbf{slow}$$
   $$HI + ICl \underset{k_{-2}}{\overset{k_2}{\rightleftharpoons}} HCl + I_2 \quad \textbf{fast}$$

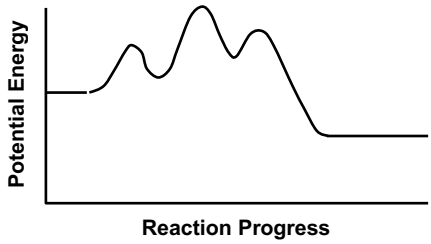
   A. rate = $k_1[ICl][H_2]$
   B. rate = $k_1[HI][HCl]$
   C. rate = $k_2[HI][ICl]$
   D. rate = $k_2[HCl][I_2]$
   E. rate = $k_1k_2[ICl]^2[H_2]$

5. Which of the following statements is **true** regarding the mechanism in question 4?

   A. HI is a catalyst.
   B. HI is an intermediate.
   C. HCl is a catalyst.
   D. HCl is an intermediate.
   E. ICl is a catalyst.

Name _____

6. The reaction progress diagram for the reaction $A + 3\ B \rightarrow 2\ C$ is shown below. Which of the following statements for this reaction is **true**?



A. The reaction mechanism has 2 elementary steps.
B. The slow step in the mechanism is step 1.
C. The rate law is rate = $k[A][B]^3$.
D. The reaction is endothermic.
E. None of the above. (All of the statements above are false.)

7. Which of the statements below is/are **false**?

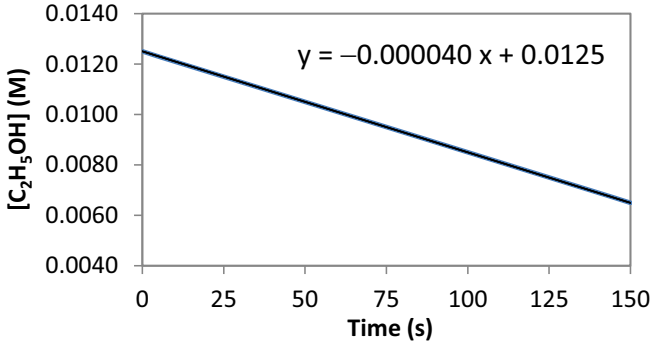
(1) A catalyst speeds up a chemical reaction by changing the mechanism.
(2) A catalyst is not altered by the reaction and therefore does not participate in the reaction.
(3) A catalyst lowers the energy of the products and the reactants.

A. Only statement (1).
B. Only statement (2)
C. Only statement (3).
D. Statements (2) and (3).
E. None of the above. (All of the statements are true.)

8. The decomposition of ethanol on an alumina surface was studied at 600°C.

$$C_2H_5OH(g) \rightarrow C_2H_4(g) + H_2O(g)$$

The data obtained is plotted on the graph to the right. What is the rate law for this reaction?



A. rate = 4.0×10^{-5} M/s
B. rate = 0.0125 M/s
C. rate = $4.0 \times 10^{-5}\ s^{-1}\ [C_2H_5OH]$
D. rate = $0.0125\ s^{-1}\ [C_2H_5OH]$
E. rate = $4.0 \times 10^{-5}\ M^{-1}s^{-1}\ [C_2H_5OH]^2$

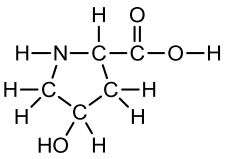
9. Initial rate data for the reaction, $A + B \rightarrow 2\ C$, is given below. This reaction is

$[A]_o$	$[B]_o$	initial rate (M/s)
0.0010	0.0010	7.0×10^{-6}
0.0010	0.0020	14×10^{-6}
0.0020	0.0020	56×10^{-6}

A. zero order in A and first order in B.
B. first order in A and zero order in B.
C. first order in A and first order in B.
D. second order in A and first order in B.
E. first order in A and second order in B.

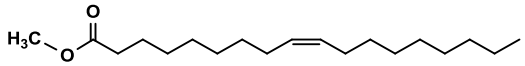
Name _____

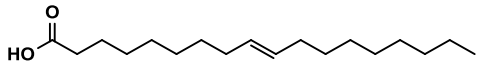
10. Hydroxyproline is a nonstandard amino acid made by a post translational modification of proline. The structure of hydroxyproline is shown to the right. Hydroxyproline is a(n) ___ amino acid.

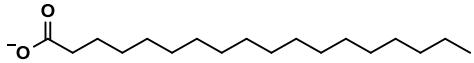


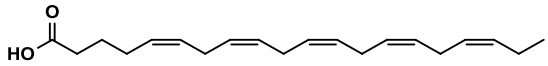
A. nonpolar B. polar, but uncharged C. acidic D. basic

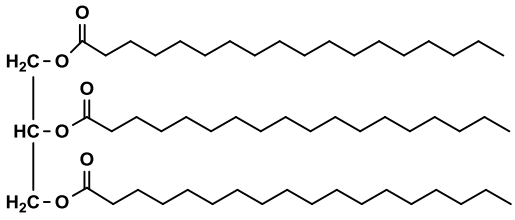
11. Which structure below is biodiesel?

A. 

B. 

C. 

D. 

E. 

12. Which of the following statements is **false**?

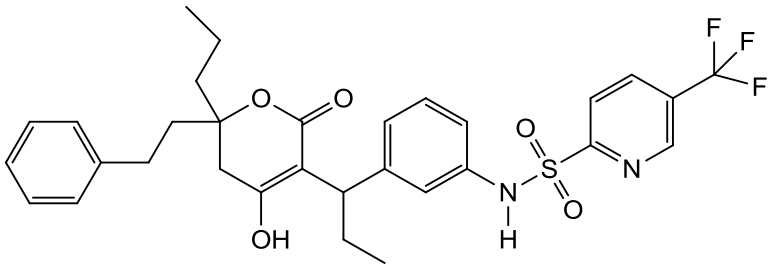
A. Enantiomers are molecules that are mirror images of one another that are not superimposable.
B. Enantiomers have identical melting points.
C. Enantiomers have the same molecular formula.
D. Enantiomers of a drug have the same physiological effect.
E. None of the above. (All of the statements are true.)

13. The primary structure of a protein is determined by

A. interactions between side chains of the amino acids.
B. interactions between two or more polypeptides.
C. hydrogen bonding between a carbonyl oxygen and an amide hydrogen.
D. the identity and order of the amino acids.
E. the overall shape of the protein resulting from complex turns and folds.

II. (6 points) The structure of Tipranavir, a protease inhibitor used to treat HIV, is shown below.

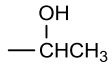
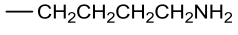
1. (4 pts) Place an asterisk (*) next to each chiral carbon atom in this structure.



2. (2 pts) How many stereoisomers are possible for this molecule? _____

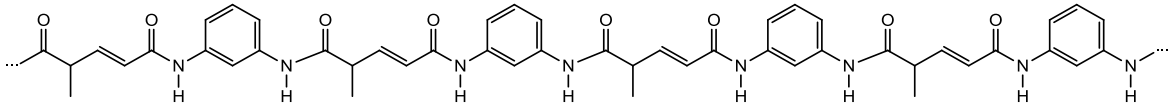
Name _____

III. (8 points) Partial hydrolysis of a tripeptide yields Thr-Lys and Gly-Thr. **SHOWING ALL ATOMS AND BONDS**, draw the structural formula of the tripeptide as it would exist at a pH of 7.4. The side chains for threonine, lysine and glycine are given below.

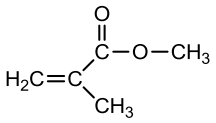
Thr:  Lys:  Gly: 

IV. (8 points) Answer the following questions by drawing any correct structural formula(s). Do not use MasteringChemistry style condensed formulas such as $CH_3C(O)CH_3$.

1. (4 pts) Draw the structural formula(s) of the monomer(s) that would result if the polymer below was completely hydrolyzed.



2. (4 pts) Plexiglass is a polymer of methyl methacrylate, shown to the right. Draw a segment of the polymer that shows at least 3 repeating units.



Name _____

V. (7 points) DDT is an insecticide that was banned from use in the U.S. in 1973. If a 20-liter drum of DDT was spilled into a pond, resulting in a concentration of 8.75×10^{-5} M DDT, how long would it take for the concentration to decline to 1.40×10^{-5} M DDT, a concentration considered safe in mammals? The decomposition of DDT is a first order process with a half-life of 56.0 days. **CLEARLY SHOW HOW YOU DETERMINE YOUR ANSWER.**

VI. (7 points) The net ionic equation for the reaction between $KMnO_4$ and NaC_2O_4 is given below:

$$2\ MnO_4^-(aq) + 5\ C_2O_4^{2-}(aq) + 16\ H^+(aq) \rightarrow 2\ Mn^{2+}(aq) + 10\ CO_2(g) + 8\ H_2O(l)$$

A 0.5046 gram sample containing an unknown amount of $Na_2C_2O_4$ (MW 134.0 g/mol) was dissolved in 30 mL of deionized water in a 250-mLflask. 15 mL of 3.0 M H_2SO_4 was added to the flask and the solution was heated to 80°C. The solution required 30.74 mL of 0.02564 M $KMnO_4$ (MW 158.0 g/mol) to reach the endpoint in a titration. What is the percent by mass of $Na_2C_2O_4$ in the sample? Report your answer using 4 significant figures. **CLEARLY SHOW HOW YOU DETERMINE YOUR ANSWER.**

THE END ☺

CHEMISTRY 104-5
Dr. Zelewski
EXAM 4
Friday, April 25, 2014

Name _____

Sec _____ TA _____

INSTRUCTIONS:

1. **DO NOT SEPARATE THE PAGES OF THE EXAM.**
2. This exam consists of 7 pages, including this cover sheet. Constants are at the top of page 2 and a periodic table is on page 7. LOOK THROUGH THE EXAM NOW to make sure you have all 7 pages. **PRINT your name at the top of each page.**
3. **ANSWERS TO THE MULTIPLE CHOICE QUESTIONS MUST BE ENTERED ON THE SCANTRON FORM**. **Only the scantron form will be graded. Circle your answer in the exam so you have a record of your answer.**
4. The scantron form is machine-scored and **must be filled out using a #2 PENCIL**. PRINT your last name, first name and middle initial (MI) on the scantron form, then fill in the circles corresponding to the letters in your name. Write your student ID number under Identification Number, and fill in the circles. **Circles must be filled in completely.** If you decide to change an answer on the scantron form, make sure to completely erase your previous answer.
5. On questions other than multiple choice questions, you must clearly show how you obtained your answer. **NO CREDIT WILL GIVEN FOR NUMERICAL VALUES THAT DO NOT SHOW HOW THE NUMBER WAS DETERMINED.**
6. You have up to 50 minutes to complete the exam. Budget your time. First, look over the entire exam; plan your work; then begin.
7. Good luck!

II.	_____/8
III.	_____/10
IV.	_____/12
SCORE	_____/30

Name _____

R = 8.314 J/K·mol	R = 0.08021 L·atm/K·mol	$K_w = 1.0 \times 10^{-14}$ at 25°C	$N_A = 6.022 \times 10^{23}$/mol

I. (45 points) Multiple choice. Each question is worth 3 points. There is **one** best response to each question. Circle your answer, then fill in the scantron form. **THE ANSWERS ON THE SCANTRON FORM ARE THE ONLY ANSWERS THAT WILL BE GRADED.**

1. Which solution has the **highest** pH?

   A. 1.0 M KOC_6H_5 $K_a(HOC_6H_5) = 1.3 \times 10^{-10}$
   B. 1.0 M CsF $K_a(HF) = 6.8 \times 10^{-4}$
   C. 1.0 M NaClO $K_a(HClO) = 6.8 \times 10^{-8}$
   D. 1.0 M KCH_3COO $K_a(CH_3COOH) = 1.8 \times 10^{-5}$
   E. 1.0 M KBrO $K_a(HBrO) = 2.5 \times 10^{-9}$

2. What is the pH of a 100.0 mL solution consisting of 0.020 M HClO and 0.060 M NaClO? $K_a(HClO) = 6.8 \times 10^{-8}$.

   A. 6.16
   B. 6.69
   C. 7.09
   D. 7.64
   E. 8.06

3. Which solution will produce a **buffer** with a pH < 7?

   A. 0.1 M HCN/0.1 M NaCN $K_a(HCN) = 3.3 \times 10^{-10}$
   B. 0.1 M H_2CO_3/0.1 M $NaHCO_3$ $K_a(H_2CO_3) = 4.3 \times 10^{-7}$
   C. 0.1 M NH_4Cl/0.1 M NH_3 $K_a(NH_4^+) = 5.6 \times 10^{-10}$
   D. 0.1 M CH_3NH_2/0.1 M CH_3NH_3Cl $K_a(CH_3NH_3^+) = 2.0 \times 10^{-11}$
   E. 0.1 M HNO_3/0.1 M $NaNO_3$ $K_a(HNO_3) = 20$

4. Which species does **not** have a conjugate acid?

   A. N_2 B. NH_3 C. ClO_4^- D. O^{2-} E. HSO_4^-

5. Which salt gives a solution with a pH ≤ 7 when dissolved in water at 25 °C? You may find the ionization constants below helpful in answering this question.

   $K_a(HNO_2) = 4.5 \times 10^{-4}$ $K_a(NH_4^+) = 5.6 \times 10^{-10}$ $K_a(HBrO) = 2.5 \times 10^{-9}$

   A. NH_4NO_2
   B. KCl
   C. NH_4BrO
   D. NH_4NO_2 and KCl
   E. NH_4NO_2, KCl, and NH_4BrO

6. The pH of a 0.065 M solution of $Ba(OH)_2$ is

   A. 0.89 B. 13.11 C. 13.87 D. 12.81 E. 1.19

Name _____

7. Addition of nitric acid, HNO_3, to a saturated solution of lead(II) hydroxide, $Pb(OH)_2$, in water would cause

   A. the concentrations of both Pb^{2+} and OH^- to decrease.
   B. the concentrations of both Pb^{2+} and OH^- to increase.
   C. no change in the solubility of $Pb(OH)_2$.
   D. the solubility of $Pb(OH)_2$ to decrease.
   E. the OH^- concentration to decrease and the Pb^{2+} concentration to increase.

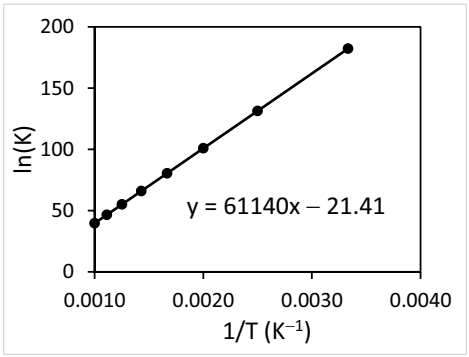
8. In the following reaction: $Cu^{2+}(aq) + 6\ NH_3(aq) \rightleftharpoons Cu(NH_3)_6^{2+}(aq)$, NH_3 is (a)

   A. Bronsted-Lowry acid.
   B. Bronsted-Lowry base.
   C. Lewis acid.
   D. Lewis base.
   E. amphiprotic.

9. The following reaction: $CH_3NH_3^+(aq) + F^-(aq) \rightleftharpoons CH_3NH_2(aq) + HF(aq)$ is ($K_b(CH_3NH_2) = 4.4 \times 10^{-4}$ and $K_a(HF) = 6.8 \times 10^{-4}$)

   A. reactant favored because $CH_3NH_3^+$ is a stronger acid than HF.
   B. product favored because $CH_3NH_3^+$ is a stronger acid than HF.
   C. reactant favored because HF is a stronger acid than $CH_3NH_3^+$.
   D. product favored because HF is a stronger acid than $CH_3NH_3^+$.
   E. neither a reactant favored or product favored reaction.

10. The value of the equilibrium constant, K, for the reaction, $2\ PCl_3(g) + O_2(g) \rightleftharpoons 2\ POCl_3(g)$ was determined at several temperatures and the graph to the right was prepared. What is $\Delta H°$ for the reaction?



   A. 178.0 J
   B. 61,140 J
   C. –21.41 J
   D. –7354 J
   E. –508.3 kJ

11. Arsenic acid is a triprotic acid with $K_{a1} = 4.9 \times 10^{-3}$, $K_{a2} = 8.9 \times 10^{-8}$ and $K_{a3} = 1.3 \times 10^{-12}$. Which of the following chemical equilibria corresponds to the equilibrium constant K_{b2}?

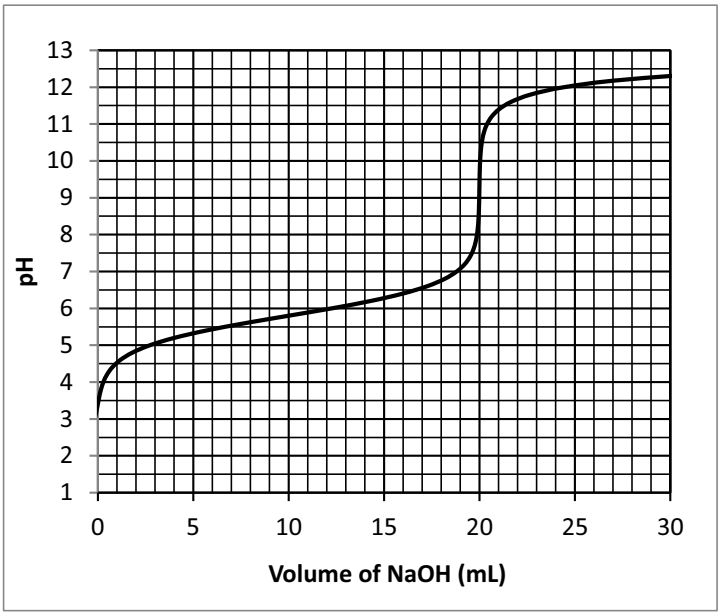
   A. $H_2AsO_4^-(aq) + H_2O(l) \rightleftharpoons H_3AsO_4(aq) + OH^-(aq)$
   B. $HAsO_4^{2-}(aq) + H_3O^+(aq) \rightleftharpoons H_2AsO_4^-(aq) + H_2O(l)$
   C. $H_2AsO_4^-(aq) + OH^-(aq) \rightleftharpoons HAsO_4^{2-}(aq) + H_2O(l)$
   D. $HAsO_4^{2-}(aq) + OH^-(aq) \rightleftharpoons AsO_4^{3-}(aq) + H_2O(l)$
   E. $HAsO_4^{2-}(aq) + H_2O(l) \rightleftharpoons H_2AsO_4^-(aq) + OH^-(aq)$

12. If the ratio of acid to base increases by a factor of 10 in a buffer solution, the pH of the buffer

   A. increases by 10.
   B. increases by 1.
   C. decreases by 10.
   D. decreases by 1.
   E. remains unchanged.

Name _____

Questions 13 through 15 refer to the graph below for the titration of a weak acid with 0.10 M NaOH.



13. What is the pH at the equivalence point?

A. 5.30
B. 5.80
C. 6.30
D. 9.20
E. 12.30

14. What is the pK_a of the acid?

A. 3.40
B. 5.30
C. 5.80
D. 6.30
E. 9.20

15. Which of the indicators listed below can be used to determine the endpoint in this titration?

A. thymol blue, $pK_a = 8.9$
B. bromothymol blue, $pK_a = 7.1$
C. alizarin yellow, $pK_a = 11.0$
D. methyl orange, $pK_a = 3.5$
E. chlorophenol red, $pK_a = 6.0$

Name _____

II. (8 points) Short Answer.

1. (3 pts) Write the balanced chemical reaction that corresponds to the K_{sp} for iron(II) phosphate, $Fe_3(PO_4)_2$. Include states in your reaction.

____/3

2. (5 pts) When you hold your breath, carbon dioxide gas is trapped in your body. Does this increase or decrease your blood pH? **Explain your answer using <u>complete sentences</u>. Include chemical reactions as part of your explanation. Include states in your reaction(s).**

____/5

/8

III. (10 points) A beaker contains 500.0 mL of a buffer solution that is 0.12 M in benzoic acid, $HC_7H_5O_2$, and 0.10 M in sodium benzoate, $NaC_7H_5O_2$. 15.0 mL of 0.85 M NaOH is added to the buffer solution. What is the pH of the solution ***AFTER*** the NaOH is added? The acid dissociation constant of benzoic acid, K_a, is 6.3×10^{-5}. **CLEARLY SHOW HOW YOU DETERMINE YOUR ANSWER.**

/10

Name _____

IV. (12 points) 50.0 mL of 0.0850 M chloroacetic acid, $ClCH_2COOH$, is titrated with 0.132 M NaOH. Calculate the pH at the equivalence point in the titration. ($K_a(ClCH_2COOH) = 1.4 \times 10^{-3}$) **CLEARLY SHOW HOW YOU DETERMINE YOUR ANSWER.**

/12

THE END

CHEMISTRY 104-5
Dr. Zelewski
FINAL EXAM
Wednesday, May 14, 2014
10:05 a.m.– 12:05 p.m.

Name _____

Sec _____ TA _____

INSTRUCTIONS:

1. **DO NOT SEPARATE THE PAGES OF THE BOOKLETS.**

2. This exam consists of three components:
   - This booklet containing 50 multiple choice questions
   - One booklet containing constants, a periodic table and blank pages.
   - One scantron form.

3. **PRINT your name, section number, and TA's name on the cover page of each booklet.**

4. The scantron form is machine-scored and **must be filled out using a #2 PENCIL**.

5. PRINT your last name, first name and middle initial (MI) on the scantron form, then fill in the circles corresponding to the letters in your name. Write your student ID number under Identification Number, and fill in the circles. **Circles must be filled in completely.**

6. **ANSWERS TO THE MULTIPLE CHOICE QUESTIONS MUST BE FILLED IN ON THE SCANTRON FORM.** Circles must be filled in completely in order to be scored. Do not make any stray marks on the form. If you decide to change an answer on the scantron form, make sure to completely erase your previous answer. **Each question has one best answer.**

7. You have up to 2 hours to complete the exam. When you are finished with the exam, turn in both booklets, the scantron form, and your 8½" × 11" paper with notes.

8. Good luck!

Name _____

(This page is intentionally left blank.)

Name _____

Questions 1 and 2 refer to the balanced reaction below:

$$8\ H^+(aq) + Cr_2O_7^{2-}(aq) + 3\ SO_3^{2-}(aq) \rightarrow 2\ Cr^{3+}(aq) + 3\ SO_4^{2-}(aq) + 4\ H_2O(aq)$$

1. How many electrons are transferred in the above reaction?

   A. 3 B. 4 C. 5 D. 6 E. 12

2. What is the oxidizing agent in the above reaction?

   A. $Cr_2O_7^{2-}$ B. SO_3^{2-} C. Cr^{3+} D. SO_4^{2-} E. H_2O

Questions 3, 4 and 5 refer to the half cells below that are used to construct a voltaic cell:

Half cell #1: A nickel metal electrode in a solution of 0.0250 M $Ni(NO_3)_2$.
Half cell #2: A platinum electrode in a solution of 0.050 M $Fe(NO_3)_2$ and 0.25 M $Fe(NO_3)_3$.

3. What is the balanced overall reaction for the cell?

   A. $2Fe^{2+}(aq) + Ni^{2+}(aq) \rightarrow 2Fe^{3+}(aq) + Ni(s)$
   B. $Fe^{2+}(aq) + Ni^{2+}(aq) \rightarrow Fe^{3+}(aq) + Ni(s)$
   C. $2Fe^{3+}(aq) + Ni(s) \rightarrow 2Fe^{2+}(aq) + Ni^{2+}(aq)$
   D. $Fe^{3+}(aq) + Ni(s) \rightarrow Fe^{2+}(aq) + Ni^{2+}(aq)$
   E. None of the above.

4. What is the standard cell potential, E°_{cell}?

   A. +1.82 V
   B. +1.05 V
   C. +0.49 V
   D. –1.05 V
   E. +1.26 V

5. Which of the following statements is **true** regarding this cell?

   A. Pt is the anode and electrons are flowing from the Pt to Ni.
   B. Ni is the anode and electrons are flowing from Ni to Pt.
   C. Pt is the cathode and electrons are flowing from Pt to Ni.
   D. Ni is the cathode and electrons are flowing from Ni to Pt.

6. What is the equilibrium constant, K, for the reaction below at 25°C?

$$Cl_2(g) + 2Br^-(aq) \rightleftharpoons 2Cl^-(aq) + Br_2(l)$$

   A. 1.2×10^{-10}
   B. 8.7×10^{9}
   C. 1.3×10^{41}
   D. 9.3×10^{4}
   E. 9.9

Name _____

7. What is the oxidation number of sulfur in SO_4^{2-}?

   A. –6 B. –7 C.–8 D. +6 E. +7

8. Which of the following metals: Cu, Sn, Zn and Al, is/are capable of reducing Fe^{2+} to Fe(s)?

   A. Cu
   B. Sn, Zn and Al
   C. Zn and Al
   D. Cu and Sn
   E. Cu, Sn, Zn and Al

9. Consider the following standard reduction potentials in acid solution:

   $Cr^{3+} + 3e^- \rightarrow Cr$ $E° = –0.74$ V
   $Co^{2+} + 2e^- \rightarrow Co$ $E° = –0.28$ V
   $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$ $E° = +1.51$ V

   The **strongest** reducing agent listed above is

   A. Cr^{3+} B. Cr C. Mn^{2+} D. Co E. MnO_4^-

10. The standard cell potential, E°, of a voltaic cell constructed using the reaction below is 0.76 V:

    $$Zn(s) + 2H^+(aq) \rightarrow Zn^{2+}(aq) + H_2(g)$$

    With $P_{H_2} = 1.0$ atm and $[Zn^{2+}] = 1.0$ M, the cell potential is 0.66 V. The concentration of H^+ in the cathode compartment is _____ .

    A. 2.0×10^{-2} M
    B. 4.2×10^{-4} M
    C. 1.4×10^{-1} M
    D. 4.9×10^{1} M
    E. 1.0×10^{-12} M

11. In the electrolysis of an aqueous solution of $Ca(NO_3)_2$,

    A. Ca(*s*) forms at the anode.
    B. Ca(*s*) forms at the cathode.
    C. $H_2(g)$ forms at the anode.
    D. $H_2(g)$ forms at the cathode.
    E. $O_2(g)$ forms at the cathode.

12. A current of 0.80 A was applied to an electrolytic cell containing molten $CdCl_2$ for 2.5 hours. What mass of cadmium metal was deposited?

    A. 3.2×10^{-7} g
    B. 1.2×10^{-3} g
    C. 4.2 g
    D. 8.4 g
    E. 16.8 g

Name _____

13. Which of the following chemical reactions involved in Chemistry 104 demonstrations this semester is an oxidation reduction reaction?

    A. Combustion of hydrogen gas: $H_2(g) + O_2(g) \rightarrow 2\ H_2O(l)$
    B. Detonation of trinitrotoluene:
       $2\ C_7H_5N_3O_6(s) \rightarrow 3\ N_2(g) + 7\ CO(g) + 5\ H_2O(l) + 7C(s) + 2\ H_2O(l)$
    C. Decomposition of nitrogen triiodide: $2\ NI_3(s) \rightarrow N_2(g) + 3\ I_2(s)$
    D. Decomposition of hydrogen peroxide: $2\ H_2O_2(aq) \rightarrow 2\ H_2O(l) + O_2(g)$
    E. All of the above.

14. Which of the following salt solutions: NaF(*aq*), NH_4F(*aq*), and NaCl(*aq*) will have a pH ≥ 7 at 25 °C? You may find the ionization constants below helpful in answering this question: $K_a(HF) = 6.8 \times 10^{-4}$ and $K_a(NH_4^+) = 5.6 \times 10^{-10}$.

    A. Only NaF
    B. NaF and NH_4F
    C. NH_4F and NaCl
    D. NaF and NaCl
    E. NaF, NH_4F, and NaCl

15. Which of the following substances: K_2O, NO_2, KNO_2, will produce a **basic** solution when dissolved in water?

    A. Only K_2O
    B. Only NO_2
    C. Only KNO_2
    D. K_2O and KNO_2
    E. K_2O, NO_2 and KNO_2

16. The local anesthetic, novocaine, is the hydrogen chloride salt of an organic base, procaine.

$$\underset{\text{procaine}}{C_{13}H_{20}N_2O_2(aq)} + HCl(aq) \rightarrow \underset{\text{novocaine}}{HC_{13}H_{20}N_2O_2Cl(aq)}$$

    The K_a of novocaine is 1.4×10^{-9}. What is the pH of a 0.0015 M solution of novocaine?

    A. 4.43
    B. 5.15
    C. 5.34
    D. 5.84
    E. 8.85

17. Which of the following salts: AgBr, $PbCl_2$, $Mg(OH)_2$ and ZnS become(s) more soluble as the pH is lowered?

    A. Only $Mg(OH)_2$
    B. AgBr and $PbCl_2$
    C. $Mg(OH)_2$ and ZnS
    D. AgBr, $PbCl_2$ and ZnS
    E. AgBr, $Mg(OH)_2$ and ZnS

Name _____

18. The pH of 0.010 M H_2SO_4 is

A. less than 1.7
B. equal to 1.7
C. greater than 1.7 and less than 2.0
D. equal to 2.0
E. greater than 2.0

19. 50.0 mL of 0.010 M $AgNO_3$ is added to 50.0 mL of 0.050 M Na_2SO_4. Which of the following statements is **true**? ($K_{sp}(Ag_2SO_4) = 1.5 \times 10^{-5}$)

A. $Q < K_{sp}$. The solution is supersaturated and Ag_2SO_4 will precipitate.
B. $Q < K_{sp}$. The solution is unsaturated and Ag_2SO_4 will not precipitate.
C. $Q > K_{sp}$. The solution is supersaturated and Ag_2SO_4 will precipitate.
D. $Q > K_{sp}$. The solution is unsaturated and Ag_2SO_4 will not precipitate.

20. There are 4 beakers, each containing 1.0 liter of 0.20 M $HC_2H_3O_2$. When each of the substances below is added to one of the beakers, which will produce a buffer?

(1) 0.10 mol $NaC_2H_3O_2$ (3) 0.10 mol NaOH
(2) 0.10 mol HCl (4) 0.30 mol NaOH

A. Only (1)
B. Only (1), (2) and (3)
C. Only (3) and (4)
D. Only (2)
E. Only (1) and (3)

21. The net ionic equation for the reaction between magnesium hydroxide and hydrochloric acid is shown below. What is the value of the equilibrium constant, K, at 25 ºC for the reaction?

$$Mg(OH)_2(s) + 2\ H^+(aq) \leftrightarrow Mg^{2+}(aq) + 2\ H_2O(l)$$

You may find these equilibrium constants helpful in answering this question: $K_{sp}(Mg(OH)_2) = 1.8 \times 10^{-11}$ and $K_w = 1.0 \times 10^{-14}$.

A. $K = 1.8 \times 10^{3}$
B. $K = 5.6 \times 10^{10}$
C. $K = 1.0 \times 10^{14}$
D. $K = 1.8 \times 10^{17}$
E. None of the above.

22. 25.0 mL of 0.500 M HCl was added to a sample of solid $Co(NH_3)_6Cl_3$ (MW: 267.48 g/mol) in an erlenmeyer flask. The resulting solution was back titrated with 0.116 M NaOH. 23.24 mL of NaOH was required to reach the end point in the back titration. What is the mass of $Co(NH_3)_6Cl_3$ in the erlenmeyer flask?

A. 2.62 g
B. 0.437 g
C. 0.120 g
D. 0.721 g
E. 3.34 g

Name _____

23. 75.0 mL of a buffer solution contains 0.0225 moles of lactic acid ($HC_3H_5O_3$, $pK_a = 3.85$) and 0.0225 moles of sodium lactate ($NaC_3H_5O_3$). 10.0 mL of 0.25 M HNO_3 is added to the buffer solution. What is the pH of the solution after the HNO_3 has been added?

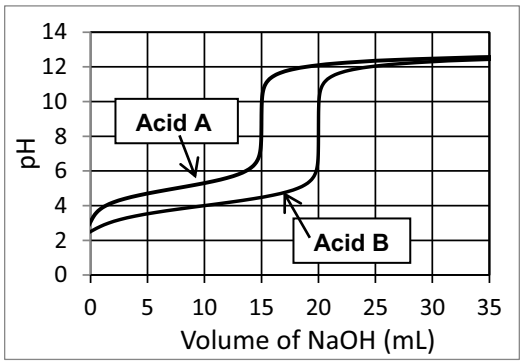
A. 3.95
B. 3.85
C. 4.05
D. 3.65
E. 3.75

24. At the equivalence point, which of the following reactions will have a pH greater than 7?

(1) $HNO_3(aq) + NaOH(aq) \rightleftharpoons NaNO_3(aq) + H_2O(l)$
(2) $HIO_3(aq) + NaOH(aq) \rightleftharpoons NaIO_3(aq) + H_2O(l)$
(3) $(CH_3)_3N(aq) + HCl(aq) \rightleftharpoons (CH_3)_3NHCl(aq)$

A. (1), (2), and (3)
B. (1) and (2)
C. Only (1)
D. Only (2)
E. None of the reactions will have a pH greater than 7 at the equivalence point.

25. 50.0 mL of Acid A was titrated with 0.10 M NaOH. In a second titration, 50.0 mL of Acid B was titrated with 0.10 M NaOH. Both titration curves are shown on the graph below. Which of the following statements is/are **true**?



(1) The acid dissociation constant, K_a, of Acid A is smaller than the acid dissociation constant of Acid B.
(2) The volume of base required to reach the equivalence point in the titration of Acid A is less than the volume of base required to reach the equivalence point in the titration of Acid B.
(3) Methyl red ($pK_a \sim 5.0$) can be used to determine the equivalence point in both titrations.

A. Only (1)
B. Only (2)
C. (1) and (2)
D. (2) and (3)
E. (1), (2) and (3)

Name _____

26. What is the pH of a 100.0 mL solution consisting of 0.015 M NH_3 and 0.025 M NH_4Cl? $K_b(NH_3) = 1.8 \times 10^{-5}$.

A. 4.52
B. 4.74
C. 4.96
D. 9.03
E. 9.48

27. The sublimation of solid biphenyl, $C_{12}H_{10}$, to gaseous biphenyl has a ΔH value of 82 kJ/mol at 298 K. Which of the following statements is **true**?

A. This process is always spontaneous.
B. This process is never spontaneous.
C. This process is spontaneous at low temperatures.
D. This process is spontaneous at high temperatures.
E. None of the above statements is true.

28. When you dissolve compound MX_2 in a glass of water at room temperature, you notice that the glass becomes cold. Which of the following statements is **true**?

A. The dissolution of MX_2 is exothermic.
B. The dissolution of MX_2 results in an increase in entropy of the system.
C. The dissolution of MX_2 is non-spontaneous.
D. The entropy of both the universe and the surroundings increase.
E. None of the above statements is true.

29. Which of the following statements is **true**?

A. The entropy of 1 mole of chlorine, $Cl_2(g)$, is greater than the entropy of 1 mole of 1-chloropentane, $C_5H_{11}Cl(g)$, at the same temperature and pressure.
B. The second law of thermodynamics states that the entropy of the universe increases for any spontaneous process.
C. The enthalpy change for the reaction $2\ NH_3(aq) + Ag^+(aq) \rightarrow [Ag(NH_3)_2]^+(aq)$ is defined as $\Delta H_f°$ for ammonia.
D. The first law of thermodynamics states that the total energy of the universe increases for any spontaneous process.
E. None of the above statements is true.

30. Carbon tetrachloride, CCl_4, can be produced by the following reaction:

$$CS_2(g) + 3\ Cl_2(g) \leftrightarrow S_2Cl_2(g) + CCl_4(g)$$

1.2 mol CS_2 and 3.6 mol Cl_2 are placed in an empty 1.00 liter flask and the flask is sealed. After the system has reaches equilibrium, the mixture contains 0.90 mol CCl_4. What is the value of the equilibrium constant, K, for the reaction?

A. 3.7
B. 3.0
C. 1.0
D. 0.33
E. 0.27

Name _____

31. Consider the reaction below, at equilibrium, in a 10.0 liter container:

$2\ N_2(g)\ +\ 6\ H_2O(l)\ \leftrightarrow\ 4\ NH_3(g)\ +\ O_2(g),\ \Delta H° = 1530.4\ kJ$

Which of the following perturbations will **increase** the amount of ammonia?

A. Decrease the temperature.
B. Decrease the volume of the container.
C. Add water without changing the total gas volume.
D. Add oxygen without changing the total gas volume.
E. None of the above perturbations will increase the amount of ammonia in the flask.

32. The reaction between pyridine, C_5H_5N, and methyl iodide, CH_3I was studied and the initial rate data was collected:

Experiment	$[C_5H_5N]_o$ (M)	$[CH_3I]_o$ (M)	Initial Rate (Ms^{-1})
1	1.0×10^{-4}	1.0×10^{-4}	7.5×10^{-7}
2	1.0×10^{-4}	2.0×10^{-4}	3.0×10^{-6}
3	2.0×10^{-4}	2.0×10^{-4}	6.0×10^{-6}

A. The reaction is first order in pyridine and first order in methyl iodide.
B. The reaction is first order in pyridine and second order in methyl iodide.
C. The reaction is second order in pyridine and second order in methyl iodide.
D. The reaction is second order in pyridine and first order in methyl iodide.
E. The reaction is zero order in pyridine and first order in methyl iodide.

33. A proposed mechanism for the destruction of ozone, O_3, in the stratosphere is given below:

step 1: $O_3(g)\ +\ NO(g)\ \rightarrow\ NO_2(g)\ +\ O_2(g)$ ***slow***
step 2: $NO_2(g)\ +\ O(g)\ \rightarrow\ NO\ (g)\ +\ O_2(g)$ ***fast***

Which of the following statements is **true**?

A. NO_2 is a catalyst and NO is an intermediate.
B. NO is a catalyst and NO_2 is an intermediate.
C. NO and NO_2 are intermediates.
D. O is a catalyst and O_2 is an intermediate.
E. NO_2 and O_2 are intermediates.

34. The rate law for the mechanism shown in the question above is

A. $-\frac{d[O_3]}{dt} = \frac{k[O_2]^2}{[O_3][O]}$

B. $-\frac{d[O_3]}{dt} = \frac{k[NO_2][O_2]}{[O_3][NO]}$

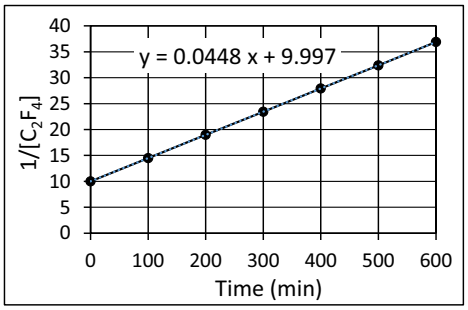
C. $-\frac{d[O_3]}{dt} = k[O_3][O]$

D. $-\frac{d[O_3]}{dt} = k[O_3][NO]$

E. $-\frac{d[O_3]}{dt} = k[NO_2][O_2]$

Name _____

The compound C_2F_4 dimerizes according to the reaction: $2\ C_2F_4 \rightarrow C_4F_8$. This reaction was studied and the graph below was prepared. **Questions 35 and 36 refer to this reaction and the graph below.**



35. What is the rate law for the reaction?

A. rate = 0.0448 M min^{-1}
B. rate = 9.997 min^{-1} $[C_2F_4]$
C. rate = 0.0448 min^{-1} $[C_2F_4]$
D. rate = 9.997 $M^{-1}min^{-1}$ $[C_2F_4]^2$
E. rate = 0.0448 $M^{-1}min^{-1}$ $[C_2F_4]^2$

36. If the initial concentration of C_2F_4 is 1.0 M, how long will it take for the concentration to decrease to 0.50 M?

A. 22.3 min
B. 15.5 min
C. 11.2 min
D. 9.997 min
E. 0.10 min

37. Which of the following statements is/are **true** regarding activation energy, E_a, for a reaction?

(1) Activation energy decreases with temperature.
(2) The greater the activation energy, the faster the reaction.
(3) Catalysts generally work by lowering the activation energy for a reaction.

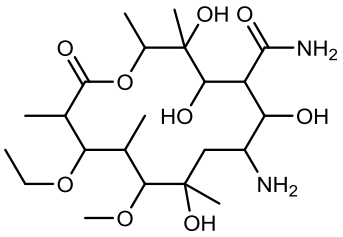
A. Only (1)
B. Only (2)
C. Only (3)
D. (2) and (3)
E. (1), (2) and (3)

38. Rank the following compounds from **highest to lowest** boiling point:

A. 1-butanol > 1-decanol > acetone > 1-pentene
B. acetone > 1-pentene > 1-butanol > 1-decanol
C. 1-pentene > acetone > 1-butanol > 1-decanol
D. 1-butanol > 1-decanol > 1-pentene > acetone
E. 1-decanol > 1-butanol > acetone > 1-pentene

Name _____

Questions 39 through 42 refer to the structure shown below:



molecule A

39. Which letter below includes **ALL** of the functional groups present in molecule A?

A. alcohol and ester
B. alcohol and amide
C. alcohol, amide, amine, and ester
D. alcohol, amine, ester
E. None of the above includes all functional groups.

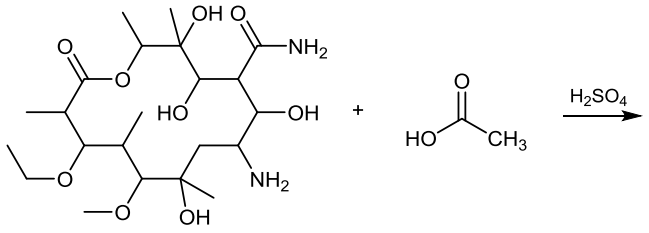
40. How many primary amines are present in molecule A?

A. 0 B. 1 C. 2 D. 3 E. 4

41. When molecule A reacts with $KMnO_4$, how many alcohols will be oxidized?

A. 0 B. 1 C. 2 D. 3 E. 4

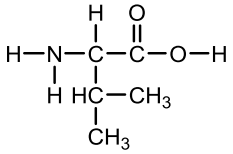
42. When molecule A reacts with excess acetic acid and sulfuric acid, how many (additional) esters will be formed in the resulting product? Assume no hydrolysis occurs.



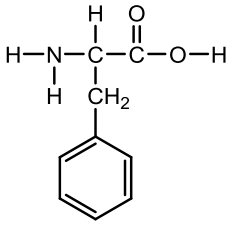
A. 1 B. 2 C. 3 D. 4 E. 5

43. Intermolecular forces between the side chains of amino acids are responsible for the tertiary structure of proteins. The structures of valine and phenylalanine are shown below. The side chains of valine and phenylalanine interact through

A. dispersion forces.
B. dipole-dipole forces.
C. hydrogen bonding.
D. salt bridges.
E. disulfide bonds.



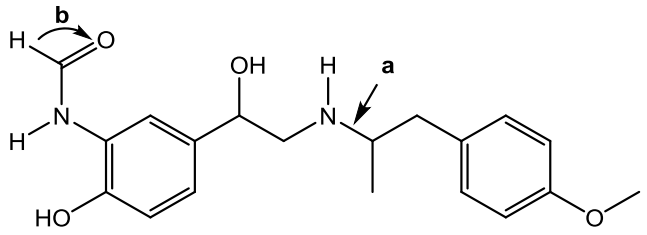
Valine



Phenylalanine

Name _____

The structure of one of the active ingredients in Symbicort (a drug commonly prescribed for the management of asthma and chronic obstructive pulmonary disease) is shown below.
Questions 44 through 47 refer to this structure.



44. The bond labeled **a** is formed from the overlap of the following orbitals:

A. sp^3(C) and sp^3(N)
B. sp^3(C) and sp^2(N)
C. sp^2(C) and sp^2(N)
D. sp^2(C) and sp^3(N)
E. None of the above.

45. The bond angle labeled **b** is

A. 60° B. 90° C. 109° D. 120° E. 180°

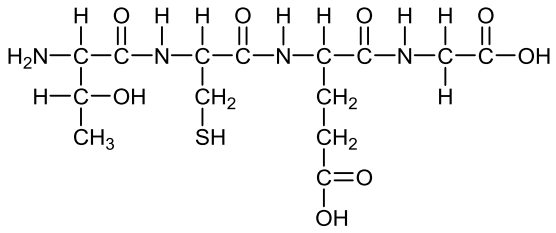
46. The structure shown above has

A. zero chiral carbon centers. It does not have enantiomers or diastereomers.
B. one chiral carbon center. It has enantiomers, but no diastereomers.
C. one chiral carbon center. It has diastereomers, but no enantiomers.
D. two chiral carbon centers. It has enantiomers, but no diastereomers.
E. two chiral carbon centers. It has enantiomers and diastereomers.

47. The number of hydrogen atoms in the structure above is ____.

A. 24 B. 23 C. 22 D. 19 E. 17

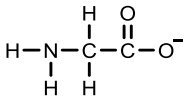
48. How many amino acids were used to make the polypeptide shown below?

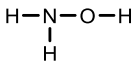


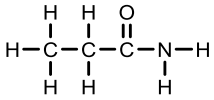
A. 1 B. 2 C. 3 D. 4 E. 5

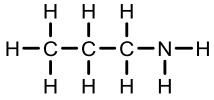
Name _____

49. Which of the following is **NOT** a weak base?

A. 

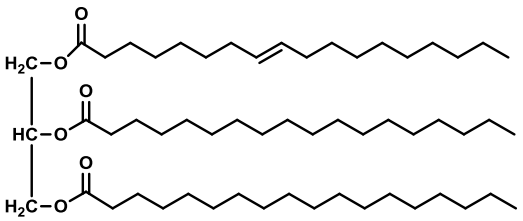
B. 

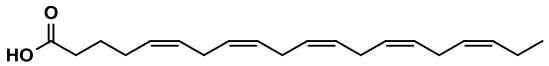
C. 

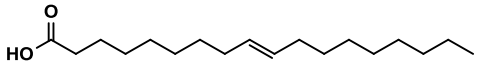
D. 

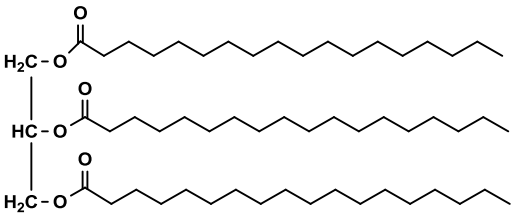
E. None of the above. (All of the structures shown above are weak bases.)

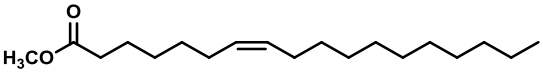
50. Which structure below is a trans fat?

A. 

B. 

C. 

D. 

E. 

THE VERY END!

Appendix E: Course Syllabi

Appendix E contains course syllabi for the experimental and control lectures used during this study. These lectures include:

Study I: Chem 104, Spring 2013 (Lecture 2, experimental and control)

Study II: Chem 109, Fall 2013 (Lecture 2, experimental)

Study II: Chem 109, Fall 2013 (Lecture 1, control)

Study III: Chem 104, Spring 2014 (Lecture 5, experimental)

Study III: Chem 104, Spring 2014 (Lecture 6, control)

CHEMISTRY 104

Lecture 3, Spring 2013

Read This Syllabus Today
Keep It for Future Reference

General Chemistry 104	5 credit hours
Lectures:	1:20 PM MWF 1351 Chemistry
Lecturer:	Professor John W. Moore 1305 Chemistry (262-5154) jwmoore@chem.wisc.edu
Office Hours:	T, R 4:30-5:30 PM or email for appointment.
Lecture Help Session:	1:20-2:10 PM most Fridays
Quizzes	Given in the second discussion section each week
Website (Moodle)	https://courses.moodle.wisc.edu/
General Chem Website	http://genchem.chem.wisc.edu/
Undergraduate Office	Room 1328 Chemistry 263-2424

Chemistry 104 is the second semester of a first-year course in college chemistry.
Students in Chemistry 104 are presumed to have taken Chemistry 103 or its equivalent.

Required Material

Unless you already have it, you will need to purchase each item. These are the only required items for this lecture.

Textbook: A free, online textbook is available for this course, so no textbook purchase is necessary. Many students prefer to also have a printed textbook. Either *Chemistry: The Central Science*, 12th ed. Brown et al., 2012, or *Chemistry: The Molecular Science*, 4th ed. Moore, Stanitski, Jurs, Brooks/Cole 2011 is OK. A course schedule with reading assignments from either textbook is available in the Moodle course.

Lab Book: *Chemistry 104 Laboratory Manual, Spring 2013*, Chemistry Department, University of Wisconsin-Madison; available in the chemistry building lobby from Alpha Chi Sigma, cash only.

Lab Notebook: Carbonless laboratory notebook with duplicate pages available from Alpha Chi Sigma or local bookstores. (You can continue to use your 103 lab notebook until you run out of pages.)

Safety Goggles: Industrial quality eye protection is required at all times when you are in the lab. Safety goggles that completely seal around the eyes and fit over regular glasses can be purchased from local bookstores.

USB Flash Drive: A USB flash drive that will hold at least 2 GB is required for lab data collection.

Calculator: An inexpensive calculator is required. It should have capabilities for square roots, logarithms and exponentiation (antilogarithms), and exponential (scientific) notation operations. The calculator will be used on homework assignments, quizzes, exams, and in the lab. A programmable calculator may be used on exams as long as no information is stored on it, such as chemical formulas or equations. It must be of the type allowable on an ACT or SAT exams (no cell phone or iPod calculators). You must clear the memory before entering the exam room.

Web-Based Course Materials and Class Emails

To access Web-based materials, you must have activated your UW-Madison NetID so you have an ID and password. You probably have already done this. If not, activate your NetID by going to https://www.mynetid.wisc.edu/activate, entering your ID number, and following the directions.

Much information about this course will be transmitted via email, using an automated email list based on registration in the course. An email was sent to everyone on this list on January 17. If you did not receive such an email, you probably are not reading your @wisc.edu emails. It is best to use your @wisc.edu email for UW-Madison communications. You can tell your other email accounts to forward to your @wisc.edu email account, or *vice versa*.

Technology Enhanced Learning: Online Textbook; Moodle Web Site

A free, online **textbook** is at http://chempaths.chemeddl.org/services/chempaths/. In the menu in the middle of the screen, click on "How to Use This Site". When you finish, click on "Chemistry 104, Lecture 3, Spring 2013" (right sidebar) to go to the textbook. The textbook is keyed to each lecture in the course, so the first entry you want is Exam 1 Material, W Jan 23.

Much of Chem 104 is only available via **Moodle**, a course management system similar to Learn@UW. You automatically have access to the 104 materials in Moodle if you are enrolled in this course. You can use Moodle on your own computer, a friend's computer, or any other computer on campus. Direct your Web browser to https://courses.moodle.wisc.edu/. If necessary, log in by entering your NetID and Password. Look for two courses: Chemistry 104, Spring 2013; and Chemistry 104-109 Study Questions. Click on Chemistry 104, Spring 2013 to see your assignments; this is the main course. Chemistry 104-109 Study Questions provides additional questions like the homework questions in the main course, for extra practice.

Log in to Chemistry 104, Spring 2013, Lecture 3 in Moodle as soon as possible. Using the link in the center panel, or on the Quizzes page (Quizzes is in Assignments panel on the left), work on the **Practice Quiz**, which is designed to check your computer to make sure it will do everything you will need during the semester. Do the Practice Quiz on the computer you are most likely to use for online homework assignments and tutorials this semester. The **Practice Quiz is due at 11:55 PM, Monday, Jan. 28**, but don't wait until the last minute to do it. If you have trouble getting your own computer to do the Practice Quiz, use a computer in the chemistry building to complete the assignment. If you change computers during the semester, do the Practice Quiz on the new computer to be sure everything works.

Also begin to work on **Homework 1**, **Academic Honesty Quiz**, and **Survey 1**, which are **due at 11:55 PM on Mon, Jan 28**.

Safety Quiz

Before your lab period the week of Jan 28, you must take a **Safety Quiz** and achieve a perfect score. The Safety Quiz is available in Moodle under the second week's assignments or on the Quizzes page. If you carefully read the safety pages (pp xix to xxii) in your lab manual before taking the Safety Quiz, you should have no difficulty getting a perfect score.

Health or Disability Concerns

All students at UW are entitled to an accessible, accommodating, and supportive teaching and learning environment. The provision of reasonable accommodation for students with disabilities is a shared faculty and student responsibility. Students are expected to inform their professor of their need for accommodation; the professor and TA are expected to make the reasonable arrangements. If you have special needs, please contact Prof. Moore and your TA at your earliest convenience. If you have a condition that might result in a seizure, loss of consciousness, or other situation that might endanger your safety or the safety of others in the laboratory, please inform your TA.

Plagiarism and Academic Misconduct

You will be writing laboratory reports and answers to questions on Moodle homework in this course. It is not OK to simply copy and paste material from the Web into these reports or answers. The UW-Madison Writing Center has a good description of how to paraphrase or quote material that you did not write yourself. It is available at http://writing.wisc.edu/Handbook/QuotingSources.html. Also read Appendix 3, Writing for the Sciences, pp A3-1 to A3-6 in your laboratory manual. This gives good information about how to write up an experiment, including how to cite references. Copying results or answers to quizzes, homeworks, or examinations from someone else and passing them off as your own work is academic misconduct and will not be tolerated. Such misconduct is grounds for a failing grade in this course. The UW-Madison statement on academic misconduct is available at http://students.wisc.edu/saja/misconduct/UWS14.html. More information is provided later in this syllabus.

The complete syllabus is in Moodle at https://courses.moodle.wisc.edu/. Use Moodle to read it NOW. It contains information about how your final grade will be determined and much more.

Midterm and Final Exam Schedule

There will be three midterm exams of 50 minutes each and a two-hour final exam. No make-up exams will be given. All exams will include questions based on laboratory as well as lecture and discussion.

Exam I	Wednesday,	February 20,	1:20-2:10 PM,	Room 1351 or another room
Exam II	Wednesday,	March 20,	1:20-2:10 PM,	Room 1351 or another room
Exam III	Friday ,	April 26,	1:20-2:10 PM,	Room 1351 or another room
Final Exam	Tuesday	May 14,	5:05–7:05 PM	Room to be announced

Course Organization

This course has been designed and organized to help you learn chemistry, but no course or instructor can learn for you. **Learning is something only you can do. For that reason you are the most important feature of the course**. This means that you will need to devote considerable out-of-class time to studying the subject. The rest of this syllabus outlines the features of the course than will help you learn.

Throughout Chemistry 104 emphasis will be placed on understanding chemistry and learning to think effectively in solving scientific problems. However, **to think effectively and to understand problems, it is necessary to have a basic knowledge of facts and terms: a vocabulary of chemistry**. Most of this background and vocabulary should have been obtained from Chemistry 103 or its equivalent. From time to time you may need to review material you studied last semester (or whenever you took Chemistry 103 or its equivalent) in order to understand the new material in this course. Chemistry is cumulative; what you learn this semester will build upon background material that you learned earlier.

Lectures.

During lectures we will discuss principles, outline goals, and present illustrations and demonstrations. A lecture is not intended to describe or explain everything you should learn; rather, it will indicate what topics it is important to study and should provide some insight into those topics. Lecture will also give you an opportunity to think about these topics and see if you understand them. You should take notes during lecture, but this should not be a passive, unthinking process. **Your notes should reflect your understanding of what you heard and saw, not just a repetition of what the lecturer said or wrote on the chalkboard**. Sample lecture notes taken by a TA will be posted in Moodle (under Course Information) shortly after each lecture. Do not expect to learn everything you need to know from the lectures; you will learn far better by working on your own or with a group of other students outside of class. The lectures will indicate what is important to study and provide insights into course topics, **but the lecturer cannot learn for you. Learning is something you have to do.**

Lecture Demonstrations. Many chemical reactions and other phenomena are sufficiently dangerous or expensive that it is not practical for all students to experience them first hand. Nevertheless such reactions may illustrate important principles or show important facts that will be useful later on in chemistry and other science courses, or in everyday life. The UW-Madison Chemistry Department has a tradition of using lecture demonstrations to help students understand chemistry. **When a demonstration is done in class, make careful observations of what happens and make certain that you understand the principles the demonstration is designed to illustrate**. If you do not, ask questions, either in lecture or in your discussion section. Take notes on what you saw, heard, smelled or otherwise experienced. Some demonstrations will not be explained in detail in lecture; instead you will need to discuss them with your TA in discussion section to arrive at a complete understanding of what occurred. All demonstrations are important, and **questions about observations or principles that have been presented via demonstrations often occur on examinations.**

Friday Sessions.

The regular class time each Friday (except for the first week of classes and the week of an exam) may be used for a help session in room 1351. If there is still material on which I have not lectured on Monday and Wednesday, Fridays may also be used for lecture, but often no formal presentation or lecture will be made. You are welcome to come with any questions, comments, suggestions, or other concerns and discuss them. Or email me ahead of time with questions or topics you would like me to discuss.

Discussion/Laboratory Sections.

A group of 22 or fewer students constitutes a discussion/laboratory section supervised by one Teaching Assistant (TA). Discussion sections are for questions, help, review, and problem solving relevant to recent lectures, homework, laboratory experiments, computer exercises, and other assigned material. You should be prepared when you come to the discussion class. This means that you should have at least tried to work out the homework problems. Ask specific questions of your TA. Make sure you understand the questions and the answers given by your TA and fellow students.

In laboratory you will have the opportunity to do chemistry and to apply experimental techniques to solving chemical problems. The lab book and experiments change each year, so do not purchase an old lab book.

Student Board.
So that I obtain feedback from students, I would like to set up a Student Board of Directors consisting of one representative chosen from the students in each discussion/lab section. The board will meet with me on approximately a weekly schedule to discuss course policies and course content. Student Board meetings will be at 1:20 PM on Thursdays and will last no more than 40 minutes. If this time fits your schedule and you are interested in joining the board, send an email message to jwmoore@chem.wisc.edu to let me know. In your message indicate why you want to be on the board and what qualifications you have for being a member. Also give your discussion section number (a three-digit number between 441 and 456).

Online Textbook.

A textbook for this course is entirely online and is available at zero cost to you. The textbook will continue to be available online after the course is over and you will continue to have access to it for at least two years. The textbook contains the usual text, equations, and figures, but it also contains videos, animations, molecular structures that can be manipulated with your mouse, and other features. Mousing over some words will give you a definition, and clicking on an element name will take you to information about that element. We would like to hear from you about how you like these features and how you use them. You can pass the word along to the Student Board member from your section, email your comments to Prof. Moore, or enter comments into a forum in Moodle.

Because the textbook is online, you will be able to use it in new and different ways. Instead of making notes in the margin and highlighting different passages, you will be able to annotate your personal copy of the textbook and also to share your annotations with others in the class (or the world). The online tool that allows this is called **Diigo**. Diigo is a social bookmarking tool built for academics. Social bookmarking is a relatively new technology that involves storing your bookmarks, or links to websites, online and sharing them with others. Various sites, such as *del.icio.us* or *digg* allow users to access sites which others have found to be useful and share them. Diigo focuses on people who want to manage websites as research and learning tools. It allows you to store your bookmarks in personal Lists and to share bookmarks with specific Groups (such as the 104 class in general, your section, or just your study partners). It also allows you to highlight text online and to put sticky notes on these websites to be viewed later. You can make private annotations for your personal study, or share them with others. You can even put a sticky note online and ask your TA to respond to a question about a specific page or paragraph in your online textbook.

Using Diigo. To use Diigo, you must register for their site. Registration and use of Diigo is not required, but it is highly encouraged. At the ChemPaths (textbook) website (http://chempaths.chemeddl.org/services/chempaths/), you will find that instructions for using Diigo are part of the pathway called "How do I use this site?". The instructions will take you through the process of registration and learning specific tools. Once you have registered, you should join the 104 group by going to this URL: http://groups.diigo.com/group/chem104_3_spring_2013 and clicking on the orange-yellow "Join Group" button. You should be able to join the group automatically. You can also feel free to make your own groups, if you would like. One important note: Always be aware of whether you are posting sticky notes or highlights publicly, privately, or to certain groups. Until you get the hang of things, it is probably better to post to the 104 group rather than publicly.

Using Your Textbook. We recommend that you read the assigned sections of the textbook prior to each lecture. Each section is identified by the date of a lecture, so you would read the section "W Jan 23" under the heading "Exam 1 Material" before the first lecture. Take the time to carefully review the illustrations, equations, animations, videos, and graphs in your online textbook. Visualization is an important tool that chemists use to understand the world, especially when thinking about molecular structure. Try to make your reading an active process; keep track of those concepts that are confusing, so you will be able to pay especially close attention as those concepts are covered in class. As soon as possible after class, try to work the sample exercises without looking at the answers. When you understand the sample exercises, practice your problem solving skills by working the related online homework questions or the extra questions in the Chemistry 104 Study Questions Moodle site for that material. Many of these will be directly linked to the online textbook sections. Review the learning/exam objectives that relate to a given topic as you study.

The online textbook has several advantages. In many parts of the textbook there are animations, videos, interactive molecular structures (Jmol), and other interactive features. Also, the online homework will direct you to the parts of the online textbook that are appropriate for you to study if you miss any of the homework questions. Just click on the relevant link and your browser will take you to the part of the online textbook you need to study. Many students have found it helpful to open both your homework and your textbook in separate windows.

Gen Chem Web Site and Computer Room

Course information is also available on the Gen Chem Web Site for Chemistry 104, Lecture 1. The URL is http://www.chem.wisc.edu/content/genchem-main and most of what you need is under "Information for Students" or in the lab section. Often the same information is available on both the Gen Chem and the Moodle Web sites, but you need to be familiar with both, because some information may be available on only one of these sites, or one site might be down. Always check both sites before deciding that you cannot find what you want.

All of the software you need for this course as well as access to the Internet and Moodle is available in the General Chemistry Computer Room, room 1327 on the first floor of Chemistry. If you have trouble with running software for any of your assignments on your own computer or on a computer at some other location, you can always go to the Gen Chem Computer Room to do the assignment.

Weekly Moodle Online Homework.

Online Homework will be available via Moodle. You can do each Online Homework three times and your highest score will count. It is to your advantage to start the Online Homework early, because it will provide you with study guidance. Because only your highest score counts, you can use the guidance to direct your study during the week and then score well on the third try near the deadline. The Online Homework is due every Friday at 11:55 PM (except for the first week of classes and weeks when there is an exam—see schedule).

Online Homework questions provide feedback that should help you figure out how to approach similar problems on quizzes or exams. Most of the feedback is keyed to sections in the online textbook.

Laboratory

The laboratory is extremely important to an understanding and appreciation of chemistry. Examinations will include questions based upon the laboratory material. Each laboratory experiment will have its own criteria for grading and your TA will apply those criteria to evaluating your work. **You must successfully complete the laboratory assignments, achieving a score of 137 points (62.5%) or more, in order to receive a passing grade in the course**.

In some cases you will need to work with other students in your lab to devise an experimental procedure to solve a problem. We encourage you to discuss your work with your fellow students and TA while doing the experiment. However, your lab write-up must be done as indicated in the lab manual, which often means an individual write-up. A more detailed description of how lab work will be carried out is provided in the lab manual.

Pre-lab Quizzes. Laboratory work requires preparation and planning. You are required to prepare for each experiment as described in the lab manual. If you cannot show your TA that you are adequately prepared, you will not be permitted to do the experiment. You are required to take a Pre-lab Quiz for each lab. The quiz will check whether you have studied the online ChemPages Laboratory Resources listed in the lab manual for each experiment. You will be expected to complete and hand in most labs during the lab period, and you will not be able to do this unless you read the experimental directions and prepare your lab notebook ahead of time. Pre-lab Quizzes will be available via Moodle. You can take each Pre-lab Quiz twice and your higher score will count. Pre-lab Quizzes must be completed one hour before you go to your scheduled laboratory class; that is, if you have lab at 7:45 AM on Tuesday, you must take the Pre-lab Quiz for that week before 6:45 AM on Tuesday.

ChemPages Laboratory. You will be able to access this interactive, Web based encyclopedia of laboratory techniques using your own computer, or from the general chemistry computer room. ChemPages Laboratory contains multimedia demonstrations of the laboratory techniques that you will use in Chemistry 104. For almost every laboratory one or two ChemPages sections will be assigned. You should complete these before coming to lab and before taking the Pre-lab Quiz. Your lab manual indicates which ChemPages modules you need for each lab.

Quizzes.

Quizzes will be given every week in the second discussion section, except the first week of classes and the week of an exam. Each quiz will contain several questions, some of which will be designed to help you learn to apply several ideas to a more realistic situation than most problems at the ends of the chapters in the book or on the homework. Questions that combine concepts are often encountered on exams, and the quizzes are designed to help you learn how to answer the types of questions you will encounter on exams and in real-world situations.

Quizzes will cover mainly material from each week's lectures, homework, and other assignments, though earlier material will sometimes be included. The more complicated questions will cover material from the week prior to the week of the quiz and perhaps from the week of the quiz as well.

Biomolecules Tutorials

Seven Biomolecules Tutorials (Proteins 1, Proteins 2, DNA 1, DNA 2, Lipids, Carbohydrates, and Enzymes) are available on the Gen Chem Web site at http://chem.wisc.edu/deptfiles/genchem/netorial/index.htm. The tutorials complement the lecture and textbook material on biochemistry and the content of the tutorials will be included on exams. There are four quizzes that accompany the tutorials, one for Proteins 1 and 2, one for DNA 1 and 2, one for Lipids and Carbohydrates, and one for Enzymes. To get credit for doing the tutorials, you must complete the four quizzes, which are available in Moodle.

Safety Quiz, Academic Honesty Quiz, Practice Quiz, and Surveys.

The Safety Quiz must be passed with a perfect score before you can begin lab work. Therefore you should study the safety information in your laboratory manual and take the Safety Quiz as soon as possible. You must complete the Safety Quiz before your laboratory session the week of Jan 28. You can take the Safety Quiz as many times as necessary to attain a perfect score.

The Academic Honesty Quiz must be completed with a perfect score by 11:55 PM on Monday, January 28. If you read the material in the Lab Manual regarding academic honesty, you should be able to pass this quiz easily.

The practice quiz assignment is designed to make certain that the computer you will use for homework assignments will show you all the things you need to see, such as molecular structures and Quicktime movies. You can do the practice quiz as many times as you need to until you get your computer set up properly. As soon as possible, use your own computer or the computer you plan to use for homework and other course assignments to log into Moodle, try the practice quiz, and note which questions (if any) you have trouble with. If you cannot see what you are supposed to see, guess at the answer to that question, have the homework graded, and then follow the directions in the feedback for the questions you had trouble with. If there are problems you cannot fix by yourself or with the help of your roommate or friends, contact Rachel Bain (rbain@chem.wisc.edu) by email and ask for help.

There will be a Survey at the beginning of the semester and one at the end of the semester. Surveys are designed to collect information about your experience in this course. Survey 1 must be completed by 11:55 PM on Monday, January 28. The End-of-Semester Survey will not be available until the last week of classes and it must be completed before 11:55 PM on Friday, May 10, the last day of classes.

TA Personal Evaluation

This provides a means for your TA to evaluate your overall performance in discussion section and in lab. Your grade will be based on your attendance, preparation, and effective participation in discussion and lab.

Chem 104 Wiki Project

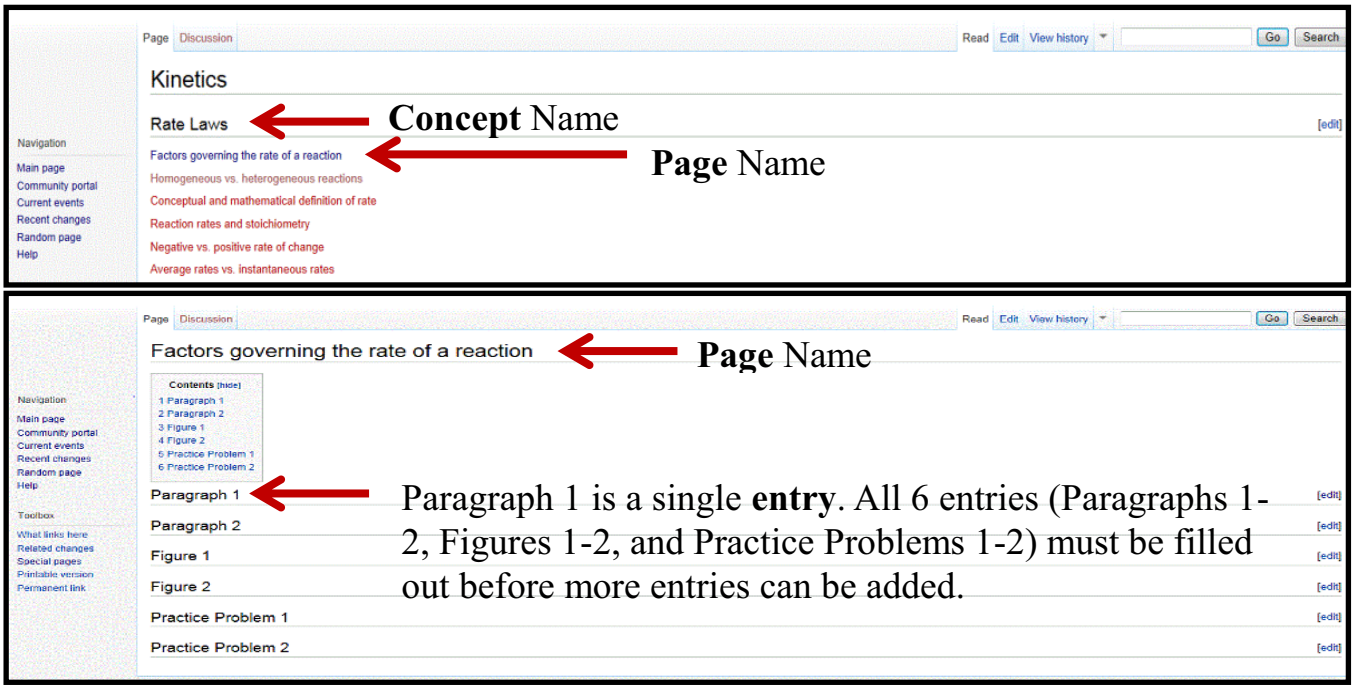
This semester we will begin development of a wiki that will consist of useful information for Chem 104 students contributed by Chem 104 students. Part of your grade this semester will be based on your contributions to a wiki that will be written by the entire class. A wiki is a collaborative website in which the content is added and edited freely. The wiki that our CHEM 104 class will construct will be a free resource that anyone enrolled in the class may use. We expect that the quality of the wiki will be high and that it will serve as a resource for future Chem 104 classes as well. Original contributions to the wiki are part of the required coursework and you may also earn extra credit by editing prior contributions from your classmates.

The goal of using this interactive website is to determine the effect of this type of medium on student performance in general chemistry. A chemical education research project is being conducted by a graduate student researcher (Jackie Brown) during the course of the semester and you may participate in it if you decide to give consent. If you have any questions concerning this study, you may contact Jackie Brown at jackie.brown@chem.wisc.edu.

Mandatory wiki contributions: One wiki contribution per exam period is required (see "Wiki Contribution Guidelines" in Moodle) and must be entered and saved on the wiki by noon (12:00 P.M.) the day before the exam. Each contribution is worth up to 5 points.

You will be assigned to a concept (e.g. “Rate laws”). You may choose to contribute to any page within that concept, and will be required to make one entry. For example, you could write a paragraph describing factors governing the rate of a reaction or you could supply a figure that defines rate of reaction or you could supply a practice problem about rate of reaction.

Once you have contributed to an entry, you may go back at any time and edit your entry. However, please do not start any additional entries until the six required entries on that particular page have already been completed by other students. Also, please do not edit or add content to any entry where another student has started contributing. You may not contribute to topics on future exams until the current exam is finished.



Final Exam Contributions (due by noon, Friday, May 10): Between Exam 3 and the final exam, a relatively smaller portion of material will be covered compared to the first three exams so it will be harder to find a concept to contribute to. Therefore, after exam 3, all previous pages of wiki content will become available to edit. If you are unable to find an open page to contribute to, you may edit previous portions of the wiki in an analogous fashion to earning extra credit (see next paragraph). You may earn 0, 3, or 5 points for your mandatory final exam contribution depending on the number of edits you make. Five edits will result in the maximum five point allotment.

Extra credit contributions: Once an exam period is over, you may go back to the previous exam topics and edit the wiki for extra credit. Edits may consist of (a) adding additional content, or (b) reformatting the wiki text to be more legible and visually appealing. You may not edit your own contributions for extra credit. For every exam period, you can earn up to five points of extra credit, i.e. one point for every edit. You can only edit the previous exam’s topics for extra credit, i.e. you can only earn up to 5 points during any given exam period.

Point breakdown: Contribution	Number of points
Mandatory entry due by 12:00 P.M. the day before each exam	4 entries × 5 points = 20 points
Optional edits on exam 1 topics due by 12:00 P.M. the day before Exam 2	0-5 edits × 1 point = 0-5 points
Optional edits on Exam 2 topics due by 12:00 P.M. the day before exam 3	0-5 edits X 1 point = 0-5 points
Optional edits on exam 3 topics due by 12:00 P.M. the day before final exam	0-5 edits X 1 point = 0-5 points
Total	20 points (up to 35 points)

Grades

Your grade will be based on a maximum of 1000 points divided as follows:

Twelve weekly Online Homeworks (Moodle) @ 10 points each *(due every Friday at 11:55 PM)*	120 points;
Laboratory: eleven experiments @ 20 points each *(each week's experiment is listed in the Course Assignment Schedule; 20-point total includes Pre-Lab Quizzes in Moodle if they are available)*	220 points;
Nine out of ten Quizzes @ 10 points each (lowest score dropped) *(Quizzes will be given in the second discussion section each week)*	90 points;
Seven Biomolecules tutorials and four biomolecules quizzes @ 5 points each	20 points;
Three Special Quizzes, two Surveys @ 5 points each *(Safety Quiz due before first lab; Practice Quiz, Survey 1, and Academic Honesty Quiz all due Monday, Jan. 28, 11:55 PM; End-of-Semester Survey due Friday, May 10, 11:55 PM.)*	25 points;
Four Chem 104 Wiki Mandatory Contributions @ 5 points each* *(Each contribution is due at noon the day before an exam except the last, which is due at 12:00 noon Friday, May 10.)*	20 points;
TA Personal Evaluation @ 35 points	35 points;
Three 50-min. exams @ 90 points each *(dates are listed in the Course Assignment Schedule)*	270 points;
Final Exam *(Tuesday, May 14, 5:05-7:05 PM, room to be announced)*	200 points.
==========	==========
Total	1000 points

Letter Grades.
Final grades will be based upon the absolute scale shown below. If you score the number of points indicated, then you will receive the letter grade indicated, regardless of how many other students achieve the same grade. There is no curve. Therefore it is to your benefit (and to your friends' benefit) that you help other students learn and they help you learn.

A	900 points or more
AB	870 to 899 points
B	790 to 869 points
BC	760 to 789 points
C	630 to 759 points
D	580 to 629 points

If necessary, laboratory grades will be normalized to a common scale at the end of the semester to minimize differences in grading practices among sections. Each item that contributes to your grade has been described earlier in this syllabus.

*Up to 15 points of extra credit is available if you edit wiki contributions (other than your own) after each exam. The 15 points extra credit will be recorded in a separate column in Moodle. Whether you choose to do extra-credit work or not has no effect on the point totals for letter grades.

CHEMISTRY 109

Lecture 2, Fall 2013

Read This Syllabus Today. Keep It for Future Reference.

Advanced General Chemistry:	5 credit hours
Lecture:	2:25 PM MWF 1351 Chemistry
Instructor Information:	Professor John W. Moore 1305 Chemistry (262-5154) jwmoore@chem.wisc.edu
Office Hours:	MR 3:30-4:30 PM 1305 Chemistry or email for an appointment

Chemistry 109 is a one-semester, accelerated, first-year college course in chemistry. The goals of this course are: 1) to build your skills in problem solving, mathematical and analytical reasoning, and laboratory manipulation, and 2) to build your knowledge of the fundamental chemical principles of atomic and molecular structure, kinetics, and thermodynamics. In this class we will apply these principles to condensation-hydrolysis reactions, acid-base reactions, and oxidation-reduction reactions. We will emphasize applications in living organisms (for example in drug design), and in the industrial world (for example in fuel production and utilization).

Is Chemistry 109 the right course for me? It is, provided you can answer yes to all of these questions. 1) Does your potential major require chemistry beyond General Chemistry, or are you considering a major that would require more chemistry? 2) Did you qualify for placement into Calculus (Math 221) or a higher math course? 3) Have you taken one year of high school chemistry with a grade of A- or better and scored at least 29 on the ACT or at least 650 on the SAT math test, or have you taken two years of high school chemistry (AP is good) and scored at least 27 on the ACT or 620 on the SAT math test? 4) Do you enjoy science, feel reasonably well prepared, and have a strong work ethic?

Course Organization and Expectations

This course is designed to help you to learn chemistry. Prof. Moore and your TA will do their best to guide you in mastering the material, but no course or instructor can learn for you. You will need to devote considerable outside-of-class time to studying chemistry. A good rule of thumb is that you should be spending approximately three hours outside of class for each hour you are in class. A recommended study strategy for this course is this: 1) read the assigned material in the textbook before each class session, 2) attend class and take your own notes, 3) as soon as possible after class, begin to work homework problems. When you encounter problems that you cannot solve, refer to the textbook, your notes, a tutorial, or your fellow students. Forming a study group to work through problems is an excellent way to learn chemistry.

Throughout this course emphasis will be placed on understanding chemistry and learning to think effectively in solving problems. Successful problem solving requires a basic knowledge of principles, facts, and terms: a vocabulary of chemistry. Some of this background and vocabulary should have been obtained from your high school chemistry course. From time to time you may need to review material you studied in high school in order to understand the new material presented in this course. To help you review there are three Review Homework assignments. The first of these must be completed Sunday, Sept. 8, and the second two weeks later. The third comes in early November. Chemistry is a cumulative subject; what you learn this semester will build upon background material that you learned earlier.

To help you to master the new material presented in this course, specific learning objectives are provided for each exam. These objectives will be available under the Exam Preparation Materials headings in Moodle (see below). Use the learning objectives to guide your work on the homework sets and to review for the exams. Study questions keyed to the learning objectives are also available in the same location to give you more problem-solving practice. Practice exams, and fully worked out answers, will be available for you to use in preparing for each exam. Some additional objectives will become available from time to time to cover material introduced for the first time this year.

Required Texts & Materials

You will need to purchase each item listed below. These are the only required items for this course.

Textbook: *Chemistry: The Molecular Science* 4th ed. Moore, Stanitski, Jurs (or you can use the free online textbook).

Lab Manual: *Chemistry 109 Laboratory Manual, Fall 2013,* Chemistry Department, University of Wisconsin-Madison: available from Alpha Chi Sigma (the co-ed chemistry fraternity) in chemistry building lobby the first week of classes.

Lab Notebook: Carbonless laboratory notebook with duplicate pages: available from Alpha Chi Sigma or local bookstores (where it is more expensive).

Safety Goggles: Industrial quality eye protection—goggles that completely seal around the eyes and fit over regular glasses— is required at all times when you are in the lab. Purchase from Alpha Chi Sigma or local bookstores (~$10).

Calculator: An inexpensive calculator is required. It should have capabilities for square roots, logarithms and exponentiation (antilogarithms), and exponential (scientific) notation operations. The calculator will be used on homework assignments, pre-lab quizzes, exams, and in the lab. You may use programmable calculators in this course.

Web-Based Course Materials and Class Emails

To access Web-based materials, you must activate your UW-Madison NetID so you have an ID and password. You probably did this at SOAR during the summer. If not, activate your NetID by going to http://my.wisc.edu, clicking on Activate your NetID, and following the directions. You may also change your NetID password at this same Web site.

Much information about this course will be transmitted via email, using an automated email list based on registration in the course. An email was sent to everyone on this list on August 21. If you did not receive such an email, either you were not yet enrolled or you are not reading your @wisc.edu emails. It is best to use your @wisc.edu email for UW-Madison communications. You can tell your other email accounts to forward to your @wisc.edu email account, or *vice versa*.

Technology Enhanced Learning: Moodle Web Site; Chem109Wiki; Online Textbook

Much of Chem 109 is only available via a course management system called **Moodle**. You automatically have access if you are enrolled in this course. You can use Moodle on your own computer, a friend's computer, or any other computer on campus. Direct your Web browser to http://courses.moodle.wisc.edu. Click Login at the upper right on the screen; enter your NetID and Password. Choose Fall 2013 and click Chem 109-2 Advanced General Chemistry Fall 2013.

Part of your grade this semester will be based on your contributions to a wiki that is written by the entire class. There is evidence that writing about chemistry in a wiki can help students learn and can result in higher scores on exams. We are testing that hypothesis. A complete Student Guide to the ChemWiki is posted on Moodle. A video tutorial on how to use the ChemWiki can be found at https://www.youtube.com/watch?v=wA7skDRxlFg.

An optional **textbook** for this course is online and free. Click this link to access it. Then click on How to Use This Site in the menu on the left side of the screen. Next, go back to UW-Madison Chem 109-2013 to access the textbook. The online textbook is keyed to each lecture in the course, so the first entry you want is W Sep 4. This date gives you review readings for material you have studied in high school. Readings should be done before the lecture on the specified date.

Please log in to Moodle as soon as possible. Using the link provided in the center panel, or on the Quizzes page (link to quizzes is in Activities panel on the left), work on the **Practice Quiz**, which is designed to check out your computer to make sure it will do everything you will need during the semester. Do the Practice Quiz on the computer you are most likely to use for online homework assignments and tutorials this semester. The **Practice Quiz is due at midnight, Sunday, September 8**, but don't wait until the last minute to do it. If you have trouble getting your own computer to do the Practice Quiz, then use a computer in the chemistry building to complete the assignment. If you change computers during the semester, do the Practice Quiz on the new computer to be sure everything works.

Also begin to work on **Review Homework 1**, which is **due at midnight Sunday, Sept. 8** and on **Homework 1**, which is **due at midnight on Sunday, Sept. 15**.

Safety Quiz

Before your first lab period you must achieve a perfect score on a Safety Quiz and an Academic Honesty Quiz in Moodle. The quizzes are listed under the second week's assignment. *If you carefully read the safety pages (pp xix to xxii) in your lab manual before taking the Safety Quiz, you should have no difficulty getting a perfect score*.

Health or Disability Concerns

All students at UW are entitled to an accessible, accommodating, and supportive teaching and learning environment. The provision of reasonable accommodation for students with disabilities is a shared faculty and student responsibility. Students are expected to inform their professor of their need for accommodation; the professor and TA are expected to make the reasonable arrangements. If you have special needs, please contact Prof. Moore and your TA at your earliest convenience. If you have a condition that might result in a seizure, loss of consciousness, or other situation that might endanger your safety or the safety of others in the laboratory, please inform your TA.

The rest of this syllabus and the course schedule are in Moodle. Log in, go to Chem 109, and use the Course Info and other panels on the right to view and download the Syllabus, Assignment Schedule, and other resources. The full syllabus contains information about how your final grade will be calculated, among other things.

Learning Activities in Chemistry 109

Chemistry 109 has different learning activities to meet the needs of the many types of students in our class. You do not need to make use of every tutorial or do every study problem; rather, your job is to sample the different types of materials offered and to select those activities that most effectively support your learning. In the lecture, Prof. Moore will lecture, do demonstrations, or lead problem solving. In discussion section, your TA will engage a smaller group of students in problem solving, answer specific questions on the course material, and discuss the laboratory exercises. Finally, in lab you will explore chemical principles through hands-on experimentation. To supplement these activities, tutorials are provided to aid your mastery of the material. Attendance at the lectures and the discussion sections is strongly encouraged, but not required; students who consistently attend outperform those who do not. Laboratory attendance is mandatory; students who do not attend will not pass this course.

Lecture

In class Prof. Moore will provide an organizational framework, discuss principles, and present illustrations and demonstrations. He will not describe or explain everything you should learn; rather, he will indicate what topics you should study and provide insights into those topics. Lectures will also give you an opportunity to think about these topics and see whether you understand them. You should take notes during lecture; note taking should be an active, thinking process. Your notes should reflect your understanding of what you heard and saw. Prof. Moore will provide opportunities for you to test your understanding of particular concepts through in class questions. If there are particular concepts or ideas that are not clear to you feel free to ask Prof. Moore or your TA about them during class, after class, by email, or in office hours. Sample lecture notes taken by a Teaching Assistant (TA) will be posted in Moodle shortly after each lecture; don't rely on these notes in place of your own, but, if you need to miss a class, they are an acceptable substitute. Please do not expect to learn everything you need to know in the classroom; you will learn far better by working problems on your own or with a group of other students outside of class.

Textbook.

In addition to the printed textbook, an online textbook is available at zero cost to you in an online system called ChemPaths. The textbook will continue to be available online after the course is over and you will continue to have access to it for at least two years. The textbook contains the usual text, equations, and figures, but it also contains videos, animations, molecular structures that can be manipulated with your mouse, and other features. Mousing over a word will give you a definition, and clicking on an element name will take you to information about that element. We would like to hear from you about how you like these features and how you use them. You can pass the word along to the Student Board member from your section, email your comments to Prof. Moore, or enter comments into a forum in Moodle.

Because the textbook is online, you will be able to use it in new and different ways. Instead of making notes in the margin and highlighting different passages, you will be able to annotate your personal copy of the textbook and also to share your annotations with others in the class (or the world). The online tool that allows this is called **Diigo**. Diigo is a social bookmarking tool built for academics. Social bookmarking involves storing your bookmarks, or links to websites, online and sharing them with others. Various sites, such as *del.icio.us* or *digg* allow users to access sites that others have found to be useful and share them. Diigo focuses on people who want to manage websites as research and learning tools. It allows you to store your bookmarks in personal Lists and to share bookmarks with specific Groups (such as the 109 class in general, your section, or just your study partners). It also allows you to highlight text online and to put sticky notes on these websites to be viewed later. You can make private annotations for your personal study, or share them with others. You can even put a sticky note online and ask your TA to respond to a question about something in particular in your online textbook.

Using Diigo. To use Diigo, you must register for their site. Registration and use of Diigo is not required as a part of 109, but it is highly encouraged. When you go to the textbook website, you will find that instructions for using Diigo are part of the pathway called "How to Use This Site". That will take you through the process of registration and learning specific tools. Once you have registered, you should join the 109 group by going to this URL: https://groups.diigo.com/group/chem_109_lectures_1_and_2_fal__2013 and clicking on the "Apply to join group" button. You should be added to the group within a day. You can also feel free to make your own groups, if you would like. One important note: Always be aware of whether you are posting sticky notes or highlights publicly, privately, or to certain groups. Until you get the hang of things, it is probably better to post only to the 109 group rather than publicly.

Using Your Textbook. We recommend that you read the assigned sections of the textbook prior to each lecture. For the printed textbook, the sections to read are listed in the course schedule for the date of each lecture. In the online textbook, each section is identified by the date of a lecture, so you would read the section "W Sep 4" before lecture the first week of classes. Take the time to carefully review the illustrations, equations, animations, videos, and graphs in the online textbook. Visualization is an important tool that chemists use to understand the world, especially when thinking about molecular structure. Try to make your reading an active process; keep track of those concepts that are confusing, so you will be able to pay especially close attention as those concepts are covered in class. As soon as possible after class, try to work the sample exercises without looking at the answers. When you understand the sample exercises, practice your

problem solving skills by working the related online homework questions or the extra questions in the Chemistry 109 Study Questions Moodle site for that material. Many of these will be directly linked to the online textbook sections. Review the learning/exam objectives that relate to a given topic as you study.

Laboratory

Laboratory work is important to understanding and appreciating chemistry, and for those of us who love chemistry, lab work is really fun. The laboratory exercises are designed to illustrate the principles described in class, and the exams will include questions based upon the laboratory material. **To receive a passing grade in Chem 109, you must successfully complete *all* laboratory assignments and achieve an overall lab score of at least 60%**.

During the lab period you will carry out the experiment, take notes, and complete your data analysis. *All your work must be turned in at the end of your lab period, in the format specified in the lab manual or by your TA.* You will be evaluated on your pre-lab preparation, your in-lab experimental technique and data analysis, and on your ability to observe chemical phenomena and record your observations in your notebook. Each laboratory experiment will have its own criteria for grading and your TA will apply those criteria to evaluating your work.

Pre-lab Quizzes. Pre-laboratory Quizzes are available via Moodle. You can take each Pre-lab Quiz twice and your higher score will count. Pre-lab Quizzes must be completed an hour before you go to your scheduled laboratory class; that is, if you have lab at 7:45 am on Tuesday, you must take the Pre-lab Quiz for that week before 6:45 am on Tuesday.

ChemPages Laboratory Resource ChemPages is an interactive, Web-based encyclopedia of laboratory techniques. You will be able to access ChemPages from any computer on the campus network either from the General Chemistry web page, http://genchem.chem.wisc.edu/ under Materials for Lab, or from the Moodle course homepage under Lab Stuff. ChemPages contains multimedia demonstrations of the laboratory techniques that you will use in this course. For almost every laboratory one or two ChemPages sections will be assigned—see your lab manual to find out which they are. You should view these pages before taking the Pre-lab Quiz, which must be completed an hour before your lab starts.

Discussion Section

Discussion sections are led by your Teaching Assistant for a group of 22 students. The discussion periods are for questions, help, review, and problem solving relevant to recent lectures, homework, laboratory experiments, computer exercises, and other assigned material. Discussion sections will be most helpful if you are prepared when you come to the class. You should have at least tried to work out the homework problems or the objective-keyed study questions from the text. Feel free to bring a printed copy of your homework with you, marked with areas where you need help; your TA has been instructed not to solve the specific problems that you have been assigned, but he or she will have a similar example for the class to solve together. Bring specific questions to ask; be sure you understand the questions asked by others and the answers given by your TA and fellow students. Your active participation in discussion will help you and your fellow students learn.

Exams

There will be three evening midterm exams of approximately 75 minutes each and a 2-hour final exam. Each midterm exam will cover the classroom, special assignment, and laboratory material up to that point in the course and since the previous exam. The final exam will be divided approximately equally between the material since the third exam and comprehensive coverage of the entire semester.

An early exam will be given before each midterm at 3:30 PM for students who have conflicts with the assigned time. Please note the exam dates on your calendar and avoid scheduling anything at those times. If you have an unavoidable conflict, contact your professor well in advance. (We are aware of a recurring conflict with certain sections of engineering courses: if you have this conflict, please notify your TA and professor.)

Midterm Exams:	Monday, Sept. 23	5:40 PM to 7:00 PM
	Monday, Oct. 21	5:40 PM to 7:00 PM
	Monday, Nov. 18	5:40 PM to 7:00 PM
Final Exam:	**Sunday, Dec. 15**	**7:25 PM – 9:25 PM**

The room in which you will take each exam will be announced later. A review session will be held in lecture class before each exam. ***No make-up exams will be given, but appropriate accommodation will be made for all students to be fairly evaluated.*** **If you have any type of special need, options are available to take the exam at an alternate time or place; please contact Prof. Moore as soon as possible to make the arrangements.**

Learning Objectives, Study Questions and Practice Exams Learning objectives for each exam, and a selected set of study questions keyed to the learning objectives, can be found in the Exam Preparation Materials panel on the course homepage in Moodle. Exams given in Chemistry 109 in a prior year are available in the same location. The study questions are typical of those you should master and you should use them for extra practice in problem solving. In some cases your online homework will suggest that you work on specific study questions to make sure you understand a concept. If you do not understand how to solve one or more study questions, ask your TA in discussion section or during

office hours. For those using the online textbook only, a set of online study questions is available in the Study Questions Course; anyone can use these questions as a study aid, but they are especially useful if you don't have access to the questions in the printed textbook.

How To Prepare For Exams A recommended strategy is: 1) review the learning objectives for the exam referring to your notes or the text if necessary, 2) work the study questions associated with each objective, spending more time on topics you find more challenging, 3) simulate the test taking situation by working the practice exam in 75 minutes in a quiet place, 4) have a partner "grade" your own test using the answer key as your guide while you "grade" the partner's work, 5) review those areas that you identify as weak, and then work the other questions on the practice test.

Online Homework

Each week you will have an online homework assignment in Moodle. Each online homework assignment (except Review Homeworks and Homework 1) is a double assignment: an Early Online Homework worth 2 points with mainly multiple-choice questions and an Online Homework worth 6 points with the same kinds of questions on the same topics as the early homework. These assignments are available only in Moodle; links to them appear under the week that they are due and they are also available through the Quizzes link. The Early Online Homework is due Tuesdays at 11:55 PM and can be done only once. If you get more than 50% correct you will receive the full 2 points; if you get less than 50%, you will receive whatever score is assigned. This homework is to encourage you to try the questions prior to your discussion section so that you can ask your TA about concepts you don't understand. The regular Online Homework is due every Sunday at 11:55 PM; you can attempt it twice and your higher score will count. Online homework can be done from any computer on the campus network. For online homework you are encouraged to form a study group and work with it to learn how to answer the questions; however, the work you submit must be your own.

To prevent loss of work, **it is wise to save your homework every 15 minutes or so**. To save, scroll to the bottom of the screen and click "Next." Moodle will indicate which questions have been saved. You can then exit Moodle (without clicking "Submit all and finish") and when you return to Moodle and access the same homework, the same questions and all of the answers you saved will still be there. You can change saved answers and answer the rest of the questions.

There are several useful things to know about online homework. 1) You will not get the same questions as other students do, although most of the questions on your homework will be on the same topics as those for other students. The second time you do the homework, you almost certainly will get different questions, but similar to the first time, so you should read each question carefully and make certain you answer the questions you have the second time, not the ones you remember from the first time. 2) You can start a homework, print a copy of the questions, exit from Moodle, answer the questions on paper, and go back at a later time to enter your answers into Moodle. 3) You are strongly encouraged to ask other students, me, or your TA to help you to learn how to solve the types of problems found on the homework, but you must submit your own answers. 4) Until you click "Submit all and finish" you have not completed an assignment; don't forget to submit! 5) Don't wait until the last minute before the deadline.

In order to for you to view the online homework and pre-lab quizzes, your computer must be configured appropriately. We have provided a **Practice Quiz** that tests all the features you will need. You should do the practice quiz on the computer you expect to use for online homework and pre-lab quizzes to make certain that on your computer you are able to view everything you need to see. If you cannot answer correctly, the Practice Quiz will tell you how to fix the problem.

There are also three Review Homework assignments to help you review material that will not be explicitly discussed in Chem 109 and should have been learned in your high school chemistry course. Two of them are due during the first and third weeks of classes; the third one is due in November.

Chem109Wiki

Part of your grade this semester will be based on your contributions to a wiki that is written by the entire class. A wiki is a collaborative website in which the content is added and edited freely. The wiki that your Chem 109 class will construct will be a free resource that anyone enrolled in the class may use. These original contributions to the wiki are part of the required coursework (see point breakdown on the last page of this syllabus).

A Student Guide to the ChemWiki can be found on Moodle. This document describes how to use the wiki and what is expected of you regarding the wiki assignments.

One wiki contribution (or written report) per exam period is required (see "Wiki Contribution Guidelines" in the Student Guide to the ChemWiki) and must be documented on the wiki (or provided to your TA) by 11:55 PM one week before the exam (see deadlines in course schedule). You will be assigned to a group (e.g. "Group 1"), which is determined by what discussion section you are in. There are four groups total (Group 1-4) in your lecture, one group for every two TAs. You will then choose a *team of 4 students that are in your discussion section*/ For each exam period you will be required to complete either a) one page in the wiki, or b) a written, traditional report that you will submit to your TA.

Before each exam, confirm your assignment by checking your group's home page (http://chem109wiki.chem.wisc.edu/mediawiki/code/index.php/Group) on the ChemWiki.

- *If you are assigned to write a Wiki Page*, you may contribute to any page that is within your group's assigned topics. You may not contribute to topics on future exams until the current exam is finished. For each exam, your group needs to select one page on the wiki to fill out as a group. **This page must be under your assigned group heading**. Please do not edit another other team's page—remember, a digital log is created for all edits made on the wiki so we can tell who edited what! Your finished wiki page is due about a week before each exam according to the schedule in the Wiki and the course schedule.

  Before you get started, you MUST watch the ChemWiki Video Tutorial. The ChemWiki Video Tutorial is a 21-minute video that introduces the ChemWiki Project and guides you through the various sections of the wiki. You will also learn how to edit wikitext using a step-by-step guide on how to do your first assignment, the User page assignment. Follow the link below to watch the full video:

  https://www.youtube.com/watch?v=wA7skDRxlFg

  Note: Be sure to change the quality of the video to 720p so that you can see the video clearly.

- *If you are assigned to write a Traditional Report*, you will submit a report on an assigned topic before each exam at the due date indicated in your course schedule. See "Traditional Report Requirements" in the Student Guide to the ChemWiki for more information.

Computer Assignments

Each of the three computer assignments (Excel Assignment; Window on the Solid State; four Biomolecules Tutorials, each with online quiz) has its own set of directions that will be mentioned in lecture and posted on the course Web site. It is your responsibility to obtain the directions from the course Web site, follow them, and turn in each Computer Assignment on time. The Computer Assignments are to be turned in to your TA at the time indicated on the assignment and in the Course Schedule. The third Computer Assignment is a set of four Biomolecules Tutorials, each worth 5 points, that you will need to work through. Three Biomolecules Tutorials are due the same week and the fourth is due two weeks later; this is indicated in the course schedule. Each Biomolecules Tutorial has an accompanying quiz that you must complete successfully to receive credit for the tutorial. The score on the quiz is your score for the tutorial.

Student Board of Directors

The Student Board of Directors helps Prof. Moore to run the course and provides feedback from students on how the course is going. The Board consists of one representative from each discussion/lab section, chosen from the students in that section. The board will meet nearly every week at 4:35 PM on Wednesdays to discuss course policies, structure, and content. Meetings will take from half an hour to an hour depending on how much we have to discuss. Your TA will solicit volunteers for this role in your first discussion. If you are interested in serving as your class representative, send Prof. Moore an email (jwmoore@chem.wisc.edu) as soon as possible explaining why you would like to be a member of the board. Include your name, your email address, and your discussion section number (541, 542, 543, 544, 545, 546, etc.) in your message; if possible, include your TA's name.

Electronic Mail

All students at UW-Madison have access to free electronic mail through the university. We strongly recommend that while you are a student you use your @wisc.edu email address to send and receive email and forward your other email accounts to the @wisc.edu account. You are encouraged to contact Prof. Moore by email if you have questions about anything to do with the course. Electronic mail is available at all times of day and night, so you can send messages whenever something comes to mind. Do not, however, expect immediate responses in the middle of the night! Prof. Moore's email address is jwmoore@chem.wisc.edu. Whenever you send an email to Prof. Moore, please begin the subject line with "109". This can be followed by whatever the subject of the message is, such as "Homework 1, problem 4". Using 109 in the header will differentiate course emails from the many other emails that Prof. Moore receives.

What to Do If You Are Sick, Or Otherwise Unable to Attend an Exam or Lab

If you are unable to attend a specific lab session because of an unavoidable schedule conflict (such as a religious observance, an athletic activity, or a family obligation), contact your TA as soon as possible to reschedule. Make-up lab times can be accommodated only during the week when the entire class is doing a lab exercise, so planning ahead is important. If you find that you are unable to attend lab because you are ill, contact your TA as soon as possible. He or she will discuss your situation and decide what to do. **If circumstances arise unexpectedly that preclude your taking an exam, please contact your TA and professor before the scheduled exam time.** We recognize that in an emergency situation, you may not be able to contact us in a timely way.

Chemistry Resource Facilities: Computer Room, Study Room, Undergrad Chemistry Office

Computers are available for use in room 1375 Chemistry. Room 1371 is a study room for chemistry students. The staff in the Undergraduate Chemistry Office, room 1328, can assist you with enrollment, advising, and many other things.

Cell Phone Policy

If you bring a cell phone to class or lab, please turn it off for the duration of the class or lab period. If circumstances require that you be able to answer your cell phone during a class, please inform your instructor before the class.

Academic Misconduct

Academic misconduct includes and is not limited to acts in which a student seeks to claim credit for the work or efforts of another without authorization or citation, uses unauthorized materials or fabricated data in any academic exercise, forges or falsifies academic documents or records, intentionally impedes or damages the academic work of others, engages in conduct aimed at making false representation of a student's academic performance, or assists other students in any of these acts. Examples include but are not limited to: cutting and pasting text from the web without quotation marks or proper citation; paraphrasing from the web without crediting the source; using notes when such use is not allowed; using another person's ideas, words, or research and presenting it as one's own by not properly crediting the originator; stealing examinations or course materials; changing or creating data in a lab experiment; altering a transcript; hiding a book knowing that another student needs it to prepare an assignment; collaboration that is contrary to the stated rules of the course, or tampering with a lab experiment or computer program of another student (read the UW-Madison statement here). Each student in this course is expected to work entirely on her/his own while taking any exam, to complete assignments on her/his own effort without the assistance of others unless directed otherwise by the instructor or teaching assistant. If you have any questions about an assignment, please ask. Academic misconduct either in lab or lecture can result in assignment of "F" by the course instructors as the final grade for the student and any additional actions mandated by University policy.

Academic misconduct applies to laboratory work as well. In your lab manual, be sure to read pages xxiii-xxiv, which deal explicitly with situations you may encounter in laboratory. Before you can work in the laboratory you need to pass a quiz on academic honesty with a perfect score.

Grades

Your grade will be based on a maximum of 1000 points divided as follows:

Sixteen Moodle Online Homeworks @ 8 points each *(see Course Assignment Schedule for due dates; includes both weekly and review homework assignments; homeworks 2-13 are divided into early, 2-point, and regular, 6-point sections)*	128 points
Chem109Wiki assignments: Pre-semester and post-semester surveys (5 points each) Beginning of semester assessment (given in lab, week of Sep 9, 5 points) User page assignment (5 points) One assignment before each exam, four total (10 points each, total 40 points) *(see Chem109Wiki or Course Assignment Schedule for due dates)*	60 points
Twelve Laboratories will make up 24% of the course grade* *(each week's experiment is listed in the schedule; point total includes Pre-Lab Quizzes in Moodle; you must score 60% in lab to pass the course.)*	240 points
Three Computer Assignments *(directions for each available in Moodle)* Window on the Solid State (5 points) Excel Assignment (5 points) Biomolecules Tutorials and Quizzes: (four @ 5 points each; total 20 points) *(due dates are listed in the schedule)*	30 points
Safety Quiz (*must be completed with a perfect score before your first lab*)	4 points
Academic Honesty Quiz (*must be completed with a perfect score before your first lab*)	4 points
Practice Quiz *(see course schedule for due date)*	4 points
TA Personal Evaluation (*based on discussion and lab work*)	30 points
Three midterm exams @ 100 points each *(dates and times are listed in the course schedule)*	300 points
Final Exam *(date and time are listed in the course schedule)*	200 points
Total	1000 points

*Each lab exercise will be graded as described in the laboratory manual. At the end of the semester we will scale the total number of lab points to obtain your final lab point total. If necessary, some grades may be normalized upward to a common scale at the end of the semester to minimize differences in grading practices among discussion/lab sections.

Letter Grades.

Final grades will be based upon the absolute scale shown below. If you score the number of points indicated, then you will receive the letter grade indicated, regardless of how many other students achieve the same grade. There is no curve. Therefore it is to your benefit (and to your friends' benefit) that you help other students learn and they help you learn. After each midterm exam you will be able to determine your probable grade by totaling your earned points, dividing by the total points possible at that time, multiplying by 1000, and comparing with this list.

A	900 points or more
AB	870 to 899 points
B	810 to 869 points
BC	780 to 809 points
C	650 to 779 points
D	600 to 649 points

If necessary some adjustments will be made at the end of the semester, but these adjustments will never lower your final letter grade, only raise it. Past experience in Chem 109 is that the class average is about 3.1 on a four-point scale—above a B average.

CHEMISTRY 104-5

SPRING 2014

General Chemistry 104:	5 credit hours
Lectures:	MWF 3:30-4:20 p.m. in 1351 Chemistry
Lecturer:	Dr. Linda Zelewski
Office:	Room 7108 Chemistry (Take the elevator in the lobby at the corner of Johnson St. and Charter St. up to the 7th floor.)
Email:	zelewski@wisc.edu (Please sign any email messages with your name, your TA's name and your discussion or lab section.)
Office hours:	See Learn@UW Homepage
Website:	https://learn@uw.wisc.edu
General Chemistry Homepage:	http://genchem.chem.wisc.edu
Undergraduate Chemistry Office:	Room 1328 Chemistry, 263-2424

Chemistry 104 is the second semester of a two-semester sequence. Chemistry 103 and 104 provide a general survey of chemical principles and facts, and are prerequisites for advanced courses such as Organic Chemistry (341 or 343), Analytical Chemistry (327 or 329), and Inorganic Chemistry (311).

The prerequisite for Chemistry 104 is Chemistry 103. If it has been more than a semester since you took Chemistry 103, you may need to put in extra effort at the beginning of the semester to gain the necessary background.

REQUIRED MATERIALS

Textbook: *Chemistry: The Central Science* with *MasteringChemistry Technology Kit*, 12th edition by Brown, LeMay, Bursten, Murphy and Woodward, available at the University Bookstore. You may purchase the hardcover edition, a less expensive unbound edition, or an electronic-only textbook (available with a MasteringChemistry account).

Mastering Chemistry Account: Required to access on-line homework assignments. MasteringChemistry accounts are bundled with new textbooks. If you took Chemistry 103 in the last two years, your MasteringChemistry code should still allow you access this semester. If you purchased a used textbook or received a textbook from another student, you must purchase your own access code to the MasteringChemistry system online at http://www.masteringchemistry.com. Instructions on how to register and join the course are given on the course homepage on Learn@UW. The course ID is CHEM104LEC5SP2014.

i>clicker: Available at local bookstores. Bring your i>clicker to every lecture. Your i>clicker must be registered in every class in which you use it. ***To register your i>clicker for Chemistry 104, go to our homepage on Learn@UW and click on "Register your i>clicker".***

Lab Manual: *Chemistry 104 Laboratory Manual*, Spring 2014, Department of Chemistry, UW-Madison, available in the chemistry building lobby from Alpha Chi Sigma ($20, cash only).

Lab Notebook: Carbonless laboratory notebook with duplicate pages, available from Alpha Chi Sigma and local bookstores. (You can continue to use your Chemistry 103 lab notebook until you run out of pages.)

Safety Goggles: Industrial quality eye protection is required at all times when you are in the lab. Safety goggles that fit over regular glasses can be purchased from local bookstores. Contact lenses should not be worn in laboratory because fumes or splashes may be trapped between them and your eyes.

Calculator: An inexpensive calculator having capabilities for square roots, logarithms and exponentiation (antilogarithms) and exponential (scientific) notation operations is required. The calculator will be used on homework assignments, exams and in the lab. A programmable calculator may be used on exams as long as no information is stored on it such as chemical formulas or equations and it does not have a separate keyboard-like key pad.

USB Drive: A USB flash drive that will hold at least 2 GB is required for laboratory data collection.

COURSE INFORMATION

This course has been designed and organized to help you learn chemistry. Your lecturer and TA will do their best to guide you in mastering the material, but no course or instructor can learn for you. Learning is something only you can do.

Many of you have developed and optimized study styles from your Chemistry 103 course. A recommended study strategy for this course is: 1) read through the textbook sections before each lecture, 2) attend class and take your own notes, 3) review your notes and fill in any missing information in your notes using the TA lecture notes posted on Learn@UW or your textbook, and 4) begin to work homework problems as soon as possible after reading each chapter section. When you encounter problems that you cannot solve, refer to the textbook and its example problems, your notes, a MasteringChemistry tutorial, or your fellow classmates. Forming a study group to work through problems is an excellent way to learn chemistry. Use the “chapter summary and key terms”, “key equations” and “key skills” at the end of each chapter to help you focus on key points.

Throughout this course, emphasis will be placed on understanding chemistry and learning to think effectively in solving problems. Successful problem solving requires a basic knowledge of principles, facts and terms: a vocabulary of chemistry. Most of this background and vocabulary should have been obtained from Chemistry 103 or its equivalent. From time to time you may need to review material you studied earlier in Chemistry 103 in order to understand the new material in this course.

LECTURE AND DISCUSSION

Lecture: During lectures, I will introduce principles and illustrate concepts with examples and demonstrations. A lecture is not intended to describe or explain everything you should learn; rather, it will indicate what topics it is important to study and provide some insight into those topics. Read the assigned sections of the textbook prior to lecture. Take notes during lecture to capture your understanding of what you heard and saw. Sample lecture notes taken by a TA will be posted on Learn@UW (under Materials, Content, Course Information) within two days after each lecture.

Classroom Etiquette: Cell phones should be turned off or silenced. While laptops are not prohibited in class, you will not have any need for them during lecture. Using the computer or other devices during class for activities not related to class (such as surfing the web, playing video games, texting, etc.) is both rude and distracting, not only for you, but for those who are sitting nearby. Our lecture room desks

are very noisy when raised or lowered, so please wait until the instructor is completely done speaking before you lower your desk at the end of class. As much as possible, class will be dismissed when the bell rings, but sometimes another minute or two may be needed to finish up. Please be considerate of your classmates.

Lecture Demonstrations: The UW-Madison Chemistry Department has a longstanding tradition of using lecture demonstrations to help students understand chemistry. When a demonstration is done in class, observe what happens and make certain that you understand the principles the demonstration is designed to illustrate. If you do not, ask questions, either in lecture or in your discussion section. All demonstrations are important and questions about demonstrations may appear on exams.

i>clickers: The purpose of using clickers in lecture is to reinforce concepts and to encourage student engagement. By answering lecture questions using your clicker, you can earn up to 25 points toward your final grade. Bring your i>clicker with you to every lecture.

In order to get credit for answering clicker questions, you must register your clicker for Chemistry 104–5 and you must attend the lecture in which you are enrolled. Register your clicker by clicking on the link on our Learn@UW homepage. When you respond to a clicker question in lecture, your clicker sends its ID number and your letter response to a base at the front of the lecture hall. In order to give you credit for your vote, I need to know what clicker number belongs to you. Registering your clicker links your clicker ID number to your name. If you attend the other lecture and use your clicker, you will not receive credit for your vote because your clicker can only be linked to the course in which you are enrolled.

In order to compensate for circumstances in which you may have to miss lecture due to an illness or another legitimate reason, or forget to bring your clicker to lecture or your battery dies, you will earn full credit (25 points) toward your final grade if you answer a minimum of 80% of the lecture questions using your clicker. If you answer less than 80% of the questions, you will earn (% questions answered × 1.25 × 25) points. For example, if you answer 40% of the questions, you will earn 0.40 × 1.25 × 25 = 12.5 points. You do not need to get the question correct in order to earn credit for participating.

Discussion Section: Twice a week, you will meet with a TA and your classmates for discussion. During these meetings you will discuss assigned homework problems, work on group exercises, learn about upcoming laboratory assignments, and have an opportunity to ask questions. Bring specific questions to discussion as it is a great opportunity for you to learn from your TA and fellow classmates. Attendance and participation are highly correlated with comprehension and good grades. When you miss discussion, you miss a learning experience that cannot be duplicated by reading the textbook or lecture notes posted on Learn@UW. To encourage attendance and participation, at the end of the semester, your TA will assign up to 25 points based on attendance and quality of participation during the discussion period. Participation will be evaluated on whether you are prepared for discussion and complete the in-class group exercises and other activities organized by your TA.

Exams: There will be four mid-term exams given during the lecture period, and one final exam. Exams will include questions on material covered in the lectures, discussion, laboratory, and the assigned reading. The final exam will cover topics from the entire semester. ***NO MAKE-UP EXAMS WILL BE GIVEN.***

On each exam you will be given a periodic table, all constants (equilibrium constants, ideal gas constant, etc.), and most of the equations you will need to work out problems on the exam. One week prior to each exam, a set of Exam Objectives will be posted on Learn@UW, which will include all of the

constants and equations that will be provided on the exam. Prior to the exam verify that you know what each variable in an equation represents and that you understand how to use each equation.

Exam 1	Wednesday, February 12	3:30-4:20 p.m.
Exam 2	Friday, March 7	3:30-4:20 p.m.
Exam 3	Wednesday, April 2	3:30-4:20 p.m.
Exam 4	Friday, April 25	3:30-4:20 p.m.
Final Exam	Wednesday, May 14	10:05 a.m.-12:05 p.m.

On-line Homework: Problem solving is a crucial aspect of this course and homework problems will be assigned on a regular basis. There will be an on-line MasteringChemistry homework assignment due most weeks during the semester. Homework problems can be accessed directly through www.masteringchemistry.com, or you can link to this site from our Learn@UW homepage. ***A subset of the problems will be required, supplemented with additional recommended (but optional) practice problems.*** In addition, each problem set will have a few extra credit problems. The maximum score for each homework assignment is 7.5 points, but these extra credit problems can offset small errors and difficulties associated with using the MasteringChemistry software. You can log on multiple times to complete an assignment. For questions with multiple parts, you need to answer all parts of the question in order to get credit for that problem. It is your responsibility to make sure you have completed the entire question before the due date. If you forget to complete all parts of a question, you will receive zero credit for that problem. ***All homework assignments must be completed by 11:59 p.m. on the day of the week it is due.*** Check the Weekly Assignments posted on Learn@UW for homework assignments and due dates.

Like all computer programs, MasteringChemistry requires the exact answer in the required format. If you have not used MasteringChemistry before, do the "Introduction to MasteringChemistry" assignment before attempting your first homework assignment. This assignment will familiarize you with the system and explain the different types of questions you will encounter and how to answer those questions. For example, in some homework problems you will be asked to draw organic structures. "Introduction to MasteringChemistry" explains how the drawing software works.

There will be eleven MasteringChemistry homework assignments, and your highest ten scores will count toward your grade. ***No extensions to the due date will be given, and you will not receive credit for late submissions.*** If you are unable to complete a homework assignment before the deadline for any reason, including illness or a family emergency, depending on how much of the problem set you were able to complete and the rest of your homework grades, this assignment may be your dropped score. Once the due date is past, you can still access homework problems; however, you will not receive points in the course for completing them.

If you encounter technical difficulties with MasteringChemistry pertaining to how answers are submitted/accepted or why you did not get credit for an answer that was actually correct, please send an email to chem104hw@chem.wisc.edu with your name, course number (104-5), and a brief description of the problem. The person receiving your email message receives email from students in other chemistry courses, so it is essential to include your course number (104-5) in your email message. The person receiving your email message will *not* be able to answer content-related questions. If you have content-related questions, please ask your TA.

Wiki Contribution and Written Report: Part of your grade this semester will be based on one written report and one contribution to a class wiki. A wiki is a collaborative website in which content is added

and edited freely. The address for the course wiki is: http://wiki104.chem.wisc.edu/. The wiki constructed by this class will be a free resource that anyone enrolled in the class may use.

You will be assigned to one of four groups determined by your discussion section. Students within a group will then choose a team of 4 students within their discussion section. During the semester, each team of students will complete one page in the wiki and one traditional written report. A Student Guide to the ChemWiki (posted on Learn@UW under "Materials", "Content", "Course Information") describes how to use the wiki and expectations for the wiki assignment. This document also specifies the requirements for the traditional report (See Section 12. Traditional Report Requirements). Information on team assignments and due dates will be posted on Learn@UW and the course wiki site later in the semester.

LABORATORY

The laboratory is a vital part of this course. In lab, you will develop skills that are not easily learned or demonstrated in the lecture hall. These skills include:

- Designing experiments
- Learning proper laboratory techniques
- Using laboratory equipment properly
- Interpreting and analyzing data
- Communicating your ideas through discussions with others and writing

YOU MUST ACHIEVE A MINIMUM SCORE OF 60% IN LAB IN ORDER TO RECEIVE A PASSING GRADE IN THE COURSE.

Safety Quiz: Read the Safety section in your laboratory manual on pages xix-xxii and take the Safety Quiz on Learn@UW (under Assignments, Quizzes). ***The Safety Quiz must be completed no later than Sunday, February 2 at 11:59 p.m.*** There is no limit on how many quiz attempts you may make, and a perfect score of 4/4 is required to pass the quiz**.** If you do not pass the Safety Quiz before February 2, you will still have to take the quiz before you can be allowed to participate in any of the laboratory exercises; however, you will receive 0/4 points toward your final grade.

Academic Honesty Quiz: Read the Statement on Academic Integrity on pps. xxiii-xxiv in your lab manual before taking the Academic Honesty Quiz on Learn@UW (under Assignments, Quizzes). You can take the quiz up to two times and the higher of your attempt(s) will be recorded in Learn@UW. ***This assignment must be completed no later than Sunday, February 2 at 11:59 p.m.*** In addition to completing the online assignment, you must complete the form following page xxiv in your lab manual, and give it to your TA before you will be allowed to perform any laboratory experiments.

Laboratory Assignments: There are ten laboratory assignments. Instructions for the labs and a description of the grading rubric are described in the lab manual. The use of cell phones in lab is strictly prohibited.

Laboratory Preparation: Before coming to lab you need to

- Read "Preparing for the Experiment" in the lab manual, and carry out the directions given. Note that online quizzes for most experiments are available on Learn@UW as a resource. ***These laboratory quizzes are not a graded component of this course.***
- Review relevant sections of your textbook.
- View the appropriate ChemPages on the web.
- Prepare your laboratory notebook. Before coming to lab, write a short summary statement and procedural outline of the experiment (see page xi in your lab manual for more information on what

this entails), make tables to record experimental data, leave areas to record experimental observations, do any pre-lab calculations, and answer any prelab questions An example of a prepared notebook is provided in the lab manual on pages xxxvii – xxxviii.

Your TA will check your notebook at the beginning of the lab session to make sure these requirements are met***. If you arrive without a properly prepared notebook, you will be asked to leave the lab to correct this.*** Points will be deducted from your lab score for that assignment in accordance with the percentage of the procedure you were unable to participate in while preparing your lab notebook.

Safety in the Laboratory: The "Safety" section of the lab manual covers general safety precautions for all experiments. Each experiment also has a "For Your Safety" section with specific precautions that you should read before coming to lab. Failure to follow proper safe laboratory practices, including not wearing safety goggles, may lead to you being ejected from the laboratory and receiving zero credit for the experiment.

Attendance: You are required to arrive to lab on time. Your TA will review safety information and any modifications to the experiment at the start of the lab period. ***If you are late and miss part or all of the prelab discussion, you may not be allowed to enter the laboratory to perform the experiment.***

Unless you are formally excused, you must attend all laboratory sessions. There are no procedures to make-up laboratories you miss, and a grade of zero will be recorded for all unexcused absences. If you have an extenuating circumstance that will require you to miss lab, notify your TA as soon as possible before the lab period, and receive confirmation from your TA that your absence meets the requirements for being excused.

Reports: For most experiments, reports are due at the end of the laboratory period unless your TA specifies otherwise. Points may be deducted if reports are turned in late. ***If you place a lab report in your TA's mailbox, it is your responsibility to send your TA an email notifying them. Lab reports turned in without email notification may not be accepted for credit.***

PRE-SEMESTER ASSESSMENT AND SURVEYS

Pre-Semester Assessment: During the second week of classes, you will be given a pre-semester assessment in your discussion section to determine your prior knowledge of concepts that will be taught in Chemistry 104. Full credit (4 points) will be given for completing this assessment; you will not be graded on accuracy.

Pre-Semester and End-of-Semester Surveys: Two on-line surveys will be given, one at the beginning and one at the end of the semester. In the surveys, you will be asked to respond to questions regarding your experiences learning chemistry. Each survey is worth 4 points and full credit will be given for completing the survey. Links to the surveys and deadlines for completing each survey will be posted on Learn@UW.

LEARN@UW

Much of the material for this course is only available via our Chemistry 104 Learn@UW webpage (https://learnuw.wisc.edu/). The site contains assignments and due dates, schedules, office hours, TA lecture notes, PowerPoint slides, course handouts, announcements, and other materials. Check this site frequently throughout the semester.

ACADEMIC MISCONDUCT

It is expected that all students will conduct themselves with honesty, integrity, and professionalism. Any student caught cheating on an exam will receive an F in the course. This penalty includes incidents such as looking at another student's paper during an exam or altering an exam after it has been graded and then submitting it for re-grading. Any student caught cheating on a lab report (for instance, copying another person's work, bringing lab notebook pages from another student to the lab or fabricating data) will receive a zero for that assignment. A second infraction will result in an F for the course. More information on what constitutes academic misconduct and UW policies on handling misconduct can be found at: http://www.wisc.edu/students/saja/misconduct/UWS14.html and http://writing.wisc.edu/Handbook/QPA_plagiarism.html.

You are responsible for understanding what constitutes academic misconduct. If you do not understand, you should consult the hyperlink above, or discuss this further with Dr. Zelewski. Note that if an assignment is completed as a group (for example, a group lab report or research paper), ***all group members are responsible for ensuring that the assignment meets the standards for academic conduct.*** All group members who contributed to an assignment that is found to violate the standards for academic honesty will be held equally responsible. If you are placing your name on an assignment, it is your responsibility to ensure that assignment was completed with integrity. If you believe that a member of your lab group is committing academic misconduct, you should notify your TA. Students who assist other students in committing academic misconduct are also in violation of UWS 14.

ATTENDANCE POLICY

Your attendance at all scheduled classes is mandatory and essential for success in the course. However, circumstances occasionally occur where a student must miss a class. Students sometimes need to miss class for a religious observance, a UW athletic commitment, a field trip for another course, or some other legitimate reason. These are PLANNED absences and ***any arrangements for making up missed work must be made well before the absence occurs.*** Students who have a religious conflict with an exam must report the conflict to their TA within the first two weeks of classes. Students who have a UW athletic commitment, UW field trip for another course, or other legitimate school related reason for missing a class must report the conflict to their TA as soon as possible and a minimum of two weeks before the absence occurs. If you are seriously ill or have a family emergency and are unable to attend class, inform your TA as soon as possible via email. Lecture notes and PowerPoint slides for missed lectures are available on Learn@UW.

GRADES

Point Distribution: If no changes are made, the total number of points you can earn is 829. The point distribution is detailed below. Minor adjustments may be made during the semester if needed. You will be advised of any changes.

Laboratory Safety Quiz	4 points
Academic Honesty Quiz	4 points
Assessment & Surveys	12 points
Wiki User Page Assignment	4 points
Wiki Page	15 points
Traditional Written Report	15 points
Laboratory: 10 experiments @ 15 points each	150 points
On-line Homework: highest 10 of 11 at @ 7.5 points each	75 points
Discussion	25 points
Clicker Participation	25 points
4 Midterm Exams @ 75 points each	300 points
Final Exam	200 points

Your letter grade will be determined by calculating your final percentage using the formula:

$$\% \text{ score} = (\text{total points earned} / \text{total possible points}) \times 100\%$$

Lab grades will be normalized to a common scale before final grades are determined to minimize differences in grading practices between laboratory sections.

Intended Grading Scale: Letter grades will be assigned at the end of the semester based on the following intended grading scale:

A	90.0%
AB	88.0%
B	80.0%
BC	78.0%
C	70.0%
D	60.0%

This scale may be adjusted downward at the end of the semester, depending on the overall class average. It will never be adjusted upward. At the end of the semester, if the average class grade is less than 78%, the grading scale will be lowered so the average course grade is at least a BC and the grade distribution is consistent with historical Chemistry 104 final grade distributions.

Review Your Grades: All grades will be entered electronically in Learn@UW. Be sure to review your scores regularly and notify your TA promptly of any discrepancies. ***Any discrepancies must be brought to your TA's attention before the final exam. After final grades have been released to the Registrar, no changes to grades will be made.***

RESOURCES

Numerous resources are available to assist you with this course and college life in general. It is up to you to take advantage of these resources to ensure your success both in this course and at UW-Madison.

Course Web-site on Learn@UW (https://learnuw.wisc.edu/): The site contains weekly assignments, due dates, schedules, office hours, TA lecture notes, course handouts, and other materials.

General Chemistry Web Site (http://www.chem.wisc.edu/content/genchem-main/): Resource materials for general chemistry students are available on the General Chemistry website. ChemPages, and other lab resources are accessed via the "Materials for Laboratory" link.

Study Groups: Students are strongly urged to form groups of several students in order to study together outside of class and to collaborate on working homework assignments and laboratory discussion questions. A study group reflects the teamwork inherent in the way modern science is normally carried out at academic institutions – namely, scientists often collaborate with one another, either within the same university and/or with individuals or groups elsewhere. However, it is important to realize that although you may collaborate with other students on assignments***, the work you turn in must be your own.*** Thus, you must turn in an individual write-up (not a copy of the study group's work) of your laboratory assignments. It has been found that students who interact with one another via Study Groups do significantly better in mastering the material in this course.

Tutoring Services: A number of tutoring resources are available on campus, some free and some for a fee. For more information, see our Learn@UW site or the General Chemistry home page.

Advising and Counseling Services: (University Health Services): College life can be stressful. If you are struggling with your academic course load or other academic issues, your advisor is a good resource. If you are struggling emotionally with anxiety, depression, or other health issues, individual counseling is available at University Counseling and Consultation Services. For more information go their website (http://www.uhs.wisc.edu/services/counseling/) or call 265-5600. Crisis intervention services are also available 24 hours a day by dialing this same phone number and pressing option 9.

Health or Disability Concerns: All students are entitled to an accessible, accommodating and supportive teaching and learning environment. Appropriate accommodations for lecture, laboratory, discussion, and/or exams can be arranged for students with disabilities. The McBurney Disability Resource Center (http://www.mcburney.wisc.edu/) can provide assistance. ***Students needing accommodations for this class should contact Dr. Zelewski and their TA during the first week of classes to discuss arrangements.***

CHEMISTRY 104-5 OUTLINE AND CALENDAR

Specific reading assignments and a complete listing of all assignments and due dates are posted on Learn@UW.

WEEK	DATE	LECTURE TOPIC	CH.	LAB
1	Jan 20 Jan 22 Jan 24	*MLK Day-No Classes* Organic and Biological Chemistry Organic and Biological Chemistry	9.2-9.6 24	*No Lab*
2	Jan 27 Jan 29 Jan 31	Organic and Biological Chemistry Organic and Biological Chemistry Organic and Biological Chemistry	24	Check In/ Molecular Structures
3	Feb 3 Feb 5 Feb 7	Organic and Biological Chemistry Organic and Biological Chemistry Organic and Biological Chemistry	24	Preparation of Aspirin and Some Flavoring Esters
4	Feb 10 Feb 12 Feb 14	Review **EXAM 1 (3:30-4:20 p.m.)** Organic and Biological Chemistry	24	*No Lab*
5	Feb 17 Feb 19 Feb 21	Organic and Biological Chemistry Organic and Biological Chemistry Chemical Kinetics	24 14	Biodiesel
6	Feb 24 Feb 26 Feb 28	Chemical Kinetics Chemical Kinetics Chemical Kinetics	14	Redox Titration
7	Mar 3 Mar 5 Mar 7	Chemical Kinetics Review **EXAM 2 (3:30-4:20 p.m.)**	14	*No Lab*
8	Mar 10 Mar 12 Mar 14	Chemical Equilibrium Chemical Equilibrium Chemical Equilibrium	15	Crystal Violet
	Mar 17-21	*Spring Recess-No Classes*		
9	Mar 24 Mar 26 Mar 28	Chemical Thermodynamics Chemical Thermodynamics Chemical Thermodynamics	19	Chemical Equilibrium and Le Châtelier's Principle
10	Mar 31 Apr 2 Apr 4	Review **EXAM 3 (3:30-4:20 p.m.)** Acid-Base Equilibria	16	*No Lab*
11	Apr 7 Apr 9 Apr 11	Acid-Base Equilibria Acid-Base Equilibria Acid-Base Equilibria	16	Chemical Equilibrium and Thermodynamics
12	Apr 14 Apr 16 Apr 18	Aqueous Equilibria Aqueous Equilibria Aqueous Equilibria	17	Acid and Base Solutions
13	Apr 21 Apr 23 Apr 25	Aqueous Equilibria Review **EXAM 4 (3:30-4:20 p.m.)**	17	*No Lab*
14	Apr 28 Apr 30 May 2	Electrochemistry Electrochemistry Electrochemistry	20	Copper Ammine
15	May 5 May 7 May 9	Electrochemistry Electrochemistry Review	20	Electrochemical Cells/ Check-out
FINALS	May 14 (Wed)	**FINAL EXAM (10:05 a.m.-12:05 p.m.)**		

Appendix F: Surveys

Appendix F contains the full survey text of all pre- and post-study surveys. These surveys were administered via Qualtrics, an online survey software package. For study I (Chem 104, spring 2013), the experimental and control groups completed the same pre- and post-study surveys. In study II (Chem 109, fall 2013), the experimental and control groups completed the same pre-study survey, but completed different post-study surveys. The experimental and control groups in study III (Chem 104, spring 2014) also completed the same pre-study survey, but completed different post-study surveys.

Chem 104 Wiki Pre-Survey (Spring 2013, Moore)

Q1 How accurately does each statement describe you?

	Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
I find chemistry concepts interesting and challenging.	❍	❍	❍	❍	❍	❍
I have trouble understanding anything based on chemistry.	❍	❍	❍	❍	❍	❍
Chemistry intimidates me.	❍	❍	❍	❍	❍	❍
I participate confidently in discussions with school friends about chemical topics.	❍	❍	❍	❍	❍	❍
I have a lot of intellectual curiosity.	❍	❍	❍	❍	❍	❍
I am good at combining ideas in ways that others have not tried.	❍	❍	❍	❍	❍	❍
I hate most academic subjects.	❍	❍	❍	❍	❍	❍
I wish I had more imagination and originality.	❍	❍	❍	❍	❍	❍
I can communicate chemistry effectively.	❍	❍	❍	❍	❍	❍

Q2 Please indicate how often you use the following resources to help you study.

	Never	Occasionally	Often	Very Often
Lecture notes that I've taken	❍	❍	❍	❍
TA lecture notes	❍	❍	❍	❍
Course textbook	❍	❍	❍	❍
Class website	❍	❍	❍	❍
Course websites from other institutions	❍	❍	❍	❍
Wikipedia	❍	❍	❍	❍
Search engine (Google, Yahoo!, Bing, etc.)	❍	❍	❍	❍
Other websites	❍	❍	❍	❍
Other resources	❍	❍	❍	❍

Q3 Please indicate how many times a week you use the following resources.

	Less than Once a Week	Once a Week	2-3 Times a Week	3-4 Times a Week	Daily
How often do you use the internet to help you learn chemistry?	❍	❍	❍	❍	❍
How often do you use Wikipedia to help you learn chemistry?	❍	❍	❍	❍	❍
How often do you use Wikipedia to help you learn about other subjects (i.e. not for studying purposes)?	❍	❍	❍	❍	❍

Q4 Have you ever edited a wiki before?
- ❍ Yes
- ❍ No

Q5 If not, why?
- ❍ Don't know how
- ❍ Takes too much time
- ❍ Do not want to make public contributions
- ❍ Not an expert on the subject material
- ❍ Not interested
- ❍ Other: _____

Q6 Why are you taking Chemistry 104? Check all that apply.
- ❑ Degree requirement
- ❑ Prerequisite for professional or graduate school (e.g. medical school, Ph.D. program)
- ❑ Personal interest in the subject matter
- ❑ Other: _____

Q7 What is your major (or intended major)?

Q8 What is your NetID? This information is needed to make sure that you receive credit for this survey.

Q9 Which discussion section are you in? This information is needed to make sure that you receive credit for this survey. Please type in 4XX form (e.g. 441)

Q10 Are you participating in the wiki research project?
- ❍ Yes
- ❍ No

Chem 104 Wiki Post-Survey

Before answering the questions below, please write down the concepts of the topics that you edited over the course of this semester. If you do not know which topics these are, follow the directions below: 1) Go to http://chem104wiki.chem.wisc.edu/mediawiki/code/index.php/Main_Page and click on "My contributions" in the top right corner of the screen. The pages (not the concepts) that you edited are listed here. Write these pages down. 2) Go to http://chem104wiki.chem.wisc.edu/mediawiki/code/index.php/Main_Page#Chemistry_104_Topics_.28divided_by_exam.29 and find the concept heading of the pages that you edited. For example, if I edited the page "Electron density model", then I edited the concept "Organic Structures: Hydrocarbons" because that is the concept heading the page is under. Please take the time and care necessary to answer the next three questions correctly. If you do not answer these questions correctly, you will not get credit for taking this survey!

1. Which exam 1 concepts did you edit?
- ❑ Intermolecular forces
- ❑ Organic Structures: Hydrocarbons
- ❑ Organic Structures: Functional Groups and Polymer
- ❑ Organic Reactions
- ❑ DNA and Proteins
- ❑ Lipids, Carbohydrates, and Polysaccharides
- ❑ I did not edit any exam 1 topics.

2. Which exam 2 concepts did you edit?
- ❑ Rate Laws
- ❑ Integrated Rate Laws
- ❑ Mechanisms and Catalysts
- ❑ Applications of Catalysis
- ❑ Equilibrium States
- ❑ Non-Equilibrium States
- ❑ I did not edit any exam 2 topics.

3. Which exam 3 concepts did you edit?
- ❑ Enthalpy and Entropy
- ❑ Gibbs Free Energy
- ❑ Intro to Acids and Bases
- ❑ Aqueous Acidic Acids and Bases
- ❑ Buffers and Lewis Acids and Bases
- ❑ Titrations
- ❑ I did not edit any exam 3 concepts.

4. How accurately does each statement describe you?

	Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
I find chemistry concepts interesting and challenging.	❍	❍	❍	❍	❍	❍
I have trouble understanding anything based on chemistry.	❍	❍	❍	❍	❍	❍
Chemistry intimidates me.	❍	❍	❍	❍	❍	❍
I participate confidently in discussions with school friends about chemical topics.	❍	❍	❍	❍	❍	❍
I have a lot of intellectual curiosity.	❍	❍	❍	❍	❍	❍
I am good at combining ideas in ways that others have not tried.	❍	❍	❍	❍	❍	❍
I hate most academic subjects.	❍	❍	❍	❍	❍	❍
I wish I had more imagination and originality.	❍	❍	❍	❍	❍	❍
I can communicate chemistry effectively.	❍	❍	❍	❍	❍	❍

5. Did you make original contributions to the wiki 4 times (i.e. one or more time prior to each exam)?

- ❍ Yes
- ❍ No

6. Please answer the following questions about your experience with the wiki.

	Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
Writing original contributions in the Chem 104 wiki helped me learn chemical concepts.	❍	❍	❍	❍	❍	❍
Reading the Chem 104 wiki helped me learn chemical concepts.	❍	❍	❍	❍	❍	❍
Editing other students' contributions on the Chem 104 wiki helped me learn chemical concepts.	❍	❍	❍	❍	❍	❍
I enjoyed contributing to the Chem 104 wiki.	❍	❍	❍	❍	❍	❍
I am proud of the contributions that I made to the Chem 104 wiki.	❍	❍	❍	❍	❍	❍
I feel comfortable using ACS style notation to cite other sources when writing scientifically.	❍	❍	❍	❍	❍	❍
I trust the content on the Chem 104 Wiki.	❍	❍	❍	❍	❍	❍
If the content of the Chem	❍	❍	❍	❍	❍	❍

104 Wiki was monitored by either a professor or TA, I would trust the content on the Chem 104 wiki more.						
I feel more comfortable editing Wikipedia or other wiki-based sites than before the beginning of this semester.	❍	❍	❍	❍	❍	❍
I feel more comfortable working with digital media (e.g. downloading files, navigating web pages) than before the beginning of this semester.	❍	❍	❍	❍	❍	❍
I corrected errors in Chem 104 wiki entries when I saw them (or I would have corrected them if I had noticed them).	❍	❍	❍	❍	❍	❍
Writing entries on the Chem 104 wiki was straightforward and user-friendly.	❍	❍	❍	❍	❍	❍

7. If you have any comments and/or suggestions on how to improve the Chem 104 wiki as a class resource, please write them here.

8. How often did you read the Chem 104 wiki?
- ❍ Less than Once a Week
- ❍ Once a Week
- ❍ 2-3 Times a Week
- ❍ 3-4 Times a Week
- ❍ Daily
- ❍ I did not read the wiki.

9. If you did read the Chem 104 wiki, how useful was it?
- ❍ Very Useless
- ❍ Useless
- ❍ Somewhat Useless
- ❍ Somewhat Useful
- ❍ Useful
- ❍ Very Useful

10. If you did not read the Chem 104 wiki, why not?
- ❑ I don't trust the content
- ❑ I didn't have time
- ❑ The material was not formatted in an appealling way
- ❑ The content was not helpful
- ❑ I had limited access to the Chem 104 wiki
- ❑ Other: _____

11. Please indicate how often you use the following resources to help you study.

	Never	Occasionally	Often	Very Often
Lecture notes that I've taken	❍	❍	❍	❍
TA lecture notes	❍	❍	❍	❍
Course textbook	❍	❍	❍	❍
Class website	❍	❍	❍	❍
Course websites from other institutions	❍	❍	❍	❍
Wikipedia (not the Chem 104 wiki)	❍	❍	❍	❍
Search engine (Google, Yahoo!, Bing, etc.)	❍	❍	❍	❍
Other websites	❍	❍	❍	❍
Other resources	❍	❍	❍	❍

12. Please indicate how many times a week you use the following resources.

	Less than Once a Week	Once a Week	2-3 Times a Week	3-4 Times a Week	Daily
How often do you use the internet to help you learn chemistry?	❍	❍	❍	❍	❍
How often do you use Wikipedia (not the Chem 104 wiki) to help you learn chemistry?	❍	❍	❍	❍	❍
How often do you use Wikipedia (not the Chem 104 wiki) to help you learn about other subjects (i.e. not for studying purposes)?	❍	❍	❍	❍	❍

13. What is your NetID (e.g. jdoe5)? This information is needed to make sure that you receive credit for this survey.

14. Which discussion section are you in? This information is needed to make sure that you receive credit for this survey. Please type in 4XX form (e.g. 441)

15. Did you sign a consent form to participate in the wiki research study?

❍ Yes

❍ No

Chem 109 Wiki Pre-Survey (Fall 2013)

Q1 How accurately does each statement describe you?

	Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
I find chemistry concepts interesting and challenging.	❍	❍	❍	❍	❍	❍
I have trouble understanding anything based on chemistry.	❍	❍	❍	❍	❍	❍
Chemistry intimidates me.	❍	❍	❍	❍	❍	❍
I participate confidently in discussions with school friends about chemical topics.	❍	❍	❍	❍	❍	❍
I have a lot of intellectual curiosity.	❍	❍	❍	❍	❍	❍
I am good at combining ideas in ways that others have not tried.	❍	❍	❍	❍	❍	❍
I hate most academic subjects.	❍	❍	❍	❍	❍	❍
I wish I had more imagination and originality.	❍	❍	❍	❍	❍	❍
I can communicate chemistry effectively.	❍	❍	❍	❍	❍	❍

Q2 Please indicate how often you use the following resources to help you study.

	Never	Occasionally	Often	Very Often
Lecture notes that I've taken	❍	❍	❍	❍
TA lecture notes	❍	❍	❍	❍
Course textbook	❍	❍	❍	❍
Online textbook (available only to Chem 109 students)	❍	❍	❍	❍
Chem 109 class website	❍	❍	❍	❍
Course websites from other institutions	❍	❍	❍	❍
Wikipedia	❍	❍	❍	❍
Search engine (Google, Yahoo!, Bing, etc.)	❍	❍	❍	❍
Other websites	❍	❍	❍	❍
Other resources	❍	❍	❍	❍

Q3 Please indicate how many times a week you use the following resources.

	Less than Once a Week	Once a Week	2-3 Times a Week	3-4 Times a Week	Daily
How often do you use the internet to help you learn chemistry?	❍	❍	❍	❍	❍
How often do you use Wikipedia to help you learn chemistry?	❍	❍	❍	❍	❍
How often do you use Wikipedia to help you learn about other subjects (i.e. not for studying purposes)?	❍	❍	❍	❍	❍

Q4 Have you ever edited a wiki before?

❍ Yes
❍ No

Q5 If you have not edited a wiki before, why?

❍ Don't know how
❍ Takes too much time
❍ Do not want to make public contributions
❍ Not an expert on the subject material
❍ Not interested
❍ Other: _____

Q6 Why are you taking general chemistry? Check all that apply.

❑ Degree requirement
❑ Prerequisite for professional or graduate school (e.g. medical school, Ph.D. program)
❑ Personal interest in the subject matter
❑ Other: _____

Q7 What is your major (or intended major)?

Q8 What is your 10-digit campus ID number? (e.g. 9061112222) This information is needed to make sure that you receive credit for this survey. Please enter all 10 digits with no spaces or hyphens between numbers.

Q9 Which discussion section are you in? This information is needed to make sure that you receive credit for this survey. Please type in XXX form (e.g. 541)

Q10 Do you plan on participating in the wiki research project?

- ❍ Yes
- ❍ No

Chem 109 Fall 2013 Post-Survey: Experimental Group

1. How accurately does each statement describe you?

	Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
I find chemistry concepts interesting and challenging.	❍	❍	❍	❍	❍	❍
I have trouble understanding anything based on chemistry.	❍	❍	❍	❍	❍	❍
Chemistry intimidates me.	❍	❍	❍	❍	❍	❍
I participate confidently in discussions with school friends about chemical topics.	❍	❍	❍	❍	❍	❍
I have a lot of intellectual curiosity.	❍	❍	❍	❍	❍	❍
I am good at combining ideas in ways that others have not tried.	❍	❍	❍	❍	❍	❍
I hate most academic subjects.	❍	❍	❍	❍	❍	❍
I wish I had more imagination and originality.	❍	❍	❍	❍	❍	❍
I can communicate chemistry effectively.	❍	❍	❍	❍	❍	❍

2. Please answer the following questions about your experience with the wiki.

	Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
Writing original contributions in the Chem 109 wiki helped me learn chemical concepts.	❍	❍	❍	❍	❍	❍
Reading the Chem 109 wiki helped me learn chemical concepts.	❍	❍	❍	❍	❍	❍
Editing other students' contributions on the Chem 109 wiki helped me learn chemical concepts.	❍	❍	❍	❍	❍	❍
I enjoyed contributing to the Chem 109 wiki.	❍	❍	❍	❍	❍	❍
I am proud of the contributions that I made to the Chem 109 wiki.	❍	❍	❍	❍	❍	❍
I feel comfortable using ACS style notation to cite other sources when writing scientifically.	❍	❍	❍	❍	❍	❍
I trust the content on the Chem 109 Wiki.	❍	❍	❍	❍	❍	❍
If the content of the Chem	❍	❍	❍	❍	❍	❍

109 Wiki was monitored by either a professor or TA, I would trust the content on the Chem 109 wiki more.						
I feel more comfortable editing Wikipedia or other wiki-based sites than before the beginning of this semester.	❍	❍	❍	❍	❍	❍
I feel more comfortable working with digital media (e.g. downloading files, navigating web pages) than before the beginning of this semester.	❍	❍	❍	❍	❍	❍
I corrected errors in Chem 109 wiki entries when I saw them (or I would have corrected them if I had noticed them).	❍	❍	❍	❍	❍	❍
Writing entries on the Chem 109 wiki was straightforward and user-friendly.	❍	❍	❍	❍	❍	❍
Writing traditional	❍	❍	❍	❍	❍	❍

reports (hard copy reports) helped me learn chemical concepts.						
Constructing entries on the Chem 109 wiki was more helpful in learning chemical concepts than writing traditional reports (hard copy reports).	❍	❍	❍	❍	❍	❍

3. Which assignment was more helpful for learning chemical concepts?
- ❍ Writing in the Chem 109 Wiki
- ❍ Writing traditional reports on chemical concepts

3_TEXT. Why was the assignment you chose in Q2.2 more helpful for learning chemical concepts?

4. If you have any comments and/or suggestions on how to improve the Chem 109 wiki as a class resource, please write them here.

5. If you have any comments and/or suggestions on how to improve the written traditional reports as an assignment, please write them here.

6. How often did you read the Chem 109 wiki?
- ❍ Less than Once a Week
- ❍ Once a Week
- ❍ 2-3 Times a Week
- ❍ 3-4 Times a Week
- ❍ Daily
- ❍ I did not read the wiki.

7. If you did read the Chem 109 wiki, how useful was it?

❍ Very Useless
❍ Useless
❍ Somewhat Useless
❍ Somewhat Useful
❍ Useful
❍ Very Useful

8. If you did not read the Chem 109 wiki, why not?

❑ I don't trust the content
❑ I didn't have time
❑ The material was not formatted in an appealing way
❑ The content was not helpful
❑ I had limited access to the Chem 109 wiki
❑ Other: _____

9. Please indicate how often you use the following resources to help you study.

	Never	Occasionally	Often	Very Often
Lecture notes that I've taken	❍	❍	❍	❍
TA lecture notes	❍	❍	❍	❍
Course textbook	❍	❍	❍	❍
Class website	❍	❍	❍	❍
Course websites from other institutions	❍	❍	❍	❍
Wikipedia (not the Chem 109 wiki)	❍	❍	❍	❍
Search engine (Google, Yahoo!, Bing, etc.)	❍	❍	❍	❍
Other websites	❍	❍	❍	❍
Other resources	❍	❍	❍	❍

10. Please indicate how many times a week you use the following resources.

	Less than Once a Week	Once a Week	2-3 Times a Week	3-4 Times a Week	Daily
How often do you use the internet to help you learn chemistry?	❍	❍	❍	❍	❍
How often do you use Wikipedia (not the Chem 109 wiki) to help you learn chemistry?	❍	❍	❍	❍	❍
How often do you use Wikipedia (not the Chem 109 wiki) to help you learn about other subjects (i.e. not for studying purposes)?	❍	❍	❍	❍	❍

11. What is your 10-digit campus ID number? This information is needed to make sure that you receive credit for this survey.

12. Which discussion section are you in? This information is needed to make sure that you receive credit for this survey. Please type in 5XX form (e.g. 541)

13. Did you sign a consent form to participate in the wiki research study?

❍ Yes

❍ No

Chem 109 Fall 2013 Post-Survey: Control Group

1. How accurately does each statement describe you?

	Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
I find chemistry concepts interesting and challenging.	❍	❍	❍	❍	❍	❍
I have trouble understanding anything based on chemistry.	❍	❍	❍	❍	❍	❍
Chemistry intimidates me.	❍	❍	❍	❍	❍	❍
I participate confidently in discussions with school friends about chemical topics.	❍	❍	❍	❍	❍	❍
I have a lot of intellectual curiosity.	❍	❍	❍	❍	❍	❍
I am good at combining ideas in ways that others have not tried.	❍	❍	❍	❍	❍	❍
I hate most academic subjects.	❍	❍	❍	❍	❍	❍
I wish I had more imagination and originality.	❍	❍	❍	❍	❍	❍
I can communicate chemistry effectively.	❍	❍	❍	❍	❍	❍

2. Please indicate how often you use the following resources to help you study.

	Never	Occasionally	Often	Very Often
Lecture notes that I've taken	❍	❍	❍	❍
TA lecture notes	❍	❍	❍	❍
Course textbook	❍	❍	❍	❍
Class website	❍	❍	❍	❍
Course websites from other institutions	❍	❍	❍	❍
Wikipedia	❍	❍	❍	❍
Search engine (Google, Yahoo!, Bing, etc.)	❍	❍	❍	❍
Other websites	❍	❍	❍	❍
Other resources	❍	❍	❍	❍

3. Please indicate how many times a week you use the following resources.

	Less than Once a Week	Once a Week	2-3 Times a Week	3-4 Times a Week	Daily
How often do you use the internet to help you learn chemistry?	❍	❍	❍	❍	❍
How often do you use Wikipedia to help you learn chemistry?	❍	❍	❍	❍	❍
How often do you use Wikipedia to help you learn about other subjects (i.e. not for studying purposes)	❍	❍	❍	❍	❍

4. What is your 10-digit campus ID number? This information is needed to make sure that you receive credit for this survey.

5. Which discussion section are you in? This information is needed to make sure that you receive credit for this survey. Please type in 5XX form (e.g. 501)

6. Did you sign a consent form to participate in the research study?

- ❍ Yes
- ❍ No

Chem 104 Wiki Pre-Survey- (Spring 2014)

Q1 How accurately does each statement describe you?

	Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
I find chemistry concepts interesting and challenging.	❍	❍	❍	❍	❍	❍
I have trouble understanding anything based on chemistry.	❍	❍	❍	❍	❍	❍
Chemistry intimidates me.	❍	❍	❍	❍	❍	❍
I participate confidently in discussions with school friends about chemical topics.	❍	❍	❍	❍	❍	❍
I have a lot of intellectual curiosity.	❍	❍	❍	❍	❍	❍
I am good at combining ideas in ways that others have not tried.	❍	❍	❍	❍	❍	❍
I hate most academic subjects.	❍	❍	❍	❍	❍	❍
I wish I had more imagination and originality.	❍	❍	❍	❍	❍	❍
I can communicate chemistry effectively.	❍	❍	❍	❍	❍	❍

Q2 Please indicate how often you use the following resources to help you study.

	Never	Occasionally	Often	Very Often
Lecture notes that I've taken	❍	❍	❍	❍
TA lecture notes	❍	❍	❍	❍
Course textbook	❍	❍	❍	❍
Online textbook (available only to Chem 104 students)	❍	❍	❍	❍
Chem 104 class website	❍	❍	❍	❍
Course websites from other institutions	❍	❍	❍	❍
Wikipedia	❍	❍	❍	❍
Search engine (Google, Yahoo!, Bing, etc.)	❍	❍	❍	❍
Other websites	❍	❍	❍	❍
Other resources	❍	❍	❍	❍

Q3 Please indicate how many times a week you use the following resources.

	Less than Once a Week	Once a Week	2-3 Times a Week	3-4 Times a Week	Daily
How often do you use the internet to help you learn chemistry?	❍	❍	❍	❍	❍
How often do you use Wikipedia to help you learn chemistry?	❍	❍	❍	❍	❍
How often do you use Wikipedia to help you learn about other subjects (i.e. not for studying purposes)?	❍	❍	❍	❍	❍

Q4 Have you ever edited a wiki before?

❍ Yes
❍ No

Q5 If you have not edited a wiki before, why?

❍ Don't know how
❍ Takes too much time
❍ Do not want to make public contributions
❍ Not an expert on the subject material
❍ Not interested
❍ Other: _____

Q6 Why are you taking general chemistry? Check all that apply.

❑ Degree requirement
❑ Prerequisite for professional or graduate school (e.g. medical school, Ph.D. program)
❑ Personal interest in the subject matter
❑ Other: _____

Q7 What is your major (or intended major)?

Q8 What is your 10-digit campus ID number? (e.g. 9061112222) This information is needed to make sure that you receive credit for this survey. Please enter all 10 digits with no spaces or hyphens between numbers.

Q9 Which discussion section are you in? This information is needed to make sure that you receive credit for this survey. Please type in XXX form (e.g. 481)

Q10 Do you plan on participating in the wiki research project?

- ❍ Yes
- ❍ No

Chem 104 Spring 2014 Post-Survey: Experimental Group

1. How accurately does each statement describe you?

	Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
I find chemistry concepts interesting and challenging.	❍	❍	❍	❍	❍	❍
I have trouble understanding anything based on chemistry.	❍	❍	❍	❍	❍	❍
Chemistry intimidates me.	❍	❍	❍	❍	❍	❍
I participate confidently in discussions with school friends about chemical topics.	❍	❍	❍	❍	❍	❍
I have a lot of intellectual curiosity.	❍	❍	❍	❍	❍	❍
I am good at combining ideas in ways that others have not tried.	❍	❍	❍	❍	❍	❍
I hate most academic subjects.	❍	❍	❍	❍	❍	❍
I wish I had more imagination and originality.	❍	❍	❍	❍	❍	❍
I can communicate chemistry effectively.	❍	❍	❍	❍	❍	❍

2. Please answer the following questions about your experience with the wiki.

	Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
Writing original contributions in the Chem 104 wiki helped me learn chemical concepts.	❍	❍	❍	❍	❍	❍
Reading the Chem 104 wiki helped me learn chemical concepts.	❍	❍	❍	❍	❍	❍
Editing other students' contributions on the Chem 104 wiki helped me learn chemical concepts.	❍	❍	❍	❍	❍	❍
I enjoyed contributing to the Chem 104 wiki.	❍	❍	❍	❍	❍	❍
I am proud of the contributions that I made to the Chem 104 wiki.	❍	❍	❍	❍	❍	❍
I trust the content on the Chem 104 Wiki.	❍	❍	❍	❍	❍	❍
If the content of the Chem 104 Wiki was edited by either a professor or TA, I would trust the content on the Chem 104 wiki.	❍	❍	❍	❍	❍	❍

I am more likely to edit Wikipedia or other wiki-based sites now than before the beginning of this semester.	❍	❍	❍	❍	❍	❍
I feel more comfortable working with digital media (e.g. downloading files, navigating web pages) than before the beginning of this semester.	❍	❍	❍	❍	❍	❍
I corrected errors in Chem 104 wiki entries when I saw them.	❍	❍	❍	❍	❍	❍
I would have corrected errors in Chem 104 wiki entries if I had noticed them.	❍	❍	❍	❍	❍	❍
Writing entries on the Chem 104 wiki was straightforward and user-friendly.	❍	❍	❍	❍	❍	❍
Writing traditional reports (hard copy reports) helped me learn chemical concepts.	❍	❍	❍	❍	❍	❍

3. Which assignment was more helpful for learning chemical concepts?
- ❍ Writing in the Chem 104 Wiki
- ❍ Writing traditional reports on chemical concepts

3_TEXT. Why was the assignment you chose in Q3 more helpful for learning chemical concepts?

4. If you have any comments and/or suggestions on how to improve the Chem 104 wiki as a class resource, please write them here.

5. If you have any comments and/or suggestions on how to improve the written traditional reports as an assignment, please write them here.

6. Which part of writing the wiki pages did you find to be the MOST useful?

7. Which part of writing the wiki pages did you find to be the LEAST useful?

8. Which aspect of writing the traditional reports did you find to be the MOST useful?

9. Which aspect of writing the traditional reports did you find to be the LEAST useful?

10. How often did you read the Chem 104 wiki?
- ❍ Less than Once a Week
- ❍ Once a Week
- ❍ 2-3 Times a Week
- ❍ 3-4 Times a Week
- ❍ Daily
- ❍ I did not read the wiki.

11. If you did read the Chem 104 wiki, how useful was it?
- ❍ Useless
- ❍ Somewhat useful
- ❍ Useful
- ❍ Very Useful
- ❍ Did not read the wiki

12. If you did not read the Chem 104 wiki, why not?
- ❑ I don't trust the content
- ❑ I didn't have time
- ❑ The material was not formatted in an appealing way
- ❑ The content was not helpful
- ❑ I had limited access to the Chem 109 wiki
- ❑ Other: _____

13. Please indicate how often you use the following resources to help you study.

	Never	Occasionally	Often	Very Often
Lecture notes that I've taken	❍	❍	❍	❍
TA lecture notes	❍	❍	❍	❍
Course textbook	❍	❍	❍	❍
Class website	❍	❍	❍	❍
Course websites from other institutions	❍	❍	❍	❍
Wikipedia (not the Chem 104 wiki)	❍	❍	❍	❍
Search engine (Google, Yahoo!, Bing, etc.)	❍	❍	❍	❍
Other websites	❍	❍	❍	❍
Other resources	❍	❍	❍	❍

14. Please indicate how many times a week you use each of these resources.

	Less than Once a Week	Once a Week	2-3 Times a Week	3-4 Times a Week	Daily
the internet to help you learn chemistry	❍	❍	❍	❍	❍
Wikipedia (not the Chem 104 wiki) to help you learn chemistry	❍	❍	❍	❍	❍
Wikipedia (not the Chem 104 wiki) to help you learn about other subjects	❍	❍	❍	❍	❍
Wikipedia (not the Chem 104 wiki) to help you learn about non-academic subjects	❍	❍	❍	❍	❍

15. What is your classification?

❍ Freshman
❍ Sophomore
❍ Junior
❍ Senior
❍ Graduate student
❍ Other (please describe) _____

16. Please select your gender:

❍ Male
❍ Female
❍ I do not wish to disclose my gender.

17. On a scale of 0.0 to 4.0, what is your current cumulative college GPA? Please enter in X.XX format (e.g. 3.29)

18. What grade did you receive in Chem 103 (first semester general chemistry)?
- ❍ A
- ❍ AB
- ❍ B
- ❍ BC
- ❍ C
- ❍ D

19. Where did you take first semester general chemistry? (e.g. Chem 103)
- ❍ University of Wisconsin-Madison
- ❍ Another institution (please name/describe) _____

20. What is your 10-digit campus ID number? This information is needed to make sure that you receive credit for this survey.

21. Which discussion section are you in? This information is needed to make sure that you receive credit for this survey. Please type in 7XX form (e.g. 781)

Chem 104 Spring 2014 Post-Survey: Control Group

.1 How accurately does each statement describe you?

	Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
I find chemistry concepts interesting and challenging.	❍	❍	❍	❍	❍	❍
I have trouble understanding anything based on chemistry.	❍	❍	❍	❍	❍	❍
Chemistry intimidates me.	❍	❍	❍	❍	❍	❍
I participate confidently in discussions with school friends about chemical topics.	❍	❍	❍	❍	❍	❍
I have a lot of intellectual curiosity.	❍	❍	❍	❍	❍	❍
I am good at combining ideas in ways that others have not tried.	❍	❍	❍	❍	❍	❍
I hate most academic subjects.	❍	❍	❍	❍	❍	❍
I wish I had more imagination and originality.	❍	❍	❍	❍	❍	❍
I can communicate chemistry effectively.	❍	❍	❍	❍	❍	❍

2. Please indicate how often you use the following resources to help you study.

	Never	Occasionally	Often	Very Often
Lecture notes that I've taken	❍	❍	❍	❍
TA lecture notes	❍	❍	❍	❍
Course textbook	❍	❍	❍	❍
Class website	❍	❍	❍	❍
Course websites from other institutions	❍	❍	❍	❍
Wikipedia	❍	❍	❍	❍
Search engine (Google, Yahoo!, Bing, etc.)	❍	❍	❍	❍
Other websites	❍	❍	❍	❍
Other resources	❍	❍	❍	❍

3. Please indicate how many times a week you use each of these resources.

	Less than Once a Week	Once a Week	2-3 Times a Week	3-4 Times a Week	Daily
the internet to help you learn chemistry	❍	❍	❍	❍	❍
Wikipedia to help you learn chemistry	❍	❍	❍	❍	❍
Wikipedia to help you learn about other academic subjects	❍	❍	❍	❍	❍
Wikipedia to help you learn about non-academic subjects	❍	❍	❍	❍	❍

4. What is your classification?
- ❍ Freshman
- ❍ Sophomore
- ❍ Junior
- ❍ Senior
- ❍ Graduate student
- ❍ Other (please describe) _____

5. Please select your gender:
- ❍ Male
- ❍ Female
- ❍ I do not wish to disclose my gender.

6. On a scale of 0.0 to 4.0, what is your current cumulative college GPA? Please enter in X.XX format (e.g. 3.29)

7. What grade did you receive in Chem 103 (first semester general chemistry)?
- ❍ A
- ❍ AB
- ❍ B
- ❍ BC
- ❍ C
- ❍ D

8. Where did you take first semester general chemistry? (e.g. Chem 103)
- ❍ University of Wisconsin-Madison
- ❍ Another institution (please name/describe) _____

9. What is your 10-digit campus ID number? This information is needed to make sure that you receive credit for this survey.

10. Which discussion section are you in? This information is needed to make sure that you receive credit for this survey. Please type in 8XX form (e.g. 801)

Appendix G: R Code and Output

All statistical analyses in this dissertation were performed using RStudio (Version 0.98.953), a statistical analysis program. The analysis was performed using the files below in the C:\Users\Owner\Desktop\Wiki Project\R Scripts subdirectory:

Study_I_Posttest_Analysis.R- this file contains functions written to subset group data and perform Welch's t-test to compare the experimental and control groups in study I.

Study_I_Survey_Analysis.R, Study_II_Survey_Analysis.R, Study_III_Survey_Analysis.R, - these files contains functions written to calculate descriptive statistics for survey items. The files also contain code that performs Welch's t-test to compare the experimental and control groups for all survey items.

Study_II_III_Analysis.R- this file contains all functions for pretest score comparisons, reliability tests, regression model optimization, t-test comparisons for treatment groups, and regression modeling for studies II and III.

All comma-separated values (csv) files contain data for each posttest. The data is tabulated by column and includes participant ID number, treatment groups, responses for each item on the posttest, and average score for posttest questions. Each participant is one row.

Treatment groups for participants were assigned via dummy variables. Four columns representing each of the treatment groups (e.g. TW = targeted concept wiki writing group) contain 1 if the participant is a member of that group and 0 if they are not a member. For example, if a participant was in the TW group, a 1 is recorded in the TW column, and 0 recorded in each of the other group columns. Participants in the control group were assigned "0" for all columns.

If the participant answered the question correctly, a score of 1 was recorded for the item. Incorrect answers were scored as 0.

The files can be found in the C:\Users\Owner\Desktop\Wiki Project\R Data subdirectory:

Study_I_Exam_1_Data.csv, Study_I_Exam_2_Data.csv, Study_I_Exam_3_Data.csv, Study_I_Exam_4_Data.csv, - contains posttest data for all participants in study I (Chem 104, spring 2013)

Study_II_Exam_1_Data.csv, Study_II_Exam_2_Data.csv, Study_II_Exam_3_Data.csv, Study_II_Exam_4_Data.csv, - contains posttest data for all participants in study II (Chem 109, fall 2013)

Study_III_Exam_2_Data.csv, Study_III_Exam_4_Data.csv, - contains posttest data for all participants in study III (Chem 104, spring 2014)

```
#####################################################################
#                                                                   #
# Study I Post-test Comparisons| Last modified 08.22.14              #
#                                                                   #
#####################################################################

setwd("C:/Users/Owner/Desktop/Wiki Project/Data/R Data")

########## Exam 1 Analysis ##########

# Read in source data
e1dat<- read.csv("Study_I_Exam_1_Data.csv")
attach(e1dat) # attaches e1dat to R search path

# Puts questions of each group into same data frame. H = hydrocarbons,
F = functional groups,
# I = intermolecular forces, O = organic reactions, D = DNA and
proteins,
# L = Lipids, Carbohydrates, and Polysaccharides
h <- cbind(Contributed,H1,H2,H3,H6)
f <- cbind(Contributed,F4,F8)
i <- cbind(Contributed,I5)
o <- cbind(Contributed,O7,O9)
d <- cbind(Contributed,D10,D11,D12)
l <- cbind(Contributed,L13,L14,L15)

h.group <- subset(h, Contributed =="H")
h.nongroup <- subset(h, Contributed !="H")
f.group <- subset(h, Contributed =="F")
f.nongroup <- subset(h, Contributed !="F")
i.group <- subset(h, Contributed =="I")
i.nongroup <- subset(h, Contributed !="I")
o.group <- subset(h, Contributed =="O")
o.nongroup <- subset(h, Contributed !="O")
d.group <- subset(h, Contributed =="D")
d.nongroup <- subset(h, Contributed !="D")
l.group <- subset(h, Contributed =="L")
l.nongroup <- subset(h, Contributed !="L")

##### Welchs t-tests of experimental vs. control groups #####

t.test(h.group, h.nongroup)
t.test(h.group, h.nongroup)
t.test(f.group, f.nongroup)
t.test(i.group, i.nongroup)
t.test(o.group, o.nongroup)
t.test(d.group, d.nongroup)
t.test(d.group, d.nongroup)
t.test(l.group, l.nongroup)

detach(e1dat) # removes e1dat to R search path
```

```
########## Exam 2 Analysis ##########

# Read in source data
e2dat<- read.csv("Study_I_Exam_2_Data.csv")
attach(e2dat) # attaches e2dat to R search path

# Puts questions of each group into same data frame. R = rate laws, I
= integrated rate laws,
# M = mechanisms and catalysis, A = applications of catalysis, E =
equilibrium states,
# N = non-equilibrium states
r <- cbind(Contributed,R1,R2,R3,R5)
i <- cbind(Contributed,I4)
m <- cbind(Contributed,M6,M7,M8)
a <- cbind(Contributed,A9,A10,A11)
e <- cbind(Contributed,E12)
n <- cbind(Contributed,N13,N14,N15)

r.group <- subset(r, Contributed =="R")
r.nongroup <- subset(r, Contributed !="R")
i.group <- subset(i, Contributed =="I")
i.nongroup <- subset(i, Contributed !="I")
m.group <- subset(m, Contributed =="M")
m.nongroup <- subset(m, Contributed !="M")
a.group <- subset(a, Contributed =="A")
a.nongroup <- subset(a, Contributed !="A")
e.group <- subset(e, Contributed =="E")
e.nongroup <- subset(e, Contributed !="E")
n.group <- subset(n, Contributed =="N")
n.nongroup <- subset(n, Contributed !="N")

##### Welchs t-tests of experimental vs. control groups #####

t.test(r.group, r.nongroup)
t.test(i.group, i.nongroup)
t.test(m.group, m.nongroup)
t.test(a.group, a.nongroup)
t.test(e.group, e.nongroup)
t.test(n.group, n.nongroup)

detach(e2dat) # removes e2dat to R search path


########## Exam 3 Analysis ##########

e3dat<- read.csv("Study_I_Exam_3_Data.csv")
attach(e3dat) # attaches e3dat to R search path

# Puts questions of each group into same data frame. A = intro to
acids and bases,
# B = buffers and Lewis acids/bases, E = enthalpy and entropy, G =
Gibbs free energy,
# S = acidic and basic Solutions, T = titrations
a <- cbind(Contributed,A1,A2,A3)
b <- cbind(Contributed,B4,B5,B6)
e <- cbind(Contributed,E7,E8,E9)
g <- cbind(Contributed,G10,G11)
s <- cbind(Contributed,S12,S13,S14)
```

```
t <- cbind(Contributed,T15)

a.group <- subset(a, Contributed =="A")
a.nongroup <- subset(a, Contributed !="A")
b.group <- subset(b, Contributed =="B")
b.nongroup <- subset(b, Contributed !="B")
e.group <- subset(e, Contributed =="E")
e.nongroup <- subset(e, Contributed !="E")
g.group <- subset(g, Contributed =="G")
g.nongroup <- subset(g, Contributed !="G")
s.group <- subset(s, Contributed =="S")
s.nongroup <- subset(s, Contributed !="S")
t.group <- subset(t, Contributed =="T")
t.nongroup <- subset(t, Contributed !="T")

########## Welchs t-tests of experimental vs. control groups
##########

t.test(a.group, a.nongroup)
t.test(b.group, b.nongroup)
t.test(e.group, e.nongroup)
t.test(g.group, g.nongroup)
t.test(s.group, s.nongroup)
t.test(t.group, t.nongroup)

detach(e3dat) # removes e3dat to R search path


########## Final Exam Analysis ##########

finaldat<- read.csv("Study_I_Final_Exam_Data.csv")
attach(finaldat) # attaches finaldat to R search path

# Puts questions of each group into same data frame. RR = redox
reactions, EC = electrochemical cells,
# AE = applications of electrochemistry
rr <- cbind(Contributed,RR35,RR36,RR37,RR38,RR39,RR40)
ec <- cbind(Contributed,EC41,EC42,EC43,EC44,EC45,EC46)
ae <- cbind(Contributed,AE47,AE48,AE49,AE50,AE51)

rr.group <- subset(rr, Contributed =="RR")
rr.nongroup <- subset(rr, Contributed !="RR")
ec.group <- subset(ec, Contributed =="EC")
ec.nongroup <- subset(ec, Contributed !="EC")
ae.group <- subset(ae, Contributed =="AE")
ae.nongroup <- subset(ae, Contributed !="AE")

##### Welchs t-tests of experimental vs. control groups #####

t.test(rr.group, rr.nongroup)
t.test(ec.group, ec.nongroup)
t.test(ae.group, ae.nongroup)

detach(finaldat) # removes finaldat to R search path
```

```
#########################################################################
#                                                                       #
# Survey Analysis for Study I| Created 08.18.2014 | Last modified
10.17.14     #
#                                                                       #
#########################################################################

setwd("C:/Users/Owner/Desktop/Wiki Project/Data/R Data")
post104<- read.csv("Study_I_Survey_Data.csv")
attach(post104)

install.packages("psych")
library("psych")

# Descriptive stats of CSc (Table 5.4)

describe(Q1_1)
describe(Q1_2)
describe(Q1_3)
describe(Q1_4)
describe(Q1_5)
describe(Q1_6)
describe(Q1_7)
describe(Q1_8)
describe(Q1_9)

# Descriptive stats of Resources (Table 5.5, Table 5.6)

describe(Q2_1)
describe(Q2_2)
describe(Q2_3)
describe(Q2_4)
describe(Q2_5)
describe(Q2_6)
describe(Q2_7)
describe(Q2_8)
describe(Q2_9)

describe(Q3_1)
describe(Q3_2)
describe(Q3_3)

#### Paired t-tests between pre and post-test: CSC (Table 5.7) ####

t.test(Q1_1, P4_1, paired = TRUE)
t.test(Q1_2, P4_2, paired = TRUE)
t.test(Q1_3, P4_3, paired = TRUE)
t.test(Q1_4, P4_4, paired = TRUE)
t.test(Q1_9, P4_9, paired = TRUE)

#### Paired t-tests between pre and post-test: Resources (Table 5.8,
Table 5.9) ####

t.test(Q2_1, P11_1, paired = TRUE)
t.test(Q2_2, P11_2, paired = TRUE)
t.test(Q2_3, P11_3, paired = TRUE)
t.test(Q2_4, P11_4, paired = TRUE)
```

```
t.test(Q2_5, P11_5, paired = TRUE)
t.test(Q2_6, P11_6, paired = TRUE)
t.test(Q2_7, P11_7, paired = TRUE)
t.test(Q2_8, P11_8, paired = TRUE)
t.test(Q2_9, P11_9, paired = TRUE)

t.test(Q3_1, P12_1, paired = TRUE)
t.test(Q3_2, P12_2, paired = TRUE)
t.test(Q3_3, P12_3, paired = TRUE)

detach(post104)

#########################################################################
#                                                                       #
# Survey Analysis for Study II | Created 08.18.2014 | Last modified
08.18.14                          #
#                                                                       #
#########################################################################
setwd("C:/Users/Owner/Desktop/Wiki Project/Data/R Data")
library("psych")

#### Experimental Group! ####

post109e<- read.csv("Study_II_Survey_Data_Experimental.csv")
attach(post109e)

# Descriptive stats of CSc (Table 5.4)
describe(Q1_1)
describe(Q1_2)
describe(Q1_3)
describe(Q1_4)
describe(Q1_5)
describe(Q1_6)
describe(Q1_7)
describe(Q1_8)
describe(Q1_9)

# Descriptive stats of Resources (Table 5.5, Table 5.6)

describe(Q2_1)
describe(Q2_2)
describe(Q2_3)
describe(Q2_4)
describe(Q2_5)
describe(Q2_6)
describe(Q2_7)
describe(Q2_8)
describe(Q2_9)

describe(Q3_1)
describe(Q3_2)
describe(Q3_3)


#### Paired t-tests between pre and post-test: CSC (Table 5.7) ####

t.test(Q1_1, P1_1, paired = TRUE)
t.test(Q1_2, P1_2, paired = TRUE)
```

```
t.test(Q1_3, P1_3, paired = TRUE)
t.test(Q1_4, P1_4, paired = TRUE)
t.test(Q1_9, P1_9, paired = TRUE)

#### Paired t-tests between pre and post-test: Resources (Table 5.8,
5.9) ####

t.test(Q2_1, P9_1, paired = TRUE)
t.test(Q2_2, P9_2, paired = TRUE)
t.test(Q2_3, P9_3, paired = TRUE)
t.test(Q2_4, P9_4, paired = TRUE)
t.test(Q2_5, P9_5, paired = TRUE)
t.test(Q2_6, P9_6, paired = TRUE)
t.test(Q2_7, P9_7, paired = TRUE)
t.test(Q2_8, P9_8, paired = TRUE)
t.test(Q2_9, P9_9, paired = TRUE)

t.test(Q3_1, P10_1, paired = TRUE)
t.test(Q3_2, P10_2, paired = TRUE)
t.test(Q3_3, P10_3, paired = TRUE)

describe(P2_1)
describe(P2_2)
describe(P2_3)
describe(P2_4)
describe(P2_5)
describe(P2_6)
describe(P2_7)
describe(P2_8)
describe(P2_9)
describe(P2_10)
describe(P2_11)
describe(P2_12)
describe(P2_13)
describe(P2_14)

detach(post109e)


#### Control Group! ####

post109c<- read.csv("Study_II_Survey_Data_Control.csv")
attach(post109c)

#### Paired t-tests between pre and post-test: CSC ####

t.test(Q1_1, P1_1, paired = TRUE)
t.test(Q1_2, P1_2, paired = TRUE)
t.test(Q1_3, P1_3, paired = TRUE)
t.test(Q1_4, P1_4, paired = TRUE)
t.test(Q1_9, P1_9, paired = TRUE)

#### Paired t-tests between pre and post-test: Resources ####

t.test(Q2_1, P2_1, paired = TRUE)
t.test(Q2_2, P2_2, paired = TRUE)
t.test(Q2_3, P2_3, paired = TRUE)
t.test(Q2_4, P2_4, paired = TRUE)
```

```
t.test(Q2_5, P2_5, paired = TRUE)
t.test(Q2_6, P2_6, paired = TRUE)
t.test(Q2_7, P2_7, paired = TRUE)
t.test(Q2_8, P2_8, paired = TRUE)
t.test(Q2_9, P2_9, paired = TRUE)

t.test(Q3_1, P3_1, paired = TRUE)
t.test(Q3_2, P3_2, paired = TRUE)
t.test(Q3_3, P3_3, paired = TRUE)

detach(post109c)


#########################################################################
#                                                                       #
# Survey Analysis for Study III | Created 08.18.2014 | Last modified
10.17.14                        #
#                                                                       #
#########################################################################

setwd("C:/Users/Owner/Desktop/Wiki Project/Data/R Data")
install.packages("psych")
library("psych")

#### Experimental Group! ####

post104e<- read.csv("Study_III_Survey_Data_Experimental.csv")
attach(post104e)

# Descriptive stats of CSc (Table 5.4)
describe(Q1_1)
describe(Q1_2)
describe(Q1_3)
describe(Q1_4)
describe(Q1_5)
describe(Q1_6)
describe(Q1_7)
describe(Q1_8)
describe(Q1_9)


# Descriptive stats of Resources (Table 5.5, Table 5.6)

describe(Q2_1)
describe(Q2_2)
describe(Q2_3)
describe(Q2_4)
describe(Q2_5)
describe(Q2_6)
describe(Q2_7)
describe(Q2_8)
describe(Q2_9)

describe(Q3_1)
describe(Q3_2)
describe(Q3_3)
```

```
#### Paired t-tests between pre and post-test: CSC (Table 5.7) ####

t.test(Q1_1, P1_1, paired = TRUE)
t.test(Q1_2, P1_2, paired = TRUE)
t.test(Q1_3, P1_3, paired = TRUE)
t.test(Q1_4, P1_4, paired = TRUE)
t.test(Q1_9, P1_9, paired = TRUE)

#### Paired t-tests between pre and post-test: Resources (Table 5.8,
5.9) ####

t.test(Q2_1, P13_1, paired = TRUE)
t.test(Q2_2, P13_2, paired = TRUE)
t.test(Q2_3, P13_3, paired = TRUE)
t.test(Q2_4, P13_4, paired = TRUE)
t.test(Q2_5, P13_5, paired = TRUE)
t.test(Q2_6, P13_6, paired = TRUE)
t.test(Q2_7, P13_7, paired = TRUE)
t.test(Q2_8, P13_8, paired = TRUE)
t.test(Q2_9, P13_9, paired = TRUE)

t.test(Q3_1, P14_1, paired = TRUE)
t.test(Q3_2, P14_2, paired = TRUE)
t.test(Q3_3, P14_3, paired = TRUE)

detach(post104e)


#### Control Group! ####

post109c<- read.csv("Study_III_Survey_Data_Control.csv")
attach(post109c)

# Descriptive stats of CSc (Table 5.4)
describe(Q1_1)
describe(Q1_2)
describe(Q1_3)
describe(Q1_4)
describe(Q1_5)
describe(Q1_6)
describe(Q1_7)
describe(Q1_8)
describe(Q1_9)

# Descriptive stats of Resources (Table 5.5, Table 5.6)

describe(Q2_1)
describe(Q2_2)
describe(Q2_3)
describe(Q2_4)
describe(Q2_5)
describe(Q2_6)
describe(Q2_7)
describe(Q2_8)
describe(Q2_9)

describe(Q3_1)
describe(Q3_2)
```

```
describe(Q3_3)


#### Paired t-tests between pre and post-test: CSC (Table 5.7) ####

t.test(Q1_1, P1_1, paired = TRUE)
t.test(Q1_2, P1_2, paired = TRUE)
t.test(Q1_3, P1_3, paired = TRUE)
t.test(Q1_4, P1_4, paired = TRUE)
t.test(Q1_9, P1_9, paired = TRUE)

#### Paired t-tests between pre and post-test: Resources (Table 5.8,
5.9) ####

t.test(Q2_1, P2_1, paired = TRUE)
t.test(Q2_2, P2_2, paired = TRUE)
t.test(Q2_3, P2_3, paired = TRUE)
t.test(Q2_4, P2_4, paired = TRUE)
t.test(Q2_5, P2_5, paired = TRUE)
t.test(Q2_6, P2_6, paired = TRUE)
t.test(Q2_7, P2_7, paired = TRUE)
t.test(Q2_8, P2_8, paired = TRUE)
t.test(Q2_9, P2_9, paired = TRUE)

t.test(Q3_1, P3_1, paired = TRUE)
t.test(Q3_2, P3_2, paired = TRUE)
t.test(Q3_3, P3_3, paired = TRUE)

detach(post109c)


#########################################################################
#                                                                       #
# Analysis for differences in pretests, Studies II and III| Created
05.26.2014 | Last modified 10.17.2014  #
#                                                                       #
#########################################################################

setwd("C:/Users/Owner/Desktop/Wiki Project/Data/R Data")
install.packages("psych")
library("psych")

########## Study II ##########

exam1data <-read.csv("Study_II_Exam_1_Data.csv", header = TRUE)
exam2data <-read.csv("Study_II_Exam_2_Data.csv", header = TRUE)
exam3data <-read.csv("Study_II_Exam_3_Data.csv", header = TRUE)
exam4data <-read.csv("Study_II_Final_Exam_Data.csv", header = TRUE)

#### ANOVA tests to see if there are differences in pre-test scores
####

# Regression models for total pre-assessment correct
exam1.P.correct <- lm(exam1data$P12.correct~exam1data$TW +
exam1data$UW +
                        exam1data$TR + exam1data$UR)
exam2.P.correct <- lm(exam2data$P12.correct~exam2data$TW +
exam2data$NW +
```

```
                        exam2data$TR + exam2data$NR)
exam3.P.correct <- lm(exam3data$P12.correct~exam3data$TW +
exam3data$UW +
                        exam3data$TR + exam3data$UR)
exam4.P.correct <- lm(exam4data$P12.correct~exam4data$TW +
exam4data$UW +
                        exam4data$TR + exam4data$UR)


summary(exam1.P.correct)
summary(exam2.P.correct)
summary(exam3.P.correct)
summary(exam4.P.correct)

########## Reliability of Posttest Questions ##########

setwd("C:/Users/Owner/Desktop/Wiki Project/Data/R Data")
ACSdata <-read.csv("Study_II_ACS_Exam_Data.csv", header = TRUE)
attach(ACSdata)

allACS <-
cbind(post1,post2,post3,post4,post5,post6,post7,post8,post9,post10,
                post35,post36,post37,post38,post39,post40,
post23,post24,post25,post27,

post17,post18,post19,post20,post21,post22,post26,post28,post29,post30,

post13,post14,post15,post16,post32,post11,post12,post31,post33,post34)

alpha(allACS)

detach(ACSdata)

########## Study III ##########

setwd("C:/Users/Owner/Desktop/Wiki Project/Data/R Data")
exam2data <-read.csv("Study_III_Exam_2_Data.csv", header = TRUE)
exam4data <-read.csv("Study_III_Exam_4_Data.csv", header = TRUE)

# Regression models for total pre-assessment correct

exam2.P.correct <- lm(exam2data$P.correct~exam2data$TW + exam2data$UW
+
                        exam2data$TR + exam2data$UR)

exam4.P.correct <- lm(exam4data$P.correct~exam4data$TW + exam4data$UW
+
                        exam4data$TR + exam4data$UR)

# ANOVA on Pre-Assessment

summary(exam2.P.correct)
summary(exam4.P.correct)

##### Reliability Tests of Final Exam (Experimental and Control groups
combined in one file) #####

setwd("C:/Users/Owner/Desktop/Wiki Project/Data/R Data")
```

```
finaldata <-read.csv("Study_III_Final_Exam_Data_Experimental.csv",
header = TRUE)
attach(finaldata)

exam1data <- cbind(F1,F2,F3,F4,F5,F6,F7,F8,F9,F10,F11,F12,F13)
exam2data <- cbind(F14,F15,F16,F17,F18,F19)
exam3data <- cbind(F20,F21,F29,F32,F33,F35,F36,F37)
exam4data <- cbind(F22,F23,F24,F25,F26,F27,F28,F30,F31,F34)
alldata <-
cbind(exam1data.control,exam2data.control,exam3data.control,exam4data.
control)

alpha(alldata)

detach(finaldata)

#########################################################################
#                                                                       #
# Optimization of Regression Models, Exams 1-4 | Created 05.26.2014 |
Last modified 09.17.14                  #
#                                                                       #
#########################################################################


##### Study II #####

setwd("C:/Users/Owner/Desktop/Wiki Project/Data/R Data")
ACSdata <-read.csv("Study_II_ACS_Exam_Data.csv", header = TRUE)

attach(ACSdata)

exam1ACS <-
cbind(post1,post2,post3,post4,post5,post6,post7,post8,post9,post10)
exam2ACS <- cbind(post35,post36,post37,post38,post39,post40)
exam3ACS <-
cbind(post17,post18,post19,post20,post21,post22,post23,post24,post25,
                  post26,post27,post28,post29,post30)
exam4ACS <-
cbind(post11,post12,post13,post14,post15,post16,post31,post32,post33,p
ost34,post35,post36)
allACS <-cbind(post1,post2,post3,post4,post5,post6,post7,
               post8,post9,post10,post11,post12,post13,post14,
               post15,post16,post17,post18,post19,post20,
               post21,post22,post23,post24,post25,post26,post27,
               post28,post29,post30,post31,post32,post33,post34,
               post35,post36,post37,post38,post39,post40)


### Models with no predictors ###

exam1model <- lm(exam1avg ~ TW + TR + NW + NR)
exam2model <- lm(exam2avg ~ TW + TR + NW + NR)
exam3model <- lm(exam3avg ~ TW + TR + NW + NR)
exam4model <- lm(exam4avg ~ TW + TR + NW + NR)

### Models with z, pre-test ###

exam1model.zp <- lm(exam1avg ~ z + p1avg + TW + TR + NW + NR)
```

```
exam2model.zp <- lm(exam2avg ~ z + p2avg +TW + TR + NW + NR)
exam3model.zp <- lm(exam3avg ~ z + p3avg +TW + TR + NW + NR)
exam4model.zp <- lm(exam4avg ~ z + p4avg +TW + TR + NW + NR)

### Models with z, pre-test, interaction terms ###

exam1model.zpi <- lm(exam1avg ~ z + p1avg + z*p1avg + TW + TR + NW +
NR)
exam2model.zpi <- lm(exam2avg ~ z + p2avg + z*p2avg + TW + TR + NW +
NR)
exam3model.zpi <- lm(exam3avg ~ z + p3avg + z*p2avg + TW + TR + NW +
NR)
exam4model.zpi <- lm(exam4avg ~ z + p4avg + z*p2avg + TW + TR + NW +
NR)

#### Model check-ANOVA ###

anova(exam1model,exam1model.zp)
anova(exam2model,exam2model.zp)
anova(exam3model,exam3model.zp)
anova(exam4model,exam4model.zp)

anova(exam1model.zp,exam1model.zpi)
anova(exam2model.zp,exam2model.zpi)
anova(exam3model.zp,exam3model.zpi)
anova(exam4model.zp,exam4model.zpi)

### Pairwise comparisons between treatments ###

# Exam 2
TW.exam2avg <- subset(ACSdata,treatment2 == 'TW', exam2avg)
TR.exam2avg <- subset(ACSdata,treatment2 == 'TR', exam2avg)
UW.exam2avg <- subset(ACSdata,treatment2 == 'UW', exam2avg)
UR.exam2avg <- subset(ACSdata,treatment2 == 'UR', exam2avg)

t.test(TW.exam2avg, TR.exam2avg)
t.test(UW.exam2avg, UR.exam2avg)
t.test(TW.exam2avg, UW.exam2avg)
t.test(TR.exam2avg, UR.exam2avg)

# Exam 4

TW.exam4avg <- subset(ACSdata,treatment4 == 'TW', exam4avg)
TR.exam4avg <- subset(ACSdata,treatment4 == 'TR', exam4avg)
UW.exam4avg <- subset(ACSdata,treatment4 == 'UW', exam4avg)
UR.exam4avg <- subset(ACSdata,treatment4 == 'UR', exam4avg)

t.test(TW.exam4avg, TR.exam4avg)
t.test(UW.exam4avg, UR.exam4avg)
t.test(TW.exam4avg, UW.exam4avg)
t.test(TR.exam4avg, UR.exam4avg)

########## Study III ##########

setwd("C:/Users/Owner/Desktop/Wiki Project/Data/R Data")
final.all<-read.csv("Study_III_Final_Exam_Data.csv")
attach(final.all)
```

```
#### Exam 2 ####

exam2model<- lm(exam2avg ~ z + P.therm.correct + TW.e2 +UW.e2 +TR.e2 +
UR.e2)
summary(exam2model)

#### Exam 4 ####


exam4model<- lm(exam4avg ~ z + P.correct + TW.e4 +UW.e4 +TR.e4 +
UR.e4)
summary(exam4model)
```

```
>#############################################################
#                                                           #
> # Study I Post-test Comparisons| Created 08.22.2014 | Last
modified 08.22.#
> #                                                         #
#############################################################
>
> setwd("C:/Users/Owner/Desktop/Wiki Project/Data/R Data")
>
> ########## Exam 1 Analysis ##########
>
> # Read in source data
> e1dat<- read.csv("Study_I_Exam_1_Data.csv")
> attach(e1dat) # attaches e1dat to R search path
The following object is masked from e1dat (position 3):

    Contributed, D10, D11, D12, F4, F8, H1, H2, H3, H6, I5, L13,
L14, L15, O7, O9, X.
The following object is masked from e2dat:

    Contributed, X.
The following object is masked from e1dat (position 5):

    Contributed, D10, D11, D12, F4, F8, H1, H2, H3, H6, I5, L13,
L14, L15, O7, O9, X.
The following object is masked from e1dat (position 6):

    Contributed, D10, D11, D12, F4, F8, H1, H2, H3, H6, I5, L13,
L14, L15, O7, O9, X.
>
> # Puts questions of each group into same data frame. H =
hydrocarbons, F = functional groups,
> # I = intermolecular forces, O = organic reactions, D = DNA
and proteins,
> # L = Lipids, Carbohydrates, and Polysaccharides
> h <- cbind(Contributed,H1,H2,H3,H6)
> f <- cbind(Contributed,F4,F8)
> i <- cbind(Contributed,I5)
> o <- cbind(Contributed,O7,O9)
> d <- cbind(Contributed,D10,D11,D12)
> l <- cbind(Contributed,L13,L14,L15)
>
> h.group <- subset(h, Contributed =="H")
> h.nongroup <- subset(h, Contributed !="H")
> f.group <- subset(h, Contributed =="F")
> f.nongroup <- subset(h, Contributed !="F")
> i.group <- subset(h, Contributed =="I")
> i.nongroup <- subset(h, Contributed !="I")
> o.group <- subset(h, Contributed =="O")
> o.nongroup <- subset(h, Contributed !="O")
> d.group <- subset(h, Contributed =="D")
> d.nongroup <- subset(h, Contributed !="D")
> l.group <- subset(h, Contributed =="L")
> l.nongroup <- subset(h, Contributed !="L")
```

```
>
> ##### Welchs t-tests of experimental vs. control groups #####
>
> t.test(h.group, h.nongroup)

     Welch Two Sample t-test

data:  h.group and h.nongroup
t = -2.0505, df = 490.212, p-value = 0.04085
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.48946493 -0.01044634
sample estimates:
mean of x mean of y
 1.117391  1.367347

> t.test(h.group, h.nongroup)

     Welch Two Sample t-test

data:  h.group and h.nongroup
t = -2.0505, df = 490.212, p-value = 0.04085
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.48946493 -0.01044634
sample estimates:
mean of x mean of y
 1.117391  1.367347

> t.test(f.group, f.nongroup)

     Welch Two Sample t-test

data:  f.group and f.nongroup
t = -4.3946, df = 590.569, p-value = 1.316e-05
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.6702931 -0.2562228
sample estimates:
mean of x mean of y
0.9317073 1.3949653

> t.test(i.group, i.nongroup)

     Welch Two Sample t-test

data:  i.group and i.nongroup
t = -0.2466, df = 379.316, p-value = 0.8054
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
```

```
 -0.3169145  0.2462845
sample estimates:
mean of x mean of y
 1.295652  1.330967

> t.test(o.group, o.nongroup)

     Welch Two Sample t-test

data:  o.group and o.nongroup
t = 3.4161, df = 225.902, p-value = 0.0007532
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 0.3632221 1.3534699
sample estimates:
mean of x mean of y
 2.053659  1.195312

> t.test(d.group, d.nongroup)

     Welch Two Sample t-test

data:  d.group and d.nongroup
t = -8.3604, df = 1001.934, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.9199159 -0.5701659
sample estimates:
mean of x mean of y
0.6952381 1.4402790

> t.test(d.group, d.nongroup)

     Welch Two Sample t-test

data:  d.group and d.nongroup
t = -8.3604, df = 1001.934, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.9199159 -0.5701659
sample estimates:
mean of x mean of y
0.6952381 1.4402790

> t.test(l.group, l.nongroup)

     Welch Two Sample t-test

data:  l.group and l.nongroup
t = 3.4768, df = 270.416, p-value = 0.0005911
```

```
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 0.3184718 1.1500286
sample estimates:
mean of x mean of y
 1.934783  1.200532

>
> detach(e1dat) # removes e1dat to R search path
> ########## Exam 2 Analysis ##########
>
> # Read in source data
> e2dat<- read.csv("Study_I_Exam_2_Data.csv")
> attach(e2dat) # attaches e2dat to R search path
The following object is masked from e1dat (position 3):

    Contributed, X.
The following object is masked from e2dat (position 4):

    A10, A11, A9, Contributed, E12, I4, M6, M7, M8, N13, N14,
N15, R1, R2, R3, R5, X.
The following object is masked from e1dat (position 5):

    Contributed, X.
The following object is masked from e1dat (position 6):

    Contributed, X.
>
> # Puts questions of each group into same data frame. R = rate
laws, I = integrated rate laws,
> # M = mechanisms and catalysis, A = applications of catalysis,
E = equilibrium states,
> # N = non-equilibrium states
> r <- cbind(Contributed,R1,R2,R3,R5)
> i <- cbind(Contributed,I4)
> m <- cbind(Contributed,M6,M7,M8)
> a <- cbind(Contributed,A9,A10,A11)
> e <- cbind(Contributed,E12)
> n <- cbind(Contributed,N13,N14,N15)
>
> r.group <- subset(r, Contributed =="R")
> r.nongroup <- subset(r, Contributed !="R")
> i.group <- subset(i, Contributed =="I")
> i.nongroup <- subset(i, Contributed !="I")
> m.group <- subset(m, Contributed =="M")
> m.nongroup <- subset(m, Contributed !="M")
> a.group <- subset(a, Contributed =="A")
> a.nongroup <- subset(a, Contributed !="A")
> e.group <- subset(e, Contributed =="E")
> e.nongroup <- subset(e, Contributed !="E")
> n.group <- subset(n, Contributed =="N")
> n.nongroup <- subset(n, Contributed !="N")
>
```

```
> ##### Welchs t-tests of experimental vs. control groups #####
>
> t.test(r.group, r.nongroup)

     Welch Two Sample t-test

data:  r.group and r.nongroup
t = 4.3822, df = 275.543, p-value = 1.672e-05
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 0.4316151 1.1356927
sample estimates:
mean of x mean of y
 1.644898  0.861244

> t.test(i.group, i.nongroup)

     Welch Two Sample t-test

data:  i.group and i.nongroup
t = -2.8381, df = 156.534, p-value = 0.005141
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.9717087 -0.1741883
sample estimates:
mean of x mean of y
 1.621622  2.194570

> t.test(m.group, m.nongroup)

     Welch Two Sample t-test

data:  m.group and m.nongroup
t = 0.0039, df = 376.576, p-value = 0.9969
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.2660531  0.2671116
sample estimates:
mean of x mean of y
 1.127358  1.126829

> t.test(a.group, a.nongroup)

     Welch Two Sample t-test

data:  a.group and a.nongroup
t = -10.6176, df = 690.475, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -1.0134988 -0.6971622
```

```
sample estimates:
mean of x mean of y
0.4568966 1.3122271

> t.test(e.group, e.nongroup)

     Welch Two Sample t-test

data:  e.group and e.nongroup
t = -7.5899, df = 368.649, p-value = 2.647e-13
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -1.5128694 -0.8902605
sample estimates:
mean of x mean of y
 1.077778  2.279343

> t.test(n.group, n.nongroup)

     Welch Two Sample t-test

data:  n.group and n.nongroup
t = 1.7004, df = 176.364, p-value = 0.09083
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.05105991  0.68674217
sample estimates:
mean of x mean of y
 1.471429  1.153587

>
> detach(e2dat) # removes e2dat to R search path
> ########## Exam 3 Analysis ##########
>
> e3dat<- read.csv("Study_I_Exam_3_Data.csv")
> attach(e3dat) # attaches e3dat to R search path
The following object is masked from e1dat (position 3):

    Contributed, X.
The following object is masked from e2dat:

    Contributed, X.
The following object is masked from e1dat (position 5):

    Contributed, X.
The following object is masked from e1dat (position 6):

    Contributed, X.
>
> # Puts questions of each group into same data frame. A = intro
to acids and bases,
```

```
> # B = buffers and Lewis acids/bases, E = enthalpy and entropy,
G = Gibbs free energy,
> # S = acidic and basic Solutions, T = titrations
> a <- cbind(Contributed,A1,A2,A3)
> b <- cbind(Contributed,B4,B5,B6)
> e <- cbind(Contributed,E7,E8,E9)
> g <- cbind(Contributed,G10,G11)
> s <- cbind(Contributed,S12,S13,S14)
> t <- cbind(Contributed,T15)
>
> a.group <- subset(a, Contributed =="A")
> a.nongroup <- subset(a, Contributed !="A")
> b.group <- subset(b, Contributed =="B")
> b.nongroup <- subset(b, Contributed !="B")
> e.group <- subset(e, Contributed =="E")
> e.nongroup <- subset(e, Contributed !="E")
> g.group <- subset(g, Contributed =="G")
> g.nongroup <- subset(g, Contributed !="G")
> s.group <- subset(s, Contributed =="S")
> s.nongroup <- subset(s, Contributed !="S")
> t.group <- subset(t, Contributed =="T")
> t.nongroup <- subset(t, Contributed !="T")
>
> ########## Welchs t-tests of experimental vs. control groups
##########
>
> t.test(a.group, a.nongroup)

     Welch Two Sample t-test

data:  a.group and a.nongroup
t = -11.3329, df = 971.43, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -1.0058420 -0.7089142
sample estimates:
mean of x mean of y
0.3206522 1.1780303

> t.test(b.group, b.nongroup)

     Welch Two Sample t-test

data:  b.group and b.nongroup
t = -4.4709, df = 363.133, p-value = 1.043e-05
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.6202533 -0.2413006
sample estimates:
mean of x mean of y
 0.719697  1.150474
```

```
> t.test(e.group, e.nongroup)

     Welch Two Sample t-test

data:  e.group and e.nongroup
t = -1.6028, df = 301.718, p-value = 0.11
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.43244566  0.04421037
sample estimates:
mean of x mean of y
0.7875000 0.9816176

> t.test(g.group, g.nongroup)

     Welch Two Sample t-test

data:  g.group and g.nongroup
t = 0.8035, df = 180.64, p-value = 0.4227
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.2163600  0.5136086
sample estimates:
mean of x mean of y
 1.414634  1.266010

> t.test(s.group, s.nongroup)

     Welch Two Sample t-test

data:  s.group and s.nongroup
t = 2.3052, df = 175.105, p-value = 0.02233
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 0.06044835 0.78009652
sample estimates:
mean of x mean of y
 1.479167  1.058894

> t.test(t.group, t.nongroup)

     Welch Two Sample t-test

data:  t.group and t.nongroup
t = 4.3493, df = 101.533, p-value = 3.256e-05
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 0.7860946 2.1043599
sample estimates:
mean of x mean of y
```

```
 3.022727  1.577500

>
> detach(e3dat) # removes e3dat to R search path
>
>
> ########## Final Exam Analysis ##########
>
> finaldat<- read.csv("Study_I_Final_Exam_Data.csv")
> attach(finaldat) # attaches finaldat to R search path
The following object is masked from e1dat (position 3):

    Contributed, X.
The following object is masked from e2dat:

    Contributed, X.
The following object is masked from e1dat (position 5):

    Contributed, X.
The following object is masked from e1dat (position 6):

    Contributed, X.
>
> # Puts questions of each group into same data frame. RR =
redox reactions, EC = electrochemical cells,
> # AE = applications of electrochemistry
> rr <- cbind(Contributed,RR35,RR36,RR37,RR38,RR39,RR40)
> ec <- cbind(Contributed,EC41,EC42,EC43,EC44,EC45,EC46)
> ae <- cbind(Contributed,AE47,AE48,AE49,AE50,AE51)
>
> rr.group <- subset(rr, Contributed =="RR")
> rr.nongroup <- subset(rr, Contributed !="RR")
> ec.group <- subset(ec, Contributed =="EC")
> ec.nongroup <- subset(ec, Contributed !="EC")
> ae.group <- subset(ae, Contributed =="AE")
> ae.nongroup <- subset(ae, Contributed !="AE")
>
> ##### Welchs t-tests of experimental vs. control groups #####
>
> t.test(rr.group, rr.nongroup)

     Welch Two Sample t-test

data:  rr.group and rr.nongroup
t = 3.8321, df = 276.773, p-value = 0.0001573
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 0.1902083 0.5920749
sample estimates:
mean of x mean of y
1.2857143 0.8945727

> t.test(ec.group, ec.nongroup)
```

```
     Welch Two Sample t-test

data:  ec.group and ec.nongroup
t = -4.5733, df = 878.538, p-value = 5.49e-06
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.2970314 -0.1186421
sample estimates:
mean of x mean of y
0.7747253 0.9825620

> t.test(ae.group, ae.nongroup)

     Welch Two Sample t-test

data:  ae.group and ae.nongroup
t = -8.5951, df = 514.302, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.4952216 -0.3109543
sample estimates:
mean of x mean of y
0.6182796 1.0213675

>
> detach(finaldat) # removes finaldat to R search path

>
#################################################################
> #
#
> # Survey Analysis for Study I | Created 08.18.2014 | Last
modified 10.17.14     #
> #
#
>
#################################################################
>
> setwd("C:/Users/Owner/Desktop/Wiki Project/Data/R Data")
> post104<- read.csv("Study_I_Survey_Data.csv")
>
> install.packages("psych")
Error in install.packages : Updating loaded packages
> library("psych")
>
> # Descriptive stats of CSc (Table 5.4)
> likert <- c("Strongly \nDisagree","Disagree","Somewhat
\nDisagree","Somewhat\n Agree","Agree","Strongly \nAgree")
>
> describe(Q1_1)
```

```
  vars   n mean   sd median trimmed mad min max range  skew
kurtosis   se
1    1 263 4.63 0.86      5    4.67   0   1   6     5 -0.98
2.14 0.05
> describe(Q1_2)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis   se
1    1 263 2.72 1.11      2    2.64 1.48   1   6     5 0.72
0.09 0.07
> describe(Q1_3)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 263 3.54 1.35      4    3.58 1.48   1   6     5 -0.24
-0.85 0.08
> describe(Q1_4)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis   se
1    1 263 3.67 1.22      4    3.69 1.48   1   6     5 -0.2    -
0.34 0.08
> describe(Q1_5)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 263 5.01 0.83      5    5.07 1.48   2   6     4 -0.55
-0.05 0.05
> describe(Q1_6)
  vars   n mean sd median trimmed  mad min max range  skew
kurtosis   se
1    1 263 4.11  1      4    4.15 1.48   1   6     5 -0.34
0.09 0.06
> describe(Q1_7)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis   se
1    1 263 1.85 0.87      2    1.73 1.48   1   6     5 1.39
3.07 0.05
> describe(Q1_8)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis   se
1    1 263 3.55 1.26      4    3.58 1.48   1   6     5 -0.2    -
0.77 0.08
> describe(Q1_9)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 263 4.05 0.97      4    4.13 1.48   1   6     5 -0.57
0.03 0.06
>
> # Descriptive stats of Resources (Table 5.5, Table 5.6)
>
> describe(Q2_1)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 263 3.35 0.73      3    3.45 1.48   1   4     3 -0.81
-0.12 0.05
> describe(Q2_2)
```

```
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 263 2.61 0.97      3    2.64 1.48   1   4     3 -0.04
-1 0.06
> describe(Q2_3)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 263 3.17 0.84      3    3.26 1.48   1   4     3 -0.65
-0.5 0.05
> describe(Q2_4)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 263 2.82 0.84      3    2.83 1.48   1   4     3 -0.07
-0.88 0.05
> describe(Q2_5)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis   se
1    1 263 1.78 0.78      2    1.67 1.48   1   4     3 0.89
0.52 0.05
> describe(Q2_6)
  vars   n mean  sd median trimmed  mad min max range skew
kurtosis   se
1    1 263 1.87 0.8      2    1.79 1.48   1   4     3 0.73
0.14 0.05
> describe(Q2_7)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis   se
1    1 263  2.7 0.81      3    2.66 1.48   1   4     3 0.29    -
0.95 0.05
> describe(Q2_8)
  vars   n mean   sd median trimmed mad min max range skew
kurtosis   se
1    1 263 1.48 0.86      1    1.28   0   1   4     3 1.77
2.08 0.05
> describe(Q2_9)
  vars   n mean   sd median trimmed mad min max range skew
kurtosis   se
1    1 263 1.54 0.93      1    1.33   0   1   4     3 1.63
1.44 0.06
>
> describe(Q3_1)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 263 3.35 1.14      3    3.38 1.48   1   5     4 -0.17
-0.74 0.07
> describe(Q3_2)
  vars   n mean   sd median trimmed mad min max range skew
kurtosis   se
1    1 263 1.78 1.09      1    1.57   0   1   5     4 1.33
0.87 0.07
> describe(Q3_3)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis   se
```

```
1    1 263 2.43 1.29      2     2.3 1.48   1   5     4 0.51    -
0.87 0.08
>
> #### Paired t-tests between pre and post-test: CSC (Table 5.7)
####
>
> t.test(Q1_1, P4_1, paired = TRUE)

     Paired t-test

data:  Q1_1 and P4_1
t = 2.5168, df = 262, p-value = 0.01244
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 0.03227077 0.26430718
sample estimates:
mean of the differences
               0.148289

> t.test(Q1_2, P4_2, paired = TRUE)

     Paired t-test

data:  Q1_2 and P4_2
t = -1.6454, df = 262, p-value = 0.1011
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.22551368  0.02019049
sample estimates:
mean of the differences
             -0.1026616

> t.test(Q1_3, P4_3, paired = TRUE)

     Paired t-test

data:  Q1_3 and P4_3
t = 0.427, df = 262, p-value = 0.6698
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.1098674  0.1707039
sample estimates:
mean of the differences
             0.03041825

> t.test(Q1_4, P4_4, paired = TRUE)

     Paired t-test

data:  Q1_4 and P4_4
t = -2.7481, df = 262, p-value = 0.006411
```

```
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.33286273 -0.05496997
sample estimates:
mean of the differences
             -0.1939163

> t.test(Q1_9, P4_9, paired = TRUE)

     Paired t-test

data:  Q1_9 and P4_9
t = -2.5859, df = 262, p-value = 0.01025
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.24111154 -0.03265272
sample estimates:
mean of the differences
             -0.1368821

>
> #### Paired t-tests between pre and post-test: Resources
(Table 5.8, Table 5.9) ####
>
> t.test(Q2_1, P11_1, paired = TRUE)

     Paired t-test

data:  Q2_1 and P11_1
t = 0.3469, df = 262, p-value = 0.7289
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.08888719  0.12691000
sample estimates:
mean of the differences
             0.01901141

> t.test(Q2_2, P11_2, paired = TRUE)

     Paired t-test

data:  Q2_2 and P11_2
t = -2.6705, df = 262, p-value = 0.008048
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.34350421 -0.05193305
sample estimates:
mean of the differences
             -0.1977186
```

```
> t.test(Q2_3, P11_3, paired = TRUE)

     Paired t-test

data:  Q2_3 and P11_3
t = 3.7053, df = 262, p-value = 0.0002576
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 0.09799178 0.32025917
sample estimates:
mean of the differences
              0.2091255

> t.test(Q2_4, P11_4, paired = TRUE)

     Paired t-test

data:  Q2_4 and P11_4
t = 0.666, df = 262, p-value = 0.506
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.08927997  0.18053472
sample estimates:
mean of the differences
             0.04562738

> t.test(Q2_5, P11_5, paired = TRUE)

     Paired t-test

data:  Q2_5 and P11_5
t = -4.8528, df = 262, p-value = 2.092e-06
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.4382959 -0.1852783
sample estimates:
mean of the differences
             -0.3117871

> t.test(Q2_6, P11_6, paired = TRUE)

     Paired t-test

data:  Q2_6 and P11_6
t = 0.7792, df = 262, p-value = 0.4366
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.06386987  0.14752006
sample estimates:
mean of the differences
```

```
              0.0418251

> t.test(Q2_7, P11_7, paired = TRUE)

     Paired t-test

data:  Q2_7 and P11_7
t = -0.0665, df = 262, p-value = 0.947
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.1163192  0.1087147
sample estimates:
mean of the differences
           -0.003802281

> t.test(Q2_8, P11_8, paired = TRUE)

     Paired t-test

data:  Q2_8 and P11_8
t = 1.4071, df = 262, p-value = 0.1606
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.03644409  0.21895360
sample estimates:
mean of the differences
             0.09125475

> t.test(Q2_9, P11_9, paired = TRUE)

     Paired t-test

data:  Q2_9 and P11_9
t = 0.8142, df = 262, p-value = 0.4163
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.08090302  0.19497146
sample estimates:
mean of the differences
             0.05703422

>
> t.test(Q3_1, P12_1, paired = TRUE)

     Paired t-test

data:  Q3_1 and P12_1
t = 0.1083, df = 262, p-value = 0.9139
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
```

```
 -0.1307075  0.1459166
sample estimates:
mean of the differences
            0.007604563

> t.test(Q3_2, P12_2, paired = TRUE)

     Paired t-test

data:  Q3_2 and P12_2
t = 0.4069, df = 262, p-value = 0.6844
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.1021806  0.1554125
sample estimates:
mean of the differences
             0.02661597

> t.test(Q3_3, P12_3, paired = TRUE)

     Paired t-test

data:  Q3_3 and P12_3
t = 0.4704, df = 262, p-value = 0.6385
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.1090291  0.1774702
sample estimates:
mean of the differences
             0.03422053

>
##################################################################
> #                                                              #
> # Survey Analysis for Study II | Created 08.18.2014 | Last
modified 08.18.14                          #
> #                                                              #
##################################################################
>
> setwd("C:/Users/Owner/Desktop/Wiki Project/Data/R Data")
> library("psych")
>
> #### Experimental Group! ####
>
> post109e<- read.csv("Study_II_Survey_Data_Experimental.csv")
> attach(post109e)
The following objects are masked from post104:

    ID, P1_1, P1_2, P1_3, P1_4, P1_5, P1_6, P1_7, P10_1, P10_2,
P10_3, P2_1, P2_2, P2_3, P2_4, P2_5,
    P2_6, P2_7, P5, P7, Q1_1, Q1_2, Q1_3, Q1_4, Q1_5, Q1_6,
Q1_7, Q1_8, Q1_9, Q2_1, Q2_2, Q2_3, Q2_4,
```

```
    Q2_5, Q2_6, Q2_7, Q2_8, Q2_9, Q2_9_TEXT, Q3_1, Q3_2, Q3_3,
Q4, Q5, Q5_TEXT, Q6_1, Q6_2, Q6_3, Q6_4,
    Q6_4_TEXT, Q7, quote
>
> # Descriptive stats of CSc (Table 5.4)
> describe(Q1_1)
  vars   n mean   sd median trimmed mad min max range  skew
kurtosis   se
1    1 207 5.12 0.79      5     5.2   0   2   6     4 -1.26
3.06 0.06
> describe(Q1_2)
  vars   n mean   sd median trimmed mad min max range skew
kurtosis   se
1    1 207 2.22 0.93      2    2.11   0   1   6     5 1.36
2.43 0.06
> describe(Q1_3)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis   se
1    1 207  2.9 1.26      3    2.85 1.48   1   6     5 0.29    -
0.75 0.09
> describe(Q1_4)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 207 4.22 1.11      4    4.27 1.48   1   6     5 -0.51
0.07 0.08
> describe(Q1_5)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 207 5.32 0.68      5    5.41 1.48   3   6     3 -0.68
0.08 0.05
> describe(Q1_6)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 207 4.42 0.85      4    4.41 1.48   1   6     5 -0.04
0.45 0.06
> describe(Q1_7)
  vars   n mean   sd median trimmed mad min max range skew
kurtosis   se
1    1 207 1.57 0.76      1    1.45   0   1   5     4 1.82
4.87 0.05
> describe(Q1_8)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 207 3.71 1.27      4    3.72 1.48   1   6     5 -0.21
-0.59 0.09
> describe(Q1_9)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 207 4.28 0.85      4    4.31 1.48   2   6     4 -0.24
0.04 0.06
>
> # Descriptive stats of Resources (Table 5.5, Table 5.6)
>
> describe(Q2_1)
```

```
  vars   n mean  sd median trimmed  mad min max range  skew
kurtosis   se
1    1 207  3.3 0.7      3     3.4 1.48   1   4     3 -0.75
0.25 0.05
> describe(Q2_2)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 207 2.85 0.83      3    2.89 1.48   1   4     3 -0.37
-0.38 0.06
> describe(Q2_3)
  vars   n mean   sd median trimmed mad min max range  skew
kurtosis   se
1    1 207 3.43 0.73      4    3.55   0   1   4     3 -1.14
0.88 0.05
> describe(Q2_4)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis   se
1    1 207 2.26 0.86      2    2.21 1.48   1   4     3  0.3    -
0.55 0.06
> describe(Q2_5)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 207 2.87 0.77      3    2.88 1.48   1   4     3 -0.17
-0.52 0.05
> describe(Q2_6)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis   se
1    1 207 2.03 0.89      2    1.94 1.48   1   4     3  0.6    -
0.36 0.06
> describe(Q2_7)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis   se
1    1 207 2.19 0.87      2    2.14 1.48   1   4     3 0.38    -
0.49 0.06
> describe(Q2_8)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis   se
1    1 207 2.72 0.85      3    2.72 1.48   1   4     3    0    -
0.82 0.06
> describe(Q2_9)
  vars   n mean   sd median trimmed mad min max range skew
kurtosis   se
1    1 207 1.59 0.89      1    1.42   0   1   4     3 1.39
0.91 0.06
>
> describe(Q3_1)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 207 3.41 1.08      3    3.48 1.48   1   5     4 -0.46
-0.1 0.08
> describe(Q3_2)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis   se
```

```
1    1 207 2.16 1.11      2    2.05 1.48   1   5     4 0.58    -
0.64 0.08
> describe(Q3_3)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis   se
1    1 207 2.75 1.29      3    2.69 1.48   1   5     4 0.23    -
0.99 0.09
>
>
> #### Paired t-tests between pre and post-test: CSC (Table 5.7)
####
>
> t.test(Q1_1, P1_1, paired = TRUE)

     Paired t-test

data:  Q1_1 and P1_1
t = 7.2016, df = 206, p-value = 1.097e-11
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 0.3753959 0.6584205
sample estimates:
mean of the differences
              0.5169082

> t.test(Q1_2, P1_2, paired = TRUE)

     Paired t-test

data:  Q1_2 and P1_2
t = -4.5362, df = 206, p-value = 9.717e-06
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.5613738 -0.2212349
sample estimates:
mean of the differences
             -0.3913043

> t.test(Q1_3, P1_3, paired = TRUE)

     Paired t-test

data:  Q1_3 and P1_3
t = -2.8854, df = 206, p-value = 0.004325
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.45538043 -0.08568237
sample estimates:
mean of the differences
             -0.2705314
```

```
> t.test(Q1_4, P1_4, paired = TRUE)

     Paired t-test

data:  Q1_4 and P1_4
t = 2.5231, df = 206, p-value = 0.01239
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 0.04646533 0.37865544
sample estimates:
mean of the differences
              0.2125604

> t.test(Q1_9, P1_9, paired = TRUE)

     Paired t-test

data:  Q1_9 and P1_9
t = 1.0045, df = 206, p-value = 0.3163
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.06976246  0.21469000
sample estimates:
mean of the differences
             0.07246377

>
> #### Paired t-tests between pre and post-test: Resources
(Table 5.8, 5.9) ####
>
> t.test(Q2_1, P9_1, paired = TRUE)

     Paired t-test

data:  Q2_1 and P9_1
t = 2.1964, df = 206, p-value = 0.02918
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 0.01483922 0.27501585
sample estimates:
mean of the differences
              0.1449275

> t.test(Q2_2, P9_2, paired = TRUE)

     Paired t-test

data:  Q2_2 and P9_2
t = 3.2884, df = 206, p-value = 0.001185
alternative hypothesis: true difference in means is not equal to
0
```

```
95 percent confidence interval:
 0.1064017 0.4249992
sample estimates:
mean of the differences
              0.2657005

> t.test(Q2_3, P9_3, paired = TRUE)

     Paired t-test

data:  Q2_3 and P9_3
t = 2.3611, df = 206, p-value = 0.01915
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 0.02948966 0.32799826
sample estimates:
mean of the differences
               0.178744

> t.test(Q2_4, P9_4, paired = TRUE)

     Paired t-test

data:  Q2_4 and P9_4
t = -5.5067, df = 206, p-value = 1.082e-07
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.6494915 -0.3070302
sample estimates:
mean of the differences
             -0.4782609

> t.test(Q2_5, P9_5, paired = TRUE)

     Paired t-test

data:  Q2_5 and P9_5
t = 5.1064, df = 206, p-value = 7.457e-07
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 0.2550528 0.5758651
sample estimates:
mean of the differences
              0.4154589

> t.test(Q2_6, P9_6, paired = TRUE)

     Paired t-test

data:  Q2_6 and P9_6
t = -3.9187, df = 206, p-value = 0.0001211
```

```
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.4937762 -0.1632286
sample estimates:
mean of the differences
             -0.3285024

> t.test(Q2_7, P9_7, paired = TRUE)

     Paired t-test

data:  Q2_7 and P9_7
t = -9.4309, df = 206, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.9286922 -0.6075397
sample estimates:
mean of the differences
             -0.7681159

> t.test(Q2_8, P9_8, paired = TRUE)

     Paired t-test

data:  Q2_8 and P9_8
t = 13.2677, df = 206, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 0.9953596 1.3428047
sample estimates:
mean of the differences
               1.169082

> t.test(Q2_9, P9_9, paired = TRUE)

     Paired t-test

data:  Q2_9 and P9_9
t = 2.3069, df = 206, p-value = 0.02206
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 0.02457679 0.31358746
sample estimates:
mean of the differences
              0.1690821

>
> t.test(Q3_1, P10_1, paired = TRUE)

     Paired t-test
```

```
data:  Q3_1 and P10_1
t = -4.6362, df = 206, p-value = 6.295e-06
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.5990176 -0.2415621
sample estimates:
mean of the differences
             -0.4202899

> t.test(Q3_2, P10_2, paired = TRUE)

     Paired t-test

data:  Q3_2 and P10_2
t = -3.1624, df = 206, p-value = 0.001801
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.4470322 -0.1036925
sample estimates:
mean of the differences
             -0.2753623

> t.test(Q3_3, P10_3, paired = TRUE)

     Paired t-test

data:  Q3_3 and P10_3
t = -0.7944, df = 206, p-value = 0.4279
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.2354765  0.1002108
sample estimates:
mean of the differences
            -0.06763285

>
> describe(P2_1)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis  se
1    1 207 3.29 1.49      4    3.31 1.48   1   6     5 -0.14
-1.14 0.1
> describe(P2_2)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis  se
1    1 207 2.82 1.39      3    2.76 1.48   1   6     5 0.12    -
1.16 0.1
> describe(P2_3)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis   se
```

```
1    1 207 2.67 1.36      2    2.57 1.48   1   6     5 0.42    -
0.79 0.09
> describe(P2_4)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis  se
1    1 207 2.68 1.51      2    2.56 1.48   1   6     5 0.44    -
0.98 0.1
> describe(P2_5)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis  se
1    1 207 3.71 1.47      4     3.8 1.48   1   6     5 -0.58
-0.76 0.1
> describe(P2_6)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 207 4.13 1.28      4    4.22 1.48   1   6     5 -0.68
-0.08 0.09
> describe(P2_7)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 207 3.68 1.27      4    3.78 1.48   1   6     5 -0.55
-0.53 0.09
> describe(P2_8)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 207 4.85 1.05      5    4.96 1.48   1   6     5 -1.08
1.66 0.07
> describe(P2_9)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 207 4.62 1.23      5     4.8 1.48   1   6     5 -1.14
1.11 0.09
> describe(P2_10)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 207    4 1.35      4    4.08 1.48   1   6     5 -0.62
-0.21 0.09
> describe(P2_11)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis  se
1    1 207 3.52 1.48      4    3.57 1.48   1   6     5 -0.28
-1.01 0.1
> describe(P2_12)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis  se
1    1 207 3.35 1.39      4     3.4 1.48   1   6     5 -0.23
-0.94 0.1
> describe(P2_13)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis  se
1    1 207 3.97 1.37      4    4.08 1.48   1   6     5 -0.74
-0.19 0.1
> describe(P2_14)
```

```
  vars   n mean  sd median trimmed  mad min max range skew
kurtosis  se
1    1 207 3.03 1.5      3    2.98 1.48   1   6     5 0.09    -
1.07 0.1
>
> detach(post109e)
>
>
> #### Control Group! ####
>
> post109c<- read.csv("Study_II_Survey_Data_Control.csv")
> attach(post109c)
The following objects are masked from post104:

    ID, P1_1, P1_2, P1_3, P1_4, P1_5, P1_6, P1_7, P2_1, P2_2,
P2_3, P2_4, P2_5, P2_6, P2_7, P3_1, P3_2,
    P3_3, Q1_1, Q1_2, Q1_3, Q1_4, Q1_5, Q1_6, Q1_7, Q1_8, Q1_9,
Q2_1, Q2_2, Q2_3, Q2_4, Q2_5, Q2_6, Q2_7,
    Q2_8, Q2_9, Q2_9_TEXT, Q3_1, Q3_2, Q3_3, Q4, Q5, Q5_TEXT,
Q6_1, Q6_2, Q6_3, Q6_4, Q6_4_TEXT, Q7,
    quote
>
> #### Paired t-tests between pre and post-test: CSC ####
>
> t.test(Q1_1, P1_1, paired = TRUE)

     Paired t-test

data:  Q1_1 and P1_1
t = 6.3071, df = 236, p-value = 1.389e-09
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 0.2698345 0.5149756
sample estimates:
mean of the differences
              0.3924051

> t.test(Q1_2, P1_2, paired = TRUE)

     Paired t-test

data:  Q1_2 and P1_2
t = -6.6441, df = 236, p-value = 2.087e-10
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.6017572 -0.3265128
sample estimates:
mean of the differences
              -0.464135

> t.test(Q1_3, P1_3, paired = TRUE)
```

```
	Paired t-test

data:  Q1_3 and P1_3
t = -2.8054, df = 236, p-value = 0.005444
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.40221469 -0.07035915
sample estimates:
mean of the differences
             -0.2362869

> t.test(Q1_4, P1_4, paired = TRUE)

	Paired t-test

data:  Q1_4 and P1_4
t = 3.1786, df = 236, p-value = 0.001678
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 0.09625522 0.41007390
sample estimates:
mean of the differences
              0.2531646

> t.test(Q1_9, P1_9, paired = TRUE)

	Paired t-test

data:  Q1_9 and P1_9
t = 3.0813, df = 236, p-value = 0.002306
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 0.07151948 0.32510499
sample estimates:
mean of the differences
              0.1983122

>
> #### Paired t-tests between pre and post-test: Resources ####
>
> t.test(Q2_1, P2_1, paired = TRUE)

	Paired t-test

data:  Q2_1 and P2_1
t = 1.1443, df = 236, p-value = 0.2537
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.05176393  0.19522384
sample estimates:
```

```
mean of the differences
             0.07172996

> t.test(Q2_2, P2_2, paired = TRUE)

     Paired t-test

data:  Q2_2 and P2_2
t = 6.4697, df = 236, p-value = 5.609e-10
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 0.3462802 0.6495004
sample estimates:
mean of the differences
              0.4978903

> t.test(Q2_3, P2_3, paired = TRUE)

     Paired t-test

data:  Q2_3 and P2_3
t = 5.3504, df = 236, p-value = 2.075e-07
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 0.2425851 0.5253474
sample estimates:
mean of the differences
              0.3839662

> t.test(Q2_4, P2_4, paired = TRUE)

     Paired t-test

data:  Q2_4 and P2_4
t = -7.3943, df = 236, p-value = 2.465e-12
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.8229136 -0.4766645
sample estimates:
mean of the differences
              -0.649789

> t.test(Q2_5, P2_5, paired = TRUE)

     Paired t-test

data:  Q2_5 and P2_5
t = 7.0064, df = 236, p-value = 2.538e-11
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
```

```
 0.4064209 0.7243808
sample estimates:
mean of the differences
              0.5654008

> t.test(Q2_6, P2_6, paired = TRUE)

     Paired t-test

data:  Q2_6 and P2_6
t = -1.7612, df = 236, p-value = 0.0795
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.30393564  0.01701581
sample estimates:
mean of the differences
             -0.1434599

> t.test(Q2_7, P2_7, paired = TRUE)

     Paired t-test

data:  Q2_7 and P2_7
t = -12.018, df = 236, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.9281950 -0.6667417
sample estimates:
mean of the differences
             -0.7974684

> t.test(Q2_8, P2_8, paired = TRUE)

     Paired t-test

data:  Q2_8 and P2_8
t = 19.8379, df = 236, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 1.200922 1.465745
sample estimates:
mean of the differences
               1.333333

> t.test(Q2_9, P2_9, paired = TRUE)

     Paired t-test

data:  Q2_9 and P2_9
t = 1.7181, df = 236, p-value = 0.08709
```

```
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.01670847  0.24455657
sample estimates:
mean of the differences
              0.1139241

>
> t.test(Q3_1, P3_1, paired = TRUE)

     Paired t-test

data:  Q3_1 and P3_1
t = -3.9717, df = 236, p-value = 9.482e-05
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.4418656 -0.1488517
sample estimates:
mean of the differences
             -0.2953586

> t.test(Q3_2, P3_2, paired = TRUE)

     Paired t-test

data:  Q3_2 and P3_2
t = -3.9097, df = 236, p-value = 0.0001208
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.4949499 -0.1632779
sample estimates:
mean of the differences
             -0.3291139

> t.test(Q3_3, P3_3, paired = TRUE)

     Paired t-test

data:  Q3_3 and P3_3
t = 0.7724, df = 236, p-value = 0.4407
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.09160269  0.20974615
sample estimates:
mean of the differences
             0.05907173

>
> detach(post109c)
>
```

```
>
#################################################################
> # Survey Analysis for Study III | Created 08.18.2014 | Last
modified 10.17.14                          #
> #                                                               #
#################################################################
>
> setwd("C:/Users/Owner/Desktop/Wiki Project/Data/R Data")
> install.packages("psych")
Error in install.packages : Updating loaded packages
> library("psych")
>
> #### Experimental Group! ####
>
> post104e<- read.csv("Study_III_Survey_Data_Experimental.csv")
> attach(post104e)
The following objects are masked from post104e (position 3):

    ID, P1_1, P1_2, P1_3, P1_4, P1_5, P1_6, P1_7, P1_8, P1_9,
P10, P11, P12_2, P12_3, P12_4, P12_5,
    P12_6, P12_6_TEXT, P13_1, P13_2, P13_3, P13_4, P13_5, P13_6,
P13_7, P13_8, P13_8_TEXT, P13_9,
    P13_9_TEXT, P14_1, P14_2, P14_3, P14_4, P14_5, P15_TEXT,
P16, P17, P18, P19, P19_TEXT, P2_1, P2_10,
    P2_11, P2_12, P2_13, P2_2, P2_3, P2_4, P2_5, P2_6, P2_7,
P2_8, P2_9, P3, P3_TEXT, P4, P5, P6, P7, P8,
    P9, PP12_1, Q1_1, Q1_2, Q1_3, Q1_4, Q1_5, Q1_6, Q1_7, Q1_8,
Q1_9, Q2_1, Q2_10, Q2_10_TEXT, Q2_2,
    Q2_3, Q2_4, Q2_5, Q2_6, Q2_7, Q2_8, Q2_9, Q2_9_TEXT, Q3_1,
Q3_2, Q3_3, Q4, Q5, Q5_TEXT, Q6_1, Q6_2,
    Q6_3, Q6_4, Q6_4_TEXT, Q7, quote
The following objects are masked from post104e (position 4):

    ID, P1_1, P1_2, P1_3, P1_4, P1_5, P1_6, P1_7, P1_8, P1_9,
P10, P11, P12_2, P12_3, P12_4, P12_5,
    P12_6, P12_6_TEXT, P13_1, P13_2, P13_3, P13_4, P13_5, P13_6,
P13_7, P13_8, P13_8_TEXT, P13_9,
    P13_9_TEXT, P14_1, P14_2, P14_3, P14_4, P14_5, P15_TEXT,
P16, P17, P18, P19, P19_TEXT, P2_1, P2_10,
    P2_11, P2_12, P2_13, P2_2, P2_3, P2_4, P2_5, P2_6, P2_7,
P2_8, P2_9, P3, P3_TEXT, P4, P5, P6, P7, P8,
    P9, PP12_1, Q1_1, Q1_2, Q1_3, Q1_4, Q1_5, Q1_6, Q1_7, Q1_8,
Q1_9, Q2_1, Q2_10, Q2_10_TEXT, Q2_2,
    Q2_3, Q2_4, Q2_5, Q2_6, Q2_7, Q2_8, Q2_9, Q2_9_TEXT, Q3_1,
Q3_2, Q3_3, Q4, Q5, Q5_TEXT, Q6_1, Q6_2,
    Q6_3, Q6_4, Q6_4_TEXT, Q7, quote
The following objects are masked from post104:

    ID, P1_1, P1_2, P1_3, P1_4, P1_5, P1_6, P1_7, P12_2, P12_3,
P2_1, P2_2, P2_3, P2_4, P2_5, P2_6, P2_7,
    P5, P7, P8, P9, Q1_1, Q1_2, Q1_3, Q1_4, Q1_5, Q1_6, Q1_7,
Q1_8, Q1_9, Q2_1, Q2_2, Q2_3, Q2_4, Q2_5,
    Q2_6, Q2_7, Q2_8, Q2_9, Q2_9_TEXT, Q3_1, Q3_2, Q3_3, Q4, Q5,
Q5_TEXT, Q6_1, Q6_2, Q6_3, Q6_4,
```

```
    Q6_4_TEXT, Q7, quote
>
> # Descriptive stats of CSc (Table 5.4)
> describe(Q1_1)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 217 4.65 0.74      5    4.63 1.48   3   6     3 -0.03
-0.38 0.05
> describe(Q1_2)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis   se
1    1 217 2.82 1.22      2    2.72 1.48   1   6     5 0.75    -
0.11 0.08
> describe(Q1_3)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 217 3.54 1.36      4    3.54 1.48   1   6     5 -0.02
-0.79 0.09
> describe(Q1_4)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 217 3.69 1.08      4    3.71 1.48   1   6     5 -0.14
-0.65 0.07
> describe(Q1_5)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 217 4.88 0.79      5    4.89 1.48   3   6     3 -0.17
-0.65 0.05
> describe(Q1_6)
  vars   n mean  sd median trimmed mad min max range skew
kurtosis   se
1    1 217 4.17 0.9      4    4.15   0   2   6     4 0.07
0.06 0.06
> describe(Q1_7)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis   se
1    1 217 1.92 0.99      2    1.78 1.48   1   6     5 1.47
2.83 0.07
> describe(Q1_8)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis   se
1    1 217 3.33 1.27      3     3.3 1.48   1   6     5  0.1    -
0.83 0.09
> describe(Q1_9)
  vars   n mean   sd median trimmed mad min max range  skew
kurtosis   se
1    1 217 4.13 0.88      4    4.15   0   1   6     5 -0.25
0.58 0.06
>
>
> # Descriptive stats of Resources (Table 5.5, Table 5.6)
>
> describe(Q2_1)
```

```
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 217 3.23 0.78      3    3.29 1.48   1   4     3 -0.53
-0.83 0.05
> describe(Q2_2)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis   se
1    1 217  2.5 0.95      2     2.5 1.48   1   4     3 0.07    -
0.94 0.06
> describe(Q2_3)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 217 2.99 0.93      3    3.06 1.48   1   4     3 -0.45
-0.84 0.06
> describe(Q2_4)
  vars   n mean   sd median trimmed mad min max range skew
kurtosis   se
1    1 217  1.7 0.92      1    1.55   0   1   4     3 1.09
0.07 0.06
> describe(Q2_5)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis   se
1    1 217 2.51 1.02      2    2.51 1.48   1   4     3 0.08    -
1.14 0.07
> describe(Q2_6)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis   se
1    1 217 1.99 0.87      2    1.91 1.48   1   4     3 0.56    -
0.42 0.06
> describe(Q2_7)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis   se
1    1 217 1.76 0.73      2    1.67 1.48   1   4     3 0.69
0.07 0.05
> describe(Q2_8)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis   se
1    1 217 2.59 0.87      3    2.61 1.48   1   4     3 0.03    -
0.74 0.06
> describe(Q2_9)
  vars   n mean   sd median trimmed mad min max range skew
kurtosis   se
1    1 217 1.48 0.84      1    1.29   0   1   4     3 1.77
2.25 0.06
>
> describe(Q3_1)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 217 3.07 1.11      3    3.09 1.48   1   5     4 -0.14
-0.66 0.08
> describe(Q3_2)
  vars   n mean  sd median trimmed mad min max range skew
kurtosis   se
```

```
1    1 217 1.63 0.9      1    1.46   0   1   5     4 1.43
1.48 0.06
> describe(Q3_3)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis   se
1    1 217 2.33 1.22      2    2.21 1.48   1   5     4 0.59    -
0.58 0.08
>
>
> #### Paired t-tests between pre and post-test: CSC (Table 5.7)
####
>
> t.test(Q1_1, P1_1, paired = TRUE)

     Paired t-test

data:  Q1_1 and P1_1
t = 1.1603, df = 216, p-value = 0.2472
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.05473552  0.21141755
sample estimates:
mean of the differences
             0.07834101

> t.test(Q1_2, P1_2, paired = TRUE)

     Paired t-test

data:  Q1_2 and P1_2
t = 0, df = 216, p-value = 1
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.161323  0.161323
sample estimates:
mean of the differences
                      0

> t.test(Q1_3, P1_3, paired = TRUE)

     Paired t-test

data:  Q1_3 and P1_3
t = 1.3144, df = 216, p-value = 0.1901
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.05755734  0.28797208
sample estimates:
mean of the differences
              0.1152074
```

```
> t.test(Q1_4, P1_4, paired = TRUE)

     Paired t-test

data:  Q1_4 and P1_4
t = -2.6881, df = 216, p-value = 0.007746
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.38338776 -0.05900855
sample estimates:
mean of the differences
             -0.2211982

> t.test(Q1_9, P1_9, paired = TRUE)

     Paired t-test

data:  Q1_9 and P1_9
t = -0.9869, df = 216, p-value = 0.3248
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.20718213  0.06893328
sample estimates:
mean of the differences
            -0.06912442

>
> #### Paired t-tests between pre and post-test: Resources
(Table 5.8, 5.9) ####
>
> t.test(Q2_1, P13_1, paired = TRUE)

     Paired t-test

data:  Q2_1 and P13_1
t = -0.9485, df = 216, p-value = 0.344
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.17021780  0.05961872
sample estimates:
mean of the differences
            -0.05529954

> t.test(Q2_2, P13_2, paired = TRUE)

     Paired t-test

data:  Q2_2 and P13_2
t = 4.2289, df = 216, p-value = 3.468e-05
alternative hypothesis: true difference in means is not equal to
0
```

```
95 percent confidence interval:
 0.1845360 0.5067082
sample estimates:
mean of the differences
              0.3456221

> t.test(Q2_3, P13_3, paired = TRUE)

     Paired t-test

data:  Q2_3 and P13_3
t = 1.8566, df = 216, p-value = 0.06472
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.007947805  0.266012322
sample estimates:
mean of the differences
              0.1290323

> t.test(Q2_4, P13_4, paired = TRUE)

     Paired t-test

data:  Q2_4 and P13_4
t = -10.7981, df = 216, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -1.166185 -0.806165
sample estimates:
mean of the differences
             -0.9861751

> t.test(Q2_5, P13_5, paired = TRUE)

     Paired t-test

data:  Q2_5 and P13_5
t = 5.9935, df = 216, p-value = 8.513e-09
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 0.3525831 0.6981081
sample estimates:
mean of the differences
              0.5253456

> t.test(Q2_6, P13_6, paired = TRUE)

     Paired t-test

data:  Q2_6 and P13_6
t = 3.584, df = 216, p-value = 0.0004182
```

```
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 0.1078469 0.3714158
sample estimates:
mean of the differences
              0.2396313

> t.test(Q2_7, P13_7, paired = TRUE)

     Paired t-test

data:  Q2_7 and P13_7
t = -12.0886, df = 216, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.9647390 -0.6942472
sample estimates:
mean of the differences
             -0.8294931

> t.test(Q2_8, P13_8, paired = TRUE)

     Paired t-test

data:  Q2_8 and P13_8
t = 14.4113, df = 216, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 0.9507481 1.2520169
sample estimates:
mean of the differences
               1.101382

> t.test(Q2_9, P13_9, paired = TRUE)

     Paired t-test

data:  Q2_9 and P13_9
t = 0.8922, df = 216, p-value = 0.3733
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.07801192  0.20704417
sample estimates:
mean of the differences
             0.06451613

>
> t.test(Q3_1, P14_1, paired = TRUE)

     Paired t-test
```

```
data:  Q3_1 and P14_1
t = 0.1219, df = 216, p-value = 0.9031
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.1398169  0.1582501
sample estimates:
mean of the differences
             0.00921659

> t.test(Q3_2, P14_2, paired = TRUE)

     Paired t-test

data:  Q3_2 and P14_2
t = -0.2091, df = 216, p-value = 0.8346
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.1441609  0.1165112
sample estimates:
mean of the differences
            -0.01382488

> t.test(Q3_3, P14_3, paired = TRUE)

     Paired t-test

data:  Q3_3 and P14_3
t = 2.5138, df = 216, p-value = 0.01267
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 0.04178986 0.34530692
sample estimates:
mean of the differences
              0.1935484

>
> detach(post104e)
>
>
> #### Control Group! ####
>
> post109c<- read.csv("Study_III_Survey_Data_Control.csv")
> attach(post109c)
The following objects are masked from post109c (position 3):

    ID, P1_1, P1_2, P1_3, P1_4, P1_5, P1_6, P1_7, P1_8, P1_9,
P2_1, P2_2, P2_3, P2_4, P2_5, P2_6, P2_7,
    P2_8, P2_8_TEXT, P2_9, P2_9_TEXT, P3_1, P3_2, P3_3, P3_4,
P4, P5, P6, P7, P8, P8_TEXT, P9, Q1_1,
```

```
    Q1_2, Q1_3, Q1_4, Q1_5, Q1_6, Q1_7, Q1_8, Q1_9, Q2_1, Q2_10,
Q2_10_TEXT, Q2_2, Q2_3, Q2_4, Q2_5,
    Q2_6, Q2_7, Q2_8, Q2_9, Q2_9_TEXT, Q3_1, Q3_2, Q3_3, Q4, Q5,
Q5_TEXT, Q6_1, Q6_2, Q6_3, Q6_4,
    Q6_4_TEXT, Q7, quote
The following objects are masked from post104e (position 4):

    ID, P1_1, P1_2, P1_3, P1_4, P1_5, P1_6, P1_7, P1_8, P1_9,
P2_1, P2_2, P2_3, P2_4, P2_5, P2_6, P2_7,
    P2_8, P2_9, P4, P5, P6, P7, P8, P9, Q1_1, Q1_2, Q1_3, Q1_4,
Q1_5, Q1_6, Q1_7, Q1_8, Q1_9, Q2_1,
    Q2_10, Q2_10_TEXT, Q2_2, Q2_3, Q2_4, Q2_5, Q2_6, Q2_7, Q2_8,
Q2_9, Q2_9_TEXT, Q3_1, Q3_2, Q3_3, Q4,
    Q5, Q5_TEXT, Q6_1, Q6_2, Q6_3, Q6_4, Q6_4_TEXT, Q7, quote
The following objects are masked from post104e (position 5):

    ID, P1_1, P1_2, P1_3, P1_4, P1_5, P1_6, P1_7, P1_8, P1_9,
P2_1, P2_2, P2_3, P2_4, P2_5, P2_6, P2_7,
    P2_8, P2_9, P4, P5, P6, P7, P8, P9, Q1_1, Q1_2, Q1_3, Q1_4,
Q1_5, Q1_6, Q1_7, Q1_8, Q1_9, Q2_1,
    Q2_10, Q2_10_TEXT, Q2_2, Q2_3, Q2_4, Q2_5, Q2_6, Q2_7, Q2_8,
Q2_9, Q2_9_TEXT, Q3_1, Q3_2, Q3_3, Q4,
    Q5, Q5_TEXT, Q6_1, Q6_2, Q6_3, Q6_4, Q6_4_TEXT, Q7, quote
The following objects are masked from post104:

    ID, P1_1, P1_2, P1_3, P1_4, P1_5, P1_6, P1_7, P2_1, P2_2,
P2_3, P2_4, P2_5, P2_6, P2_7, P3_1, P3_2,
    P3_3, P3_4, P5, P7, P8, P9, Q1_1, Q1_2, Q1_3, Q1_4, Q1_5,
Q1_6, Q1_7, Q1_8, Q1_9, Q2_1, Q2_2, Q2_3,
    Q2_4, Q2_5, Q2_6, Q2_7, Q2_8, Q2_9, Q2_9_TEXT, Q3_1, Q3_2,
Q3_3, Q4, Q5, Q5_TEXT, Q6_1, Q6_2, Q6_3,
    Q6_4, Q6_4_TEXT, Q7, quote
>
> # Descriptive stats of CSc (Table 5.4)
> describe(Q1_1)
  vars   n mean sd median trimmed  mad min max range  skew
kurtosis   se
1    1 148 4.59  1      5    4.69 1.48   1   6     5 -0.94
1.24 0.08
> describe(Q1_2)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis  se
1    1 148 2.72 1.17      2    2.64 1.48   1   6     5 0.75    -
0.14 0.1
> describe(Q1_3)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis  se
1    1 148 3.57 1.25      4    3.58 1.48   1   6     5 -0.15
-0.67 0.1
> describe(Q1_4)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis  se
1    1 148 3.76 1.18      4    3.78 1.48   1   6     5 -0.25
-0.29 0.1
```

```
> describe(Q1_5)
  vars   n mean   sd median trimmed mad min max range  skew
kurtosis   se
1    1 148 5.05 0.69      5    5.07   0   3   6     3 -0.18    -
0.55 0.06
> describe(Q1_6)
  vars   n mean   sd median trimmed mad min max range  skew
kurtosis   se
1    1 148 4.03 0.86      4    4.06   0   2   6     4 -0.19
0.14 0.07
> describe(Q1_7)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis   se
1    1 148 1.97 0.87      2    1.88 1.48   1   5     4 0.75
0.28 0.07
> describe(Q1_8)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis  se
1    1 148 3.56 1.25      4    3.56 1.48   1   6     5 -0.03
-0.56 0.1
> describe(Q1_9)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 148 4.09 1.04      4    4.15 1.48   1   6     5 -0.55
0.58 0.09
>
> # Descriptive stats of Resources (Table 5.5, Table 5.6)
>
> describe(Q2_1)
  vars   n mean   sd median trimmed mad min max range  skew
kurtosis   se
1    1 148 3.34 0.74      4    3.42   0   2   4     2 -0.64    -
0.95 0.06
> describe(Q2_2)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 148 2.56 0.96      3    2.58 1.48   1   4     3 -0.01
-0.97 0.08
> describe(Q2_3)
  vars   n mean  sd median trimmed  mad min max range  skew
kurtosis   se
1    1 148 2.92 0.8      3    2.92 1.48   1   4     3 -0.01    -
1.12 0.07
> describe(Q2_4)
  vars   n mean   sd median trimmed mad min max range skew
kurtosis   se
1    1 148 1.43 0.69      1    1.28   0   1   4     3 1.43
1.05 0.06
> describe(Q2_5)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis   se
1    1 148 2.43 0.93      2    2.42 1.48   1   4     3 0.05
-0.9 0.08
> describe(Q2_6)
```

```
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis   se
1    1 148 1.82 0.82      2    1.74 1.48   1   4     3 0.69    -
0.26 0.07
> describe(Q2_7)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis   se
1    1 148 1.71 0.75      2    1.61 1.48   1   4     3 0.91
0.56 0.06
> describe(Q2_8)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis   se
1    1 148 2.52 0.84      2    2.51 1.48   1   4     3 0.25    -
0.63 0.07
> describe(Q2_9)
  vars   n mean   sd median trimmed mad min max range skew
kurtosis   se
1    1 148 1.44 0.91      1    1.23   0   1   4     3 1.86
1.99 0.08
>
> describe(Q3_1)
  vars   n mean   sd median trimmed  mad min max range  skew
kurtosis   se
1    1 148 3.05 1.15      3    3.07 1.48   1   5     4 -0.02
-0.71 0.09
> describe(Q3_2)
  vars   n mean   sd median trimmed mad min max range skew
kurtosis   se
1    1 148 1.51 0.85      1    1.35   0   1   5     4 1.77
3.08 0.07
> describe(Q3_3)
  vars   n mean   sd median trimmed  mad min max range skew
kurtosis  se
1    1 148 2.21 1.25      2    2.08 1.48   1   5     4 0.64    -
0.77 0.1
>
>
> #### Paired t-tests between pre and post-test: CSC (Table 5.7)
####
>
> t.test(Q1_1, P1_1, paired = TRUE)

     Paired t-test

data:  Q1_1 and P1_1
t = 0.1884, df = 147, p-value = 0.8508
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.1282633  0.1552904
sample estimates:
mean of the differences
             0.01351351
```

```
> t.test(Q1_2, P1_2, paired = TRUE)

     Paired t-test

data:  Q1_2 and P1_2
t = -0.5885, df = 147, p-value = 0.5571
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.2355833  0.1274752
sample estimates:
mean of the differences
            -0.05405405

> t.test(Q1_3, P1_3, paired = TRUE)

     Paired t-test

data:  Q1_3 and P1_3
t = 2.3496, df = 147, p-value = 0.02012
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 0.03221326 0.37319214
sample estimates:
mean of the differences
              0.2027027

> t.test(Q1_4, P1_4, paired = TRUE)

     Paired t-test

data:  Q1_4 and P1_4
t = -2.1744, df = 147, p-value = 0.03128
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.36113795 -0.01724043
sample estimates:
mean of the differences
             -0.1891892

> t.test(Q1_9, P1_9, paired = TRUE)

     Paired t-test

data:  Q1_9 and P1_9
t = -0.3395, df = 147, p-value = 0.7347
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.1843594  0.1303053
sample estimates:
mean of the differences
```

```
            -0.02702703

>
> #### Paired t-tests between pre and post-test: Resources
(Table 5.8, 5.9) ####
>
> t.test(Q2_1, P2_1, paired = TRUE)

     Paired t-test

data:  Q2_1 and P2_1
t = -0.7548, df = 147, p-value = 0.4516
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.1955740  0.0874659
sample estimates:
mean of the differences
            -0.05405405

> t.test(Q2_2, P2_2, paired = TRUE)

     Paired t-test

data:  Q2_2 and P2_2
t = 2.5563, df = 147, p-value = 0.01159
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 0.06133064 0.47920990
sample estimates:
mean of the differences
              0.2702703

> t.test(Q2_3, P2_3, paired = TRUE)

     Paired t-test

data:  Q2_3 and P2_3
t = 6.003, df = 147, p-value = 1.448e-08
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 0.2946041 0.5837743
sample estimates:
mean of the differences
              0.4391892

> t.test(Q2_4, P2_4, paired = TRUE)

     Paired t-test

data:  Q2_4 and P2_4
t = -14.3054, df = 147, p-value < 2.2e-16
```

```
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -1.476513 -1.118081
sample estimates:
mean of the differences
              -1.297297

> t.test(Q2_5, P2_5, paired = TRUE)

     Paired t-test

data:  Q2_5 and P2_5
t = 3.7077, df = 147, p-value = 0.0002957
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 0.1735443 0.5696990
sample estimates:
mean of the differences
              0.3716216

> t.test(Q2_6, P2_6, paired = TRUE)

     Paired t-test

data:  Q2_6 and P2_6
t = 2.765, df = 147, p-value = 0.006423
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 0.06553167 0.39392779
sample estimates:
mean of the differences
              0.2297297

> t.test(Q2_7, P2_7, paired = TRUE)

     Paired t-test

data:  Q2_7 and P2_7
t = -11.3405, df = 147, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -1.0631843 -0.7476265
sample estimates:
mean of the differences
             -0.9054054

> t.test(Q2_8, P2_8, paired = TRUE)

     Paired t-test
```

```
data:  Q2_8 and P2_8
t = 15.1381, df = 147, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 1.10444 1.43610
sample estimates:
mean of the differences
                1.27027

> t.test(Q2_9, P2_9, paired = TRUE)

     Paired t-test

data:  Q2_9 and P2_9
t = 1.9178, df = 147, p-value = 0.05707
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.005143637  0.342981475
sample estimates:
mean of the differences
              0.1689189

>
> t.test(Q3_1, P3_1, paired = TRUE)

     Paired t-test

data:  Q3_1 and P3_1
t = 0.8259, df = 147, p-value = 0.4102
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.1035159  0.2521645
sample estimates:
mean of the differences
             0.07432432

> t.test(Q3_2, P3_2, paired = TRUE)

     Paired t-test

data:  Q3_2 and P3_2
t = 1.167, df = 147, p-value = 0.2451
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.05622799  0.21839015
sample estimates:
mean of the differences
             0.08108108

> t.test(Q3_3, P3_3, paired = TRUE)
```

```
     Paired t-test

data:  Q3_3 and P3_3
t = 3.7152, df = 147, p-value = 0.0002878
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 0.1549680 0.5071942
sample estimates:
mean of the differences
              0.3310811

>
> detach(post109c)
>
>
##################################################################
> #                                                              #
> # Analysis for differences in pretests, Studies II and III|
Created 05.26.2014 | Last modified 10.17.2014  #
> #                                                              #
##################################################################
>
> setwd("C:/Users/Owner/Desktop/Wiki Project/Data/R Data")
> install.packages("psych")
Error in install.packages : Updating loaded packages
> library("psych")
>
> ########## Study II ##########
>
> exam1data <-read.csv("Study_II_Exam_1_Data.csv", header =
TRUE)
> exam2data <-read.csv("Study_II_Exam_2_Data.csv", header =
TRUE)
> exam3data <-read.csv("Study_II_Exam_3_Data.csv", header =
TRUE)
> exam4data <-read.csv("Study_II_Final_Exam_Data.csv", header =
TRUE)
>
> #### ANOVA tests to see if there are differences in pre-test
scores ####
>
> # Regression models for total pre-assessment correct
> exam1.P.correct <- lm(exam1data$P12.correct~exam1data$TW +
exam1data$UW +
+                          exam1data$TR + exam1data$UR)
> exam2.P.correct <- lm(exam2data$P12.correct~exam2data$TW +
exam2data$NW +
+                          exam2data$TR + exam2data$NR)
> exam3.P.correct <- lm(exam3data$P12.correct~exam3data$TW +
exam3data$UW +
+                          exam3data$TR + exam3data$UR)
```

```
> exam4.P.correct <- lm(exam4data$P12.correct~exam4data$TW +
exam4data$UW +
+                          exam4data$TR + exam4data$UR)
>
>
> summary(exam1.P.correct)

Call:
lm(formula = exam1data$P12.correct ~ exam1data$TW + exam1data$UW
+
    exam1data$TR + exam1data$UR)

Residuals:
     Min       1Q   Median       3Q      Max
-0.66171 -0.20282 -0.03582  0.17129  0.46418

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)   0.53582    0.01483  36.135  < 2e-16 ***
exam1data$TW  0.01249    0.03330   0.375  0.70783
exam1data$UW  0.07175    0.03870   1.854  0.06437 .
exam1data$TR  0.02455    0.03330   0.737  0.46142
exam1data$UR  0.12589    0.04499   2.798  0.00534 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.2477 on 494 degrees of freedom
Multiple R-squared:  0.02025, Adjusted R-squared:  0.01232
F-statistic: 2.553 on 4 and 494 DF,  p-value: 0.03831

> summary(exam2.P.correct)

Call:
lm(formula = exam2data$P12.correct ~ exam2data$TW + exam2data$NW
+
    exam2data$TR + exam2data$NR)

Residuals:
     Min       1Q   Median       3Q      Max
-0.34260 -0.14983  0.01301  0.16016  0.65740

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.316834   0.010353  30.602   <2e-16 ***
exam2data$TW 0.025763   0.022989   1.121    0.263
exam2data$NW 0.023009   0.026495   0.868    0.386
exam2data$TR 0.003153   0.022620   0.139    0.889
exam2data$NR 0.016509   0.031207   0.529    0.597
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.1742 on 511 degrees of freedom
Multiple R-squared:  0.003629,     Adjusted R-squared:  -0.00417
F-statistic: 0.4653 on 4 and 511 DF,  p-value: 0.7612
```

```
> summary(exam3.P.correct)

Call:
lm(formula = exam3data$P12.correct ~ exam3data$TW + exam3data$UW
+
    exam3data$TR + exam3data$UR)

Residuals:
     Min       1Q   Median       3Q      Max
-0.46990 -0.11612  0.03334  0.07492  0.55481

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)   0.449116   0.010995  40.847   <2e-16 ***
exam3data$TW -0.003924   0.024349  -0.161    0.872
exam3data$UW  0.017541   0.033246   0.528    0.598
exam3data$TR  0.020787   0.024483   0.849    0.396
exam3data$UR -0.024034   0.028706  -0.837    0.403
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.1856 on 509 degrees of freedom
Multiple R-squared:  0.004004,     Adjusted R-squared:  -
0.003823
F-statistic: 0.5115 on 4 and 509 DF,  p-value: 0.7273

> summary(exam4.P.correct)

Call:
lm(formula = exam4data$P12.correct ~ exam4data$TW + exam4data$UW
+
    exam4data$TR + exam4data$UR)

Residuals:
     Min       1Q   Median       3Q      Max
-0.43714 -0.20791 -0.00791  0.19209  0.61509

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)   0.407914   0.013225  30.844   <2e-16 ***
exam4data$TW  0.005785   0.028999   0.199    0.842
exam4data$UW -0.029535   0.038588  -0.765    0.444
exam4data$TR  0.029229   0.029487   0.991    0.322
exam4data$UR -0.023008   0.033050  -0.696    0.487
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.2205 on 506 degrees of freedom
Multiple R-squared:  0.004956,     Adjusted R-squared:  -0.00291
F-statistic:  0.63 on 4 and 506 DF,  p-value: 0.6413
>
> ########## Reliability of Posttest Questions ##########
>
```

```
> setwd("C:/Users/Owner/Desktop/Wiki Project/Data/R Data")
> ACSdata <-read.csv("Study_II_ACS_Exam_Data.csv", header =
TRUE)
> attach(ACSdata)
The following objects are masked from finaldata (position 3):

    exam1avg, exam2avg, exam3avg, exam4avg, ID, X, X.1, X.2, X1,
X10, X11, X12, X13, X14, X15, X16, X17,
    X18, X19, X2, X20, X21, X22, X23, X24, X25, X26, X27, X28,
X29, X3, X30, X31, X32, X33, X34, X35,
    X36, X37, X38, X39, X4, X40, X41, X42, X43, X44, X45, X46,
X5, X6, X7, X8, X9
The following objects are masked from finaldata (position 4):

    exam1avg, exam2avg, exam3avg, exam4avg, ID, X, X.1, X.2, X1,
X10, X11, X12, X13, X14, X15, X16, X17,
    X18, X19, X2, X20, X21, X22, X23, X24, X25, X26, X27, X28,
X29, X3, X30, X31, X32, X33, X34, X35,
    X36, X37, X38, X39, X4, X40, X41, X42, X43, X44, X45, X46,
X5, X6, X7, X8, X9
The following objects are masked from ACSdata (position 5):

    ACT, ACT.E, ACT.M, ACT.M.z, Cluster, exam1avg, exam2avg,
exam3avg, exam3avg.A, exam3avg.C, exam4avg,
    exam4avg.A, exam4avg.C, G1R, G1W, G2R, G2W, GPA, grade, ID,
L.grade, NR, NW, P.number, p1avg,
    p1avg.1, p2avg, p2avg.1, p3avg, p3avg.1, p4avg, p4avg.1,
post1, post10, post11, post12, post13,
    post14, post15, post16, post17, post18, post19, post2,
post20, post21, post22, post23, post24,
    post25, post26, post27, post28, post29, post3, post30,
post31, post32, post33, post34, post35,
    post36, post37, post38, post39, post4, post40, post41,
post42, post43, post44, post45, post46, post5,
    post6, post7, post8, post9, S.number, SAT, SAT.M, SAT.M.z,
SAT.V, TR, Treatment, treatment2,
    treatment4, TW, UR, UW, X, X.1, X.2, X.3, X1, X10, X11, X12,
X13, X14, X15, X16, X17, X18, X19, X2,
    X20, X21, X22, X23, X24, X25, X26, X27, X28, X29, X3, X30,
X31, X32, X33, X34, X35, X36, X37, X38,
    X39, X4, X40, X41, X42, X43, X44, X45, X46, X5, X6, X7, X8,
X9, z
The following object is masked from post109c:

    ID
The following object is masked from post104e (position 7):

    ID
The following object is masked from post104e (position 8):

    ID
The following object is masked from post104:

    ID
```

```
>
> allACS <-
cbind(post1,post2,post3,post4,post5,post6,post7,post8,post9,post
10,
+                 post35,post36,post37,post38,post39,post40,
post23,post24,post25,post27,
+
post17,post18,post19,post20,post21,post22,post26,post28,post29,p
ost30,
+
post13,post14,post15,post16,post32,post11,post12,post31,post33,p
ost34)
>
> alpha(allACS)

Reliability analysis
Call: alpha(x = allACS)

  raw_alpha std.alpha G6(smc) average_r S/N   ase mean   sd
      0.84       0.8    0.85     0.089 3.9 0.012 0.56 0.15

 lower alpha upper     95% confidence boundaries
0.82 0.84 0.87

 Reliability if an item is dropped:
        raw_alpha std.alpha G6(smc) average_r S/N alpha se
post1        0.84      0.80    0.85     0.091 3.9    0.012
post2        0.85      0.80    0.85     0.092 4.0    0.012
post3        0.84      0.80    0.84     0.091 3.9    0.012
post4        0.84      0.80    0.85     0.093 4.0    0.012
post5        0.84      0.80    0.85     0.093 4.0    0.012
post6        0.84      0.80    0.85     0.092 3.9    0.012
post7        0.85      0.80    0.85     0.092 3.9    0.011
post8        0.84      0.80    0.85     0.092 4.0    0.012
post9        0.84      0.79    0.85     0.090 3.9    0.012
post10       0.84      0.80    0.85     0.091 3.9    0.012
post35       0.83      0.78    0.83     0.082 3.5    0.013
post36       0.83      0.78    0.83     0.084 3.6    0.012
post37       0.83      0.78    0.83     0.082 3.5    0.013
post38       0.83      0.78    0.83     0.082 3.5    0.013
post39       0.82      0.77    0.83     0.081 3.4    0.013
post40       0.83      0.78    0.83     0.083 3.5    0.013
post23-      0.84      0.80    0.85     0.094 4.1    0.012
post24       0.84      0.80    0.85     0.092 3.9    0.012
post25       0.85      0.80    0.85     0.092 4.0    0.011
post27       0.84      0.80    0.85     0.092 3.9    0.012
post17       0.84      0.80    0.85     0.092 3.9    0.012
post18-      0.85      0.81    0.85     0.096 4.1    0.011
post19       0.84      0.80    0.85     0.092 3.9    0.012
post20       0.84      0.80    0.85     0.092 4.0    0.012
post21       0.84      0.80    0.85     0.091 3.9    0.012
post22-      0.84      0.80    0.85     0.094 4.1    0.012
post26       0.84      0.80    0.85     0.091 3.9    0.012
post28       0.85      0.80    0.85     0.092 4.0    0.011
```

post29-	0.84	0.80	0.85	0.094	4.1	0.012
post30-	0.85	0.80	0.85	0.095	4.1	0.011
post13	0.83	0.78	0.83	0.084	3.6	0.012
post14	0.84	0.80	0.85	0.092	3.9	0.012
post15	0.82	0.77	0.83	0.081	3.4	0.013
post16	0.83	0.78	0.83	0.082	3.5	0.013
post32	0.83	0.78	0.83	0.083	3.5	0.012
post11	0.83	0.78	0.83	0.083	3.5	0.013
post12	0.83	0.79	0.84	0.086	3.7	0.012
post31	0.84	0.79	0.85	0.090	3.9	0.012
post33	0.84	0.79	0.84	0.086	3.7	0.012
post34	0.83	0.78	0.83	0.083	3.5	0.012

Item statistics

	n	r	r.cor	r.drop	mean	sd
post1	492	0.210	0.173	0.1249	0.752	0.43
post2	492	0.152	0.099	0.0703	0.833	0.37
post3	492	0.245	0.211	0.1591	0.685	0.47
post4	492	0.126	0.066	0.0513	0.890	0.31
post5	492	0.139	0.077	0.0674	0.947	0.22
post6	492	0.176	0.125	0.0939	0.795	0.40
post7	492	0.176	0.121	0.0979	0.461	0.50
post8	492	0.163	0.103	0.0781	0.935	0.25
post9	492	0.256	0.209	0.1703	0.884	0.32
post10	492	0.214	0.162	0.1316	0.900	0.30
post35	492	0.727	0.763	0.7180	0.404	0.49
post36	492	0.618	0.638	0.6084	0.537	0.50
post37	492	0.712	0.749	0.7103	0.376	0.48
post38	492	0.749	0.790	0.7436	0.417	0.49
post39	492	0.777	0.830	0.7782	0.413	0.49
post40	492	0.689	0.726	0.6864	0.433	0.50
post23-	492	0.053	-0.015	-0.0086	0.024	0.15
post24	492	0.173	0.123	0.1062	0.907	0.29
post25	492	0.154	0.091	0.0781	0.512	0.50
post27	492	0.189	0.140	0.1204	0.799	0.40
post17	492	0.187	0.132	0.0997	0.854	0.35
post18-	492	-0.054	-0.123	-0.1114	0.167	0.37
post19	492	0.191	0.144	0.1022	0.929	0.26
post20	492	0.166	0.115	0.0831	0.880	0.33
post21	492	0.217	0.171	0.1300	0.750	0.43
post22-	492	0.045	-0.021	-0.0092	0.045	0.21
post26	492	0.222	0.172	0.1467	0.750	0.43
post28	492	0.144	0.085	0.0657	0.315	0.47
post29-	492	0.038	-0.028	-0.0368	0.014	0.12
post30-	492	-0.020	-0.090	-0.0880	0.039	0.19
post13	492	0.625	0.642	0.6095	0.593	0.49
post14	492	0.190	0.133	0.1126	0.843	0.36
post15	492	0.780	0.834	0.7849	0.435	0.50
post16	492	0.702	0.727	0.6915	0.307	0.46
post32	492	0.670	0.688	0.6500	0.274	0.45
post11	492	0.671	0.697	0.6653	0.386	0.49
post12	492	0.509	0.499	0.4676	0.490	0.50
post31	492	0.265	0.218	0.1964	0.835	0.37
post33	492	0.480	0.460	0.4272	0.226	0.42

```
post34  492  0.648  0.669  0.6355 0.400 0.49

Non missing response frequency for each item
          0    1 miss
post1  0.25 0.75    0
post2  0.17 0.83    0
post3  0.32 0.68    0
post4  0.11 0.89    0
post5  0.05 0.95    0
post6  0.21 0.79    0
post7  0.54 0.46    0
post8  0.07 0.93    0
post9  0.12 0.88    0
post10 0.10 0.90    0
post35 0.60 0.40    0
post36 0.46 0.54    0
post37 0.62 0.38    0
post38 0.58 0.42    0
post39 0.59 0.41    0
post40 0.57 0.43    0
post23 0.02 0.98    0
post24 0.09 0.91    0
post25 0.49 0.51    0
post27 0.20 0.80    0
post17 0.15 0.85    0
post18 0.17 0.83    0
post19 0.07 0.93    0
post20 0.12 0.88    0
post21 0.25 0.75    0
post22 0.04 0.96    0
post26 0.25 0.75    0
post28 0.68 0.32    0
post29 0.01 0.99    0
post30 0.04 0.96    0
post13 0.41 0.59    0
post14 0.16 0.84    0
post15 0.57 0.43    0
post16 0.69 0.31    0
post32 0.73 0.27    0
post11 0.61 0.39    0
post12 0.51 0.49    0
post31 0.16 0.84    0
post33 0.77 0.23    0
post34 0.60 0.40    0
Warning message:
In alpha(allACS) :
  Some items were negatively correlated with total scale and
were automatically reversed.
>
> detach(ACSdata)
>
> ########## Study III ##########
>
> setwd("C:/Users/Owner/Desktop/Wiki Project/Data/R Data")
```

```
> exam2data <-read.csv("Study_III_Exam_2_Data.csv", header =
TRUE)
> exam4data <-read.csv("Study_III_Exam_4_Data.csv", header =
TRUE)
>
> # Regression models for total pre-assessment correct
>
> exam2.P.correct <- lm(exam2data$P.correct~exam2data$TW +
exam2data$UW +
+                          exam2data$TR + exam2data$UR)
>
> exam4.P.correct <- lm(exam4data$P.correct~exam4data$TW +
exam4data$UW +
+                          exam4data$TR + exam4data$UR)
>
> # ANOVA on Pre-Assessment
>
> summary(exam2.P.correct)

Call:
lm(formula = exam2data$P.correct ~ exam2data$TW + exam2data$UW +
    exam2data$TR + exam2data$UR)

Residuals:
     Min       1Q   Median       3Q      Max
-0.33043 -0.12149  0.03028  0.07937  0.54696

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)   0.288490   0.014610  19.746   <2e-16 ***
exam2data$TW -0.002445   0.025988  -0.094    0.925
exam2data$UW  0.014227   0.027005   0.527    0.599
exam2data$TR -0.034859   0.029770  -1.171    0.242
exam2data$UR  0.041939   0.027679   1.515    0.131
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.1759 on 369 degrees of freedom
Multiple R-squared:  0.01394, Adjusted R-squared:  0.00325
F-statistic: 1.304 on 4 and 369 DF,  p-value: 0.268

> summary(exam4.P.correct)

Call:
lm(formula = exam4data$P.correct ~ exam4data$TW + exam4data$UW +
    exam4data$TR + exam4data$UR)

Residuals:
     Min       1Q   Median       3Q      Max
-0.33025 -0.13327  0.00309  0.08073  0.58073

Coefficients:
               Estimate Std. Error t value Pr(>|t|)
(Intercept)   0.2762657  0.0161827  17.072   <2e-16 ***
```

```
exam4data$TW -0.0226425  0.0328022  -0.690   0.4905
exam4data$UW  0.0539812  0.0309092   1.746   0.0816 .
exam4data$TR -0.0225344  0.0286499  -0.787   0.4321
exam4data$UR  0.0005704  0.0299434   0.019   0.9848
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.1935 on 364 degrees of freedom
Multiple R-squared:  0.0155,  Adjusted R-squared:  0.004677
F-statistic: 1.432 on 4 and 364 DF,  p-value: 0.2227

> ##### Reliability Tests of Final Exam (Experimental and
Control groups combined in one file) #####
>
> setwd("C:/Users/Owner/Desktop/Wiki Project/Data/R Data")
> finaldata <-
read.csv("Study_III_Final_Exam_Data_Experimental.csv", header =
TRUE)
> attach(finaldata)
The following objects are masked from finaldata (position 3):

    Average, Exam.1, exam1avg, exam2avg, exam3avg, exam4avg, F1,
F10, F11, F12, F13, F14, F15, F16, F17,
    F18, F19, F2, F20, F21, F22, F23, F24, F25, F26, F27, F28,
F29, F3, F30, F31, F32, F33, F34, F35,
    F36, F37, F38, F39, F4, F40, F41, F42, F43, F44, F45, F46,
F47, F48, F49, F5, F50, F6, F7, F8, F9,
    ID, PA1...39, PA13...29, PA14...28, PA15...27, PA2...40,
PA22...7, PA23...1, PA24...2, PA3...42,
    PA4...41, PA5...38, PA6...48, X, X.1, X.2, X1, X1.1, X10,
X10.1, X11, X11.1, X12, X12.1, X13, X13.1,
    X14, X14.1, X15, X15.1, X16, X16.1, X17, X17.1, X18, X18.1,
X19, X19.1, X2, X2.1, X20, X20.1, X21,
    X21.1, X22, X22.1, X23, X23.1, X24, X24.1, X25, X25.1, X26,
X26.1, X27, X27.1, X28, X28.1, X29,
    X29.1, X3, X3.1, X30, X30.1, X31, X31.1, X32, X32.1, X33,
X33.1, X34, X34.1, X35, X35.1, X36, X36.1,
    X37, X37.1, X38, X38.1, X39, X39.1, X4, X4.1, X40, X40.1,
X41, X41.1, X42, X42.1, X43, X43.1, X44,
    X44.1, X45, X45.1, X46, X46.1, X47, X47.1, X48, X48.1, X49,
X49.1, X5, X5.1, X50, X50.1, X6, X6.1,
    X7, X7.1, X8, X8.1, X9, X9.1
The following objects are masked from finaldata.control
(position 4):

    exam1avg, exam2avg, exam3avg, exam4avg, F1, F10, F11, F12,
F13, F14, F15, F16, F17, F18, F19, F2,
    F20, F21, F22, F23, F24, F25, F26, F27, F28, F29, F3, F30,
F31, F32, F33, F34, F35, F36, F37, F38,
    F39, F4, F40, F41, F42, F43, F44, F45, F46, F47, F48, F49,
F5, F50, F6, F7, F8, F9, ID, X, X1, X13,
    X14, X15, X2, X22, X23, X24, X3, X4, X5, X6
The following objects are masked from finaldata.control
(position 5):
```

```
    exam1avg, exam2avg, exam3avg, exam4avg, F1, F10, F11, F12,
F13, F14, F15, F16, F17, F18, F19, F2,
    F20, F21, F22, F23, F24, F25, F26, F27, F28, F29, F3, F30,
F31, F32, F33, F34, F35, F36, F37, F38,
    F39, F4, F40, F41, F42, F43, F44, F45, F46, F47, F48, F49,
F5, F50, F6, F7, F8, F9, ID, X, X1, X13,
    X14, X15, X2, X22, X23, X24, X3, X4, X5, X6
>
> exam1data <- cbind(F1,F2,F3,F4,F5,F6,F7,F8,F9,F10,F11,F12,F13)
> exam2data <- cbind(F14,F15,F16,F17,F18,F19)
> exam3data <- cbind(F20,F21,F29,F32,F33,F35,F36,F37)
> exam4data <- cbind(F22,F23,F24,F25,F26,F27,F28,F30,F31,F34)
> alldata <-
cbind(exam1data.control,exam2data.control,exam3data.control,exam
4data.control)
>
> alpha(alldata)

Reliability analysis
Call: alpha(x = alldata)

  raw_alpha std.alpha G6(smc) average_r S/N   ase mean   sd
      0.79       0.8    0.85     0.097   4 0.028 0.62 0.15

 lower alpha upper     95% confidence boundaries
0.74 0.79 0.85

 Reliability if an item is dropped:
     raw_alpha std.alpha G6(smc) average_r S/N alpha se
F1        0.79      0.80    0.85     0.098 3.9    0.028
F2-       0.80      0.80    0.85     0.101 4.1    0.027
F3        0.78      0.79    0.84     0.095 3.8    0.029
F4        0.79      0.79    0.84     0.095 3.8    0.029
F5        0.78      0.79    0.84     0.094 3.7    0.029
F6        0.79      0.79    0.84     0.096 3.8    0.029
F7        0.79      0.80    0.84     0.097 3.9    0.028
F8        0.79      0.80    0.85     0.098 3.9    0.028
F9        0.79      0.80    0.85     0.100 4.0    0.028
F10       0.79      0.79    0.84     0.097 3.9    0.028
F11       0.78      0.79    0.84     0.094 3.7    0.029
F12       0.79      0.79    0.84     0.095 3.8    0.029
F13       0.79      0.79    0.84     0.097 3.8    0.029
F14       0.79      0.79    0.85     0.097 3.9    0.028
F15       0.79      0.79    0.85     0.097 3.9    0.028
F16       0.79      0.79    0.84     0.096 3.8    0.029
F17       0.78      0.79    0.84     0.094 3.7    0.029
F18       0.79      0.79    0.84     0.096 3.8    0.028
F19       0.79      0.80    0.85     0.098 3.9    0.028
F20       0.79      0.79    0.84     0.097 3.9    0.028
F21       0.78      0.79    0.84     0.094 3.7    0.029
F29       0.79      0.79    0.85     0.096 3.8    0.029
F32       0.79      0.80    0.85     0.097 3.9    0.028
F33       0.79      0.79    0.84     0.096 3.8    0.029
```

```
F35       0.79      0.79    0.84     0.097 3.9    0.028
F36       0.79      0.79    0.84     0.097 3.9    0.029
F37       0.79      0.80    0.85     0.097 3.9    0.028
F22       0.79      0.80    0.84     0.097 3.9    0.028
F23       0.79      0.79    0.84     0.097 3.9    0.028
F24       0.79      0.79    0.84     0.096 3.8    0.029
F25       0.78      0.79    0.84     0.094 3.7    0.029
F26       0.78      0.79    0.84     0.094 3.7    0.029
F27       0.79      0.79    0.84     0.096 3.8    0.029
F28       0.79      0.80    0.85     0.097 3.9    0.028
F30       0.78      0.79    0.84     0.094 3.7    0.029
F31-      0.80      0.80    0.85     0.102 4.1    0.027
F34       0.79      0.79    0.84     0.097 3.8    0.029

 Item statistics
       n     r r.cor r.drop mean   sd
F1   143 0.260 0.221 0.1820 0.48 0.50
F2-  143 0.113 0.058 0.0405 0.55 0.50
F3   143 0.427 0.409 0.3629 0.68 0.47
F4   143 0.419 0.398 0.3384 0.70 0.46
F5   143 0.458 0.444 0.3965 0.66 0.47
F6   143 0.390 0.361 0.3263 0.69 0.46
F7   143 0.315 0.286 0.2408 0.94 0.24
F8   143 0.259 0.224 0.1776 0.58 0.50
F9   143 0.174 0.128 0.1018 0.73 0.44
F10  143 0.320 0.292 0.2331 0.96 0.20
F11  143 0.461 0.445 0.3933 0.61 0.49
F12  143 0.411 0.389 0.3343 0.68 0.47
F13  143 0.351 0.326 0.2865 0.66 0.47
F14  143 0.326 0.293 0.2432 0.78 0.41
F15  143 0.344 0.311 0.2700 0.93 0.26
F16  143 0.380 0.363 0.2965 0.74 0.44
F17  143 0.487 0.474 0.4155 0.86 0.35
F18  143 0.363 0.338 0.2777 0.96 0.20
F19  143 0.271 0.230 0.1909 0.56 0.50
F20  143 0.326 0.296 0.2582 0.51 0.50
F21  143 0.468 0.458 0.4101 0.40 0.49
F29  143 0.353 0.316 0.2821 0.19 0.39
F32  143 0.308 0.274 0.2281 0.26 0.44
F33  143 0.376 0.354 0.3165 0.51 0.50
F35  143 0.329 0.300 0.2458 0.83 0.38
F36  143 0.332 0.302 0.2716 0.59 0.49
F37  143 0.307 0.275 0.2310 0.86 0.35
F22  143 0.314 0.284 0.2436 0.32 0.47
F23  143 0.321 0.292 0.2629 0.38 0.49
F24  143 0.375 0.355 0.3119 0.18 0.39
F25  143 0.489 0.483 0.4289 0.54 0.50
F26  143 0.478 0.467 0.4280 0.34 0.47
F27  143 0.353 0.327 0.2887 0.75 0.44
F28  143 0.307 0.268 0.2290 0.49 0.50
F30  143 0.469 0.461 0.4071 0.54 0.50
F31- 143 0.085 0.028 0.0049 0.76 0.43
F34  143 0.349 0.329 0.2766 0.75 0.44
```

```
Non missing response frequency for each item
       0    1 miss
F1  0.52 0.48    0
F2  0.55 0.45    0
F3  0.32 0.68    0
F4  0.30 0.70    0
F5  0.34 0.66    0
F6  0.31 0.69    0
F7  0.06 0.94    0
F8  0.42 0.58    0
F9  0.27 0.73    0
F10 0.04 0.96    0
F11 0.39 0.61    0
F12 0.32 0.68    0
F13 0.34 0.66    0
F14 0.22 0.78    0
F15 0.07 0.93    0
F16 0.26 0.74    0
F17 0.14 0.86    0
F18 0.04 0.96    0
F19 0.44 0.56    0
F20 0.49 0.51    0
F21 0.60 0.40    0
F29 0.81 0.19    0
F32 0.74 0.26    0
F33 0.49 0.51    0
F35 0.17 0.83    0
F36 0.41 0.59    0
F37 0.14 0.86    0
F22 0.68 0.32    0
F23 0.62 0.38    0
F24 0.82 0.18    0
F25 0.46 0.54    0
F26 0.66 0.34    0
F27 0.25 0.75    0
F28 0.51 0.49    0
F30 0.46 0.54    0
F31 0.76 0.24    0
F34 0.25 0.75    0
Warning message:
In alpha(alldata) :
  Some items were negatively correlated with total scale and
were automatically reversed.
>
> detach(finaldata)

>
##################################################################
> #                                                              #
> # Optimization of Regression Models, Exams 1-4 | Created
05.26.2014 | Last modified 09.17.14                    #
> #                                                              #
>
##################################################################
```

```
>
>
> ##### Study II #####
>
> setwd("C:/Users/Owner/Desktop/Wiki Project/Data/R Data")
> ACSdata <-read.csv("Study_II_ACS_Exam_Data.csv", header =
TRUE)
>
> attach(ACSdata)
The following objects are masked from ACSdata (position 3):

    ACT, ACT.E, ACT.M, ACT.M.z, Cluster, exam1avg, exam2avg,
exam3avg, exam3avg.A, exam3avg.C, exam4avg,
    exam4avg.A, exam4avg.C, G1R, G1W, G2R, G2W, GPA, grade, ID,
L.grade, NR, NW, P.number, p1avg,
    p1avg.1, p2avg, p2avg.1, p3avg, p3avg.1, p4avg, p4avg.1,
post1, post10, post11, post12, post13,
    post14, post15, post16, post17, post18, post19, post2,
post20, post21, post22, post23, post24,
    post25, post26, post27, post28, post29, post3, post30,
post31, post32, post33, post34, post35,
    post36, post37, post38, post39, post4, post40, post41,
post42, post43, post44, post45, post46, post5,
    post6, post7, post8, post9, S.number, SAT, SAT.M, SAT.M.z,
SAT.V, TR, Treatment, treatment2,
    treatment4, TW, UR, UW, X, X.1, X.2, X.3, X1, X10, X11, X12,
X13, X14, X15, X16, X17, X18, X19, X2,
    X20, X21, X22, X23, X24, X25, X26, X27, X28, X29, X3, X30,
X31, X32, X33, X34, X35, X36, X37, X38,
    X39, X4, X40, X41, X42, X43, X44, X45, X46, X5, X6, X7, X8,
X9, z
The following objects are masked from finaldata:

    exam1avg, exam2avg, exam3avg, exam4avg, ID, X, X.1, X.2, X1,
X10, X11, X12, X13, X14, X15, X16, X17,
    X18, X19, X2, X20, X21, X22, X23, X24, X25, X26, X27, X28,
X29, X3, X30, X31, X32, X33, X34, X35,
    X36, X37, X38, X39, X4, X40, X41, X42, X43, X44, X45, X46,
X5, X6, X7, X8, X9
The following objects are masked from finaldata.control
(position 5):

    ACT, ACT.E, ACT.M, Cluster, exam1avg, exam2avg, exam3avg,
exam4avg, GPA, ID, P.number, S.number, SAT,
    SAT.M, SAT.V, X, X1, X13, X14, X15, X2, X22, X23, X24, X3,
X4, X5, X6, z
The following objects are masked from finaldata.control
(position 6):

    ACT, ACT.E, ACT.M, Cluster, exam1avg, exam2avg, exam3avg,
exam4avg, GPA, ID, P.number, S.number, SAT,
    SAT.M, SAT.V, X, X1, X13, X14, X15, X2, X22, X23, X24, X3,
X4, X5, X6, z
>
```

```
> exam1ACS <-
cbind(post1,post2,post3,post4,post5,post6,post7,post8,post9,post
10)
> exam2ACS <- cbind(post35,post36,post37,post38,post39,post40)
> exam3ACS <-
cbind(post17,post18,post19,post20,post21,post22,post23,post24,po
st25,
+                   post26,post27,post28,post29,post30)
> exam4ACS <-
cbind(post11,post12,post13,post14,post15,post16,post31,post32,po
st33,post34,post35,post36)
> allACS <-cbind(post1,post2,post3,post4,post5,post6,post7,
+                 post8,post9,post10,post11,post12,post13,post14,
+                 post15,post16,post17,post18,post19,post20,
+
post21,post22,post23,post24,post25,post26,post27,
+
post28,post29,post30,post31,post32,post33,post34,
+                 post35,post36,post37,post38,post39,post40)
>
>
> ### Models with no predictors ###
>
> exam1model <- lm(exam1avg ~ TW + TR + NW + NR)
> exam2model <- lm(exam2avg ~ TW + TR + NW + NR)
> exam3model <- lm(exam3avg ~ TW + TR + NW + NR)
> exam4model <- lm(exam4avg ~ TW + TR + NW + NR)
>
> ### Models with z, pre-test ###
>
> exam1model.zp <- lm(exam1avg ~ z + p1avg + TW + TR + NW + NR)
> exam2model.zp <- lm(exam2avg ~ z + p2avg +TW + TR + NW + NR)
> exam3model.zp <- lm(exam3avg ~ z + p3avg +TW + TR + NW + NR)
> exam4model.zp <- lm(exam4avg ~ z + p4avg +TW + TR + NW + NR)
>
> ### Models with z, pre-test, interaction terms ###
>
> exam1model.zpi <- lm(exam1avg ~ z + p1avg + z*p1avg + TW + TR
+ NW + NR)
> exam2model.zpi <- lm(exam2avg ~ z + p2avg + z*p2avg + TW + TR
+ NW + NR)
> exam3model.zpi <- lm(exam3avg ~ z + p3avg + z*p2avg + TW + TR
+ NW + NR)
> exam4model.zpi <- lm(exam4avg ~ z + p4avg + z*p2avg + TW + TR
+ NW + NR)
>
> #### Model check-ANOVA ###
>
> anova(exam1model,exam1model.zp)
Analysis of Variance Table

Model 1: exam1avg ~ TW + TR + NW + NR
Model 2: exam1avg ~ z + p1avg + TW + TR + NW + NR
  Res.Df    RSS Df Sum of Sq      F    Pr(>F)
```

```
1    487 11.419
2    485 10.002  2    1.4174 34.365 1.103e-14 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> anova(exam2model,exam2model.zp)
Analysis of Variance Table

Model 1: exam2avg ~ TW + TR + NW + NR
Model 2: exam2avg ~ z + p2avg + TW + TR + NW + NR
  Res.Df    RSS Df Sum of Sq      F Pr(>F)
1    487 7.5170
2    485 7.5063  2  0.010757 0.3475 0.7066
> anova(exam3model,exam3model.zp)
Analysis of Variance Table

Model 1: exam3avg ~ TW + TR + NW + NR
Model 2: exam3avg ~ z + p3avg + TW + TR + NW + NR
  Res.Df    RSS Df Sum of Sq      F   Pr(>F)
1    487 7.5925
2    485 6.7359  2   0.85659 30.838 2.47e-13 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> anova(exam4model,exam4model.zp)
Analysis of Variance Table

Model 1: exam4avg ~ TW + TR + NW + NR
Model 2: exam4avg ~ z + p4avg + TW + TR + NW + NR
  Res.Df    RSS Df Sum of Sq      F  Pr(>F)
1    487 8.8054
2    485 8.6861  2   0.11932 3.3311 0.03657 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
>
> anova(exam1model.zp,exam1model.zpi)
Analysis of Variance Table

Model 1: exam1avg ~ z + p1avg + TW + TR + NW + NR
Model 2: exam1avg ~ z + p1avg + z * p1avg + TW + TR + NW + NR
  Res.Df    RSS Df  Sum of Sq      F Pr(>F)
1    485 10.002
2    484 10.002  1 3.0608e-05 0.0015 0.9693
> anova(exam2model.zp,exam2model.zpi)
Analysis of Variance Table

Model 1: exam2avg ~ z + p2avg + TW + TR + NW + NR
Model 2: exam2avg ~ z + p2avg + z * p2avg + TW + TR + NW + NR
  Res.Df    RSS Df  Sum of Sq      F Pr(>F)
1    485 7.5063
2    484 7.5061  1 0.00010645 0.0069  0.934
> anova(exam3model.zp,exam3model.zpi)
Analysis of Variance Table

Model 1: exam3avg ~ z + p3avg + TW + TR + NW + NR
Model 2: exam3avg ~ z + p3avg + z * p2avg + TW + TR + NW + NR
```

```
  Res.Df    RSS Df Sum of Sq      F   Pr(>F)
1    485 6.7359
2    483 6.5867  2   0.14922 5.4713 0.004471 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> anova(exam4model.zp,exam4model.zpi)
Analysis of Variance Table

Model 1: exam4avg ~ z + p4avg + TW + TR + NW + NR
Model 2: exam4avg ~ z + p4avg + z * p2avg + TW + TR + NW + NR
  Res.Df    RSS Df Sum of Sq      F Pr(>F)
1    485 8.6861
2    483 8.5799  2   0.10617 2.9884 0.0513 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
>
> ##### Summaries of Exam 1-4 Models with pre-test, z-score
#####
>
> summary(exam1model.zp)

Call:
lm(formula = exam1avg ~ z + p1avg + TW + TR + NW + NR)

Residuals:
     Min       1Q   Median       3Q      Max
-0.45868 -0.08395  0.02309  0.10262  0.30442

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.713063   0.016634  42.867  < 2e-16 ***
z            0.061399   0.009982   6.151 1.61e-09 ***
p1avg        0.120728   0.032318   3.736  0.00021 ***
TW          -0.014478   0.019360  -0.748  0.45495
TR           0.004232   0.019471   0.217  0.82803
NW           0.049813   0.026227   1.899  0.05811 .
NR          -0.006088   0.022516  -0.270  0.78698
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.1436 on 485 degrees of freedom
Multiple R-squared:  0.1345,  Adjusted R-squared:  0.1238
F-statistic: 12.56 on 6 and 485 DF,  p-value: 3.502e-13

> summary(exam2model.zp)

Call:
lm(formula = exam2avg ~ z + p2avg + TW + TR + NW + NR)

Residuals:
     Min       1Q   Median       3Q      Max
-0.55674 -0.06526 -0.05083  0.10499  0.43355

Coefficients:
```

```
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.074105   0.013480   5.497 6.25e-08 ***
z           -0.005082   0.008377  -0.607    0.544
p2avg       -0.016606   0.032401  -0.513    0.609
TW           0.807644   0.016712  48.327  < 2e-16 ***
TR           0.822007   0.016887  48.677  < 2e-16 ***
NW           0.831719   0.022635  36.745  < 2e-16 ***
NR           0.803012   0.019487  41.208  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.1244 on 485 degrees of freedom
Multiple R-squared:  0.915,   Adjusted R-squared:  0.9139
F-statistic: 869.8 on 6 and 485 DF,  p-value: < 2.2e-16

> summary(exam3model.zp)

Call:
lm(formula = exam3avg ~ z + p3avg + TW + TR + NW + NR)

Residuals:
     Min       1Q   Median       3Q      Max
-0.54234 -0.05807  0.01567  0.08251  0.23697

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.764505   0.015224  50.217  < 2e-16 ***
z            0.061008   0.007931   7.692 8.13e-14 ***
p3avg        0.026150   0.028886   0.905    0.366
TW          -0.006057   0.015830  -0.383    0.702
TR           0.008819   0.015988   0.552    0.582
NW           0.033329   0.021441   1.554    0.121
NR          -0.021857   0.018469  -1.183    0.237
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.1178 on 485 degrees of freedom
Multiple R-squared:  0.1214,  Adjusted R-squared:  0.1106
F-statistic: 11.17 on 6 and 485 DF,  p-value: 1.081e-11

> summary(exam4model.zp)

Call:
lm(formula = exam4avg ~ z + p4avg + TW + TR + NW + NR)

Residuals:
     Min       1Q   Median       3Q      Max
-0.53738 -0.06575  0.02020  0.07901  0.27932

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 0.226757   0.014704  15.422   <2e-16 ***
z           0.022686   0.008988   2.524   0.0119 *
p4avg       0.010726   0.027551   0.389   0.6972
```

```
TW          0.528814   0.017976  29.418   <2e-16 ***
TR          0.507440   0.018157  27.948   <2e-16 ***
NW          0.542994   0.024357  22.293   <2e-16 ***
NR          0.522205   0.020976  24.895   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.1338 on 485 degrees of freedom
Multiple R-squared:  0.7932,  Adjusted R-squared:  0.7906
F-statistic:   310 on 6 and 485 DF,  p-value: < 2.2e-16

>
>
> ##### Pairwise comparisons between treatments #####
>
> # Exam 2
> TW.exam2avg <- subset(ACSdata,treatment2 == 'TW', exam2avg)
> TR.exam2avg <- subset(ACSdata,treatment2 == 'TR', exam2avg)
> UW.exam2avg <- subset(ACSdata,treatment2 == 'UW', exam2avg)
> UR.exam2avg <- subset(ACSdata,treatment2 == 'UR', exam2avg)
>
> t.test(TW.exam2avg, TR.exam2avg)

     Welch Two Sample t-test

data:  TW.exam2avg and TR.exam2avg
t = -0.5539, df = 135.568, p-value = 0.5805
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.06144964  0.03455838
sample estimates:
mean of x mean of y
0.8738014 0.8872471

> t.test(UW.exam2avg, UR.exam2avg)

     Welch Two Sample t-test

data:  UW.exam2avg and UR.exam2avg
t = 0.87, df = 71.708, p-value = 0.3872
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.03745472  0.09546061
sample estimates:
mean of x mean of y
0.8970529 0.8680500

> t.test(TW.exam2avg, UW.exam2avg)

     Welch Two Sample t-test

data:  TW.exam2avg and UW.exam2avg
```

```
t = -0.7504, df = 65.699, p-value = 0.4557
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.08511743  0.03861441
sample estimates:
mean of x mean of y
0.8738014 0.8970529

> t.test(TR.exam2avg, UR.exam2avg)

     Welch Two Sample t-test

data:  TR.exam2avg and UR.exam2avg
t = 0.7055, df = 95.282, p-value = 0.4822
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.03482323  0.07321735
sample estimates:
mean of x mean of y
0.8872471 0.8680500

>
> # Exam 4
>
> TW.exam4avg <- subset(ACSdata,treatment4 == 'TW', exam4avg)
> TR.exam4avg <- subset(ACSdata,treatment4 == 'TR', exam4avg)
> UW.exam4avg <- subset(ACSdata,treatment4 == 'UW', exam4avg)
> UR.exam4avg <- subset(ACSdata,treatment4 == 'UR', exam4avg)
>
> t.test(TW.exam4avg, TR.exam4avg)

     Welch Two Sample t-test

data:  TW.exam4avg and TR.exam4avg
t = -0.6388, df = 132.057, p-value = 0.524
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.07573268  0.03875789
sample estimates:
mean of x mean of y
0.7529412 0.7714286

> t.test(UW.exam4avg, UR.exam4avg)

     Welch Two Sample t-test

data:  UW.exam4avg and UR.exam4avg
t = -0.4874, df = 68.828, p-value = 0.6275
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
```

```
 -0.09924052  0.06026994
sample estimates:
mean of x mean of y
0.7687500 0.7882353

> t.test(TW.exam4avg, UW.exam4avg)

     Welch Two Sample t-test

data:  TW.exam4avg and UW.exam4avg
t = -0.4752, df = 104.36, p-value = 0.6357
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.08178196  0.05016431
sample estimates:
mean of x mean of y
0.7529412 0.7687500

> t.test(TR.exam4avg, UR.exam4avg)

     Welch Two Sample t-test

data:  TR.exam4avg and UR.exam4avg
t = -0.4611, df = 57.55, p-value = 0.6465
alternative hypothesis: true difference in means is not equal to
0
95 percent confidence interval:
 -0.08978569  0.05617224
sample estimates:
mean of x mean of y
0.7714286 0.7882353

>
> ########## Study III ##########
>
> setwd("C:/Users/Owner/Desktop/Wiki Project/Data/R Data")
> final.all<-read.csv("Study_III_Final_Exam_Data.csv")
> attach(final.all)
The following objects are masked from final.all (position 3):

    ACT, ACT.E, ACT.M, Cluster, Correct, d, dechem, dorg,
dtherm, echem.correct, exam1avg, exam2avg,
    exam3avg, exam4avg, GPA, grade, ID, L.grade, org.correct,
P.correct, P.echem.correct, P.number,
    P.org.correct, P.therm.correct, P1, P13, P14, P15, P2, P22,
P23, P24, P3, P4, P5, P6, S.number, SAT,
    SAT.M, SAT.V, therm.correct, TR.e2, TR.e4, TW.e2, TW.e4,
UR.e2, UR.e4, UW.e2, UW.e4, X, X1, X13, X14,
    X15, X2, X22, X23, X24, X3, X4, X5, X6, z
The following objects are masked from ACSdata (position 4):

    ACT, ACT.E, ACT.M, Cluster, exam1avg, exam2avg, exam3avg,
exam4avg, GPA, grade, ID, L.grade,
```

```
    P.number, S.number, SAT, SAT.M, SAT.V, X, X1, X13, X14, X15,
X2, X22, X23, X24, X3, X4, X5, X6, z
The following objects are masked from ACSdata (position 5):

    ACT, ACT.E, ACT.M, Cluster, exam1avg, exam2avg, exam3avg,
exam4avg, GPA, grade, ID, L.grade,
    P.number, S.number, SAT, SAT.M, SAT.V, X, X1, X13, X14, X15,
X2, X22, X23, X24, X3, X4, X5, X6, z
The following objects are masked from ACSdata (position 6):

    ACT, ACT.E, ACT.M, Cluster, exam1avg, exam2avg, exam3avg,
exam4avg, GPA, grade, ID, L.grade,
    P.number, S.number, SAT, SAT.M, SAT.V, X, X1, X13, X14, X15,
X2, X22, X23, X24, X3, X4, X5, X6, z
The following objects are masked from ACSdata (position 7):

    ACT, ACT.E, ACT.M, Cluster, exam1avg, exam2avg, exam3avg,
exam4avg, GPA, grade, ID, L.grade,
    P.number, S.number, SAT, SAT.M, SAT.V, X, X1, X13, X14, X15,
X2, X22, X23, X24, X3, X4, X5, X6, z
The following object is masked from finaldata:

    exam1avg, exam2avg, exam3avg, exam4avg, ID, X, X1, X13, X14,
X15, X2, X22, X23, X24, X3, X4, X5, X6
The following objects are masked from finaldata.control
(position 9):

    ACT, ACT.E, ACT.M, Cluster, Correct, d, dechem, dorg,
dtherm, echem.correct, exam1avg, exam2avg,
    exam3avg, exam4avg, GPA, ID, org.correct, P.correct,
P.echem.correct, P.number, P.org.correct,
    P.therm.correct, P1, P13, P14, P15, P2, P22, P23, P24, P3,
P4, P5, P6, S.number, SAT, SAT.M, SAT.V,
    therm.correct, X, X1, X13, X14, X15, X2, X22, X23, X24, X3,
X4, X5, X6, z
The following objects are masked from finaldata.control
(position 10):

    ACT, ACT.E, ACT.M, Cluster, Correct, d, dechem, dorg,
dtherm, echem.correct, exam1avg, exam2avg,
    exam3avg, exam4avg, GPA, ID, org.correct, P.correct,
P.echem.correct, P.number, P.org.correct,
    P.therm.correct, P1, P13, P14, P15, P2, P22, P23, P24, P3,
P4, P5, P6, S.number, SAT, SAT.M, SAT.V,
    therm.correct, X, X1, X13, X14, X15, X2, X22, X23, X24, X3,
X4, X5, X6, z
>
> #### Exam 2 ####
>
> exam2model<- lm(exam2avg ~ z + P.therm.correct + TW.e2 +UW.e2
+TR.e2 + UR.e2)
> summary(exam2model)

Call:
```

```
lm(formula = exam2avg ~ z + P.therm.correct + TW.e2 + UW.e2 +
    TR.e2 + UR.e2)

Residuals:
    Min      1Q  Median      3Q     Max
-0.5829 -0.1171  0.0215  0.1460  0.3058

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)     0.787886   0.020272  38.865  < 2e-16 ***
z               0.053398   0.014403   3.707 0.000243 ***
P.therm.correct 0.048349   0.038048   1.271 0.204646
TW.e2          -0.051786   0.027595  -1.877 0.061377 .
UW.e2          -0.064813   0.028768  -2.253 0.024870 *
TR.e2          -0.053631   0.031664  -1.694 0.091180 .
UR.e2           0.008735   0.029752   0.294 0.769248
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.1849 on 358 degrees of freedom
Multiple R-squared:  0.06513, Adjusted R-squared:  0.04946
F-statistic: 4.157 on 6 and 358 DF,  p-value: 0.0004712

>
> #### Exam 4 ####
>
>
> exam4model<- lm(exam4avg ~ z + P.correct + TW.e4 +UW.e4 +TR.e4
+ UR.e4)
> summary(exam4model)

Call:
lm(formula = exam4avg ~ z + P.correct + TW.e4 + UW.e4 + TR.e4 +
    UR.e4)

Residuals:
     Min       1Q   Median       3Q      Max
-0.46065 -0.13396 -0.00983  0.13182  0.60285

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.38163    0.03231  11.811  < 2e-16 ***
z            0.06112    0.01567   3.899 0.000115 ***
P.correct    0.19483    0.07950   2.451 0.014734 *
TW.e4       -0.01405    0.03398  -0.413 0.679539
UW.e4        0.02461    0.03181   0.774 0.439672
TR.e4        0.05067    0.02961   1.711 0.087885 .
UR.e4        0.03849    0.03085   1.248 0.213002
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.1984 on 358 degrees of freedom
Multiple R-squared:  0.08168, Adjusted R-squared:  0.06629
F-statistic: 5.307 on 6 and 358 DF,  p-value: 2.926e-05
```