

Part I. Synthesis and Characterization of C2 Substituted Imidazolium Room

Temperature Ionic Liquids

Part II. Survey and Analysis of Organic Chemistry Textbooks

by

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A dissertation presented to the Graduate Faculty of Middle Tennessee State University

in partial fulfillment of the requirements of the requirements for the

degree of Doctor of Arts

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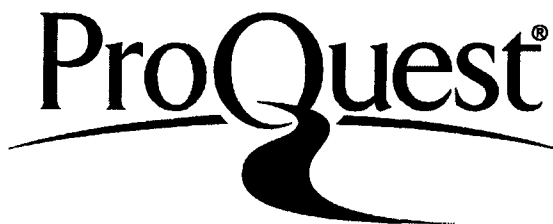
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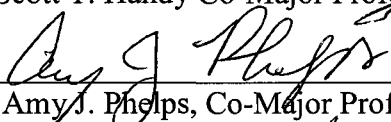
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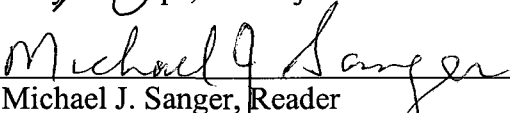
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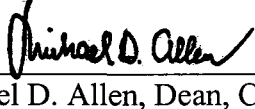
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Dedicated to my high school chemistry teacher Mrs. Virginia Eastmo, for introducing me to this complex, yet very logical subject.

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ABSTRACT

Part I. Synthesis and Characterization of C₂ Substituted Imidazolium Room Temperature Ionic Liquids

Part II. Survey and Analysis of Organic Chemistry Textbooks

Part I. Among room temperature ionic liquids (RTILs), those derived from the imidazolium cation are the most common. RTILs have generally been viewed solely as solvents, but they are able to participate in certain types of reactions, particularly due to the relatively high acidity at the imidazolium C₂. Deprotonation affords N-heterocyclic carbenes (NHCs), which can cause unwanted side reactions. Consequently, the major limitation of imidazolium RTILs is that they cannot be used as solvents in highly basic reactions such as the Baylis-Hillman and Grignard reactions. This work reveals a convenient route for the preparation of C₂-substituted imidazolium ionic liquids. This method involves the alkylation of N-heterocyclic carbenes, which are readily generated from the C₂-unsubstituted imidazolium ionic liquids. It works well for non-functionalized alkyl chlorides and less well for alkyl bromides and iodides, likely due to competing elimination reactions. The resulting C₂-substituted salts can be transformed into ionic liquids via standard anion metathesis reactions.

Part II. Recent advances in media and the increasingly encyclopedic nature of traditional textbooks have made their role in college classes uncertain. In an effort to discover what is really being taught in organic chemistry courses across the US, a survey of organic chemistry professors in all 50 states was conducted to determine what material is covered in their organic chemistry courses for science majors. Survey Monkey, an online survey program, was used to construct a short 10-item survey which was sent to organic chemistry professors at various types of institutions across the nation. We sent out 2417 surveys and received 489 responses. The results of this survey revealed what topics the professors believe is core material and what they feel is extraneous. Additionally, this research identifies the things these professors would like to see changed in the organic chemistry texts.

From the open-ended portion of the survey data, an analysis of organic chemistry textbooks was created. Books were analyzed for number and types of problems, number of example problems, and number of problems containing answers in the back of the book. The analysis of the thirteen books revealed there was a statistically significant difference between the books in number and types of problems. This work will reveal the findings of the analysis.

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Chapter 1. Synthesis and Characterization of C2 Substituted Imidazolium Room Temperature Ionic Liquids

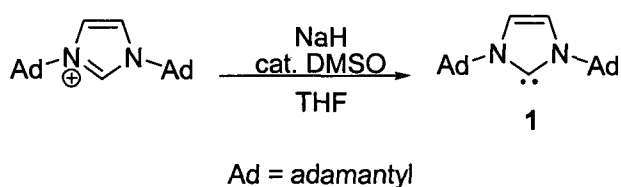
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Introduction

Room temperature ionic liquids continue to grow in terms of their range of application and in their general utilization in chemistry and related fields.¹⁻³ Part of the reason for their great utility stems from the variable physical properties that can be accessed by simply changing the anion and cation components of these materials.^{4,5} Although many different options are available, the most popular family of RTILs continues to be those based on the imidazolium cation. Within this family, much work has been done to study the influence of the two alkyl groups on nitrogen on the physical properties of these liquids. The C2 position is another source of variability, but much less is known about these materials, likely due to the fact that their preparation requires starting from a new imidazole for each substituent that is to be studied. Although certainly achievable, such a situation does require at least two or three steps for the preparation of each new compound. As such, they are more time and effort intensive to study than the simple C2-unsubstituted compounds.

The absence of information regarding many C2-substituted imidazolium RTILs is unfortunate, particularly since the unsubstituted salts are incompatible with reactions

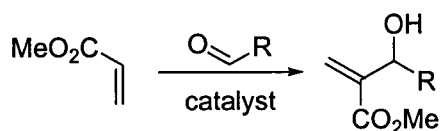
under basic conditions and thus cannot be readily applied as solvents in fundamental reactions such as organometallic additions to carbonyls or the Baylis-Hillman reaction.⁶⁻⁹ In the presence of strong base, the C2 position is deprotonated to form an N-heterocyclic carbene (NHC). These species were first proposed by Wanzlick in the 1960's and were characterized by their adducts with a variety of other compounds.¹⁰ For many years, these adducts were the only evidence that NHCs could be formed. It was only in the early 1990s that the first NHC (**1**) was isolated by Arduengo and co-workers (Scheme 1.1).¹¹ One of their key observations was that imidazolium cations with larger groups on the two nitrogens afforded air-stable isolable NHCs. While NHCs are useful as ligands in transition metal catalysis (among other applications), their presence can have some negative effects on certain reactions.



Scheme 1.1. Arduengo's Formation of an N-Heterocyclic Carbene (NHC)

Perhaps the best-documented example of the problems resulting from unwanted NHC formation is that of the Baylis-Hillman reaction in imidazolium RTILs. The Baylis-Hillman reaction involves the addition of an aldehyde to an electron-deficient alkene in the presence of a Lewis base such as 1,4-diazabicyclo[2.2.2]octane (DABCO) or trialkyl phosphines (Scheme 1.2).¹² Because it is an atom efficient reaction (all atoms from the

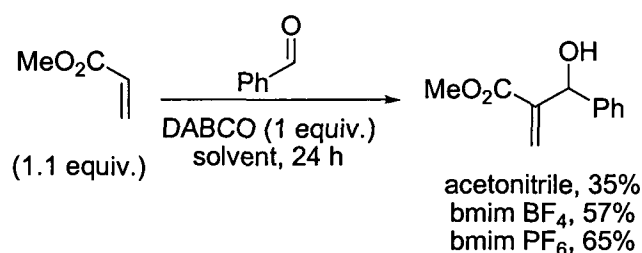
starting reagents are incorporated into the final product), it is seen as a ‘green’ process. Unfortunately, the reaction can be difficult when using aliphatic aldehydes, substituted alkenes, or enones and is generally sluggish (reaction times of days, weeks, or even months). Attempts to avoid these substrate limitations and increase the reaction rate have included high pressure, microwaves, ultrasound, the use of different catalysts such as DBU, different Lewis acids such as TiCl_4 , and different solvents such as water and simple alcohols. Most recently, the use of RTILs as the solvent has been examined.



Scheme 1.2. The Baylis-Hillman Reaction

Afonso and co-workers were the first to investigate the use of RTILs as a solvent for the Baylis-Hillman reaction (Scheme 1.3).¹³ They reacted benzaldehyde and methyl acrylate in acetonitrile, BMIM BF_4 , and BMIM PF_6 and observed that the reaction was significantly faster in either of the RTILs than in acetonitrile. They also performed the reaction using different aldehydes and esters and found the reaction to be functional for a variety of aldehydes and esters in the ionic liquids. Lastly, they evaluated the potential of the ionic liquid to be recycled and used multiple times. Interestingly, they observed an increase in yield with each cycle (from 53% in the first cycle to 76% by the fourth cycle for the reaction of p-chlorobenzaldehyde with methyl acrylate). The proposed

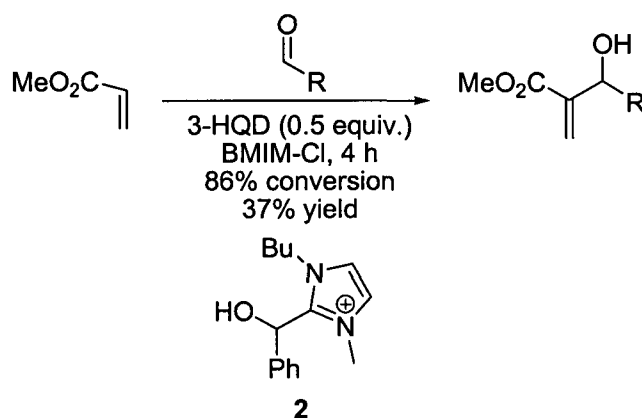
explanation was that DABCO accumulated in the RTIL since the ether extraction (used for product separation) failed to completely remove the DABCO. Since a full equivalent of DABCO was added for each new reaction, this led to a build-up of DABCO over the course of several recyclings.



Scheme 1.3. Afonso's Baylis-Hillman Results

A subsequent study by Aggarwal and co-workers raised some serious questions regarding the observations of Afonso.⁸ Aggarwal also explored the use of RTILs in the Baylis-Hillman reaction but noted that the imidazolium ionic liquids are not inert under the reaction conditions. In studying the rate of the reaction in BMIM chloride, they noted that benzaldehyde was consumed at a much higher rate than the methyl acrylate in their reaction. In investigating the source of this rapid consumption, they found that a mild base such as 3-hydroxyquinuclidine (3-HQD) or DABCO will readily deprotonate the C2 position of the ionic liquid, a feature that was not recognized at that time. Indeed, they were even able to isolate the addition product of an NHC with the aldehyde (product **2**). (Scheme 1.4) Very significant amounts of this NHC adduct **2** forms during the reaction.

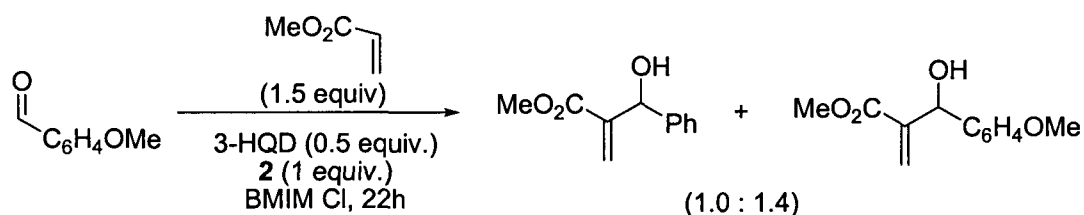
This observation was used to explain the poor to modest performance of the imidazolium RTILs as solvents for the Baylis-Hillman reaction. At the same time, the use of halide salts (which readily undergo deuterium exchange in the absence of added base) by Aggarwal and PF_6 salts (which do not undergo deuterium exchange in the absence of added base) by Afonso may mean that carbene formation is a problem in the former but not operational in the latter.¹⁴ A direct comparison of the two salts under otherwise identical conditions would serve to resolve this question.



Scheme 1.4. Aggarwal's Baylis-Hillman Results

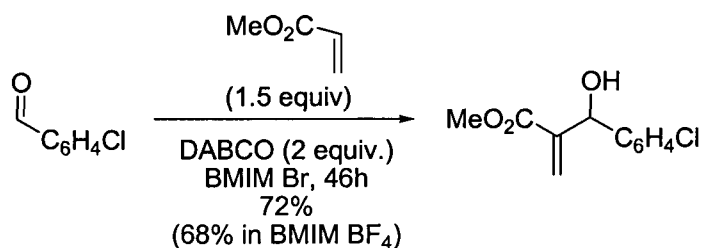
As an interesting additional portion of their study, Aggarwal and co-workers used the RTIL that had been used in previous trials (containing adduct **2**) and performed the Baylis-Hillman reaction of methyl acrylate and *p*-methoxybenzaldehyde (Scheme 1.5). This was performed to see if the side reaction between the NHC and the aldehyde is reversible or not. They found that it was indeed reversible with the Baylis-Hillman

product being a 1.4:1.0 mixture of the methoxy-containing product (the product of a normal Baylis-Hillman reaction) and the simple phenyl product (which could only result from a reversion of adduct **2** to the carbene and benzaldehyde). The implication of this observation is that recycling the RTIL through different Baylis-Hillman reactions could lead to a mixture of products due to the reversibility of the side reaction.



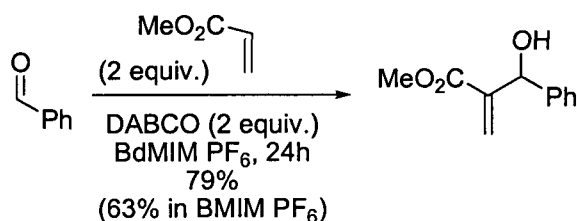
Scheme 1.5. Aggarwal's Equilibration Study

Further confusion over the generality of NHC formation being a problem for the Baylis-Hillman reaction comes from the work of Tsai and co-workers.¹⁵ They evaluated the reaction of methylvinylketone and p-chlorobenzaldehyde in the presence of DABCO using BMIM bromide as the solvent (Scheme 1.6). Although the reaction times were rather long, the isolated yields were fair (72%) and no NHC adduct was observed. Further, similar results were observed using BMIM BF₄ as the solvent. Given the rather long reaction times and the demonstrated reversibility of NHC-aldehyde adduct formation, some NHC formation cannot be ruled out. Still, the reactions did work, even in a halide-containing solvent.



Scheme 1.6. Tsai's Baylis-Hillman Studies

In a clear effort to avoid the potential problems of NHC formation in the Baylis-Hillman reaction, Hsu and coworkers performed a DABCO catalyzed reaction in 1-butyl-2,3-dimethylimidazolium hexafluorophosphate (BdMIM PF₆) (Scheme 1.7).¹⁶ They found the reaction to proceed smoothly and cleanly in this solvent and that the RTIL could be recycled at least 4 times with no decrease in yield of the Baylis-Hillman product. They also performed the same set of reactions in BMIM PF₆ for comparison and found the yields decreased in the BMIM ionic liquid compared to BdMIM, although only by very modest amounts (generally 10-20%). They were however, able to confirm that NHC-aldehyde adducts were only observed in the BMIM cases and not the 2-methyl substituted (BdMIM) cases.



Scheme 1.7. Hsu's Baylis-Hillman Studies

In an effort to address the limited utility of imidazolium RTILs and to develop a more concise route for the preparation of a variety of C2-substituted imidazolium RTILs, we have considered the possibility of alkylating the N-heterocyclic carbenes derived from readily available simple imidazolium RTILs such as butyl-methyl-imidazolium bromide shown in Figure 1.1.

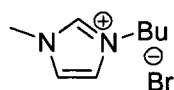
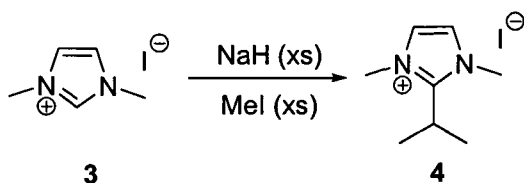


Figure 1.1. A Simple Imidazolium Ionic Liquid

The attractive features of such an approach are that many RTILs like **3** are commercially available or can be synthesized in a single, simple step. From these materials, a wide range of C2-substituted RTILs could be prepared via standard alkylation chemistry, thereby enabling the preparation of many new RTILs from a single starting material. This would then help to address the limited physical data available regarding such compounds and enable a more accurate prediction regarding the choice of future compounds for application in particular situations.

The idea of alkylating NHCs is not completely novel, although it has received very little attention. Begtrup initially reported that the treatment of imidazolium salt **3** with methyl iodide and base resulted in alkylation at C2 (Scheme 3).¹⁷ Interestingly, this reaction was also able to further alkylate the C2 methyl group by using an excess of methyl iodide and base, ultimately leading to the installation of an isopropyl group at C2

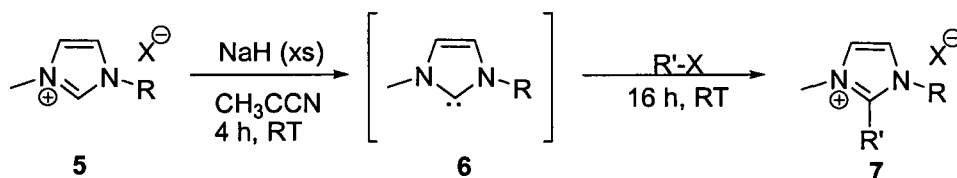
(product 4). Alder has also reported a few alkylations of simple imidazolium salts by treatment with base and alkyl bromides.¹⁸



Scheme 1.8. Begtrup Alkylation

Results and Discussion

To realize this approach to C2-substituted ionic liquids, the N-heterocyclic carbene (NHC) intermediate 6 was first generated from the requisite imidazolium salt 5 using standard conditions (Scheme 1.9).^{19,20} At this point, the desired alkyl halide was added and the reaction allowed to stir overnight to afford the alkylated product 7.



Scheme 1.9. Alkylation Reactions

Initial attempts employed only slight excesses of base and alkyl halide. These reactions afforded mixtures of starting material and product which proved to be effectively inseparable. However, resubmission of these mixtures to the alkylation conditions did enable eventual complete conversion of all the starting imidazolium salts and never led to further alkylation of the C2 substituent, unlike the reactions of Begtrup. This difference is likely due to the greater steric hindrance imposed by the butyl/methyl combination compared to the dimethyl system studied by Begtrup. The partial conversion in the alkylation reaction is presumably due to competing elimination reactions of the alkyl halides, which is supported by the presence of alkene signals in the ^1H NMR of the crude reaction mixtures of reactions with longer alkyl halides (such as chlorodecane).

On the basis of this initial information, further alkylations were conducted using an excess of both the base and the alkyl halide in order to overcome the problems of elimination (Table 1.1). The size of the alkyl halide did not appear to have any significant effect on reaction yield as primary alkyl halides ranging in size from two to sixteen carbons were found to be effective reaction partners with the imidazolium carbene intermediate formed in the reaction. On the other hand, the halide did have a significant impact, with primary alkyl chlorides being superior to their bromo and iodo analogues. Operationally, this can be seen by comparing the number of equivalents of sodium hydride and alkyl halide required for the reaction to proceed to completion. With alkyl chlorides, 3 equivalents were required to insure complete conversion of the starting imidazolium salt, while 3.5-4 equivalents were required with alkyl bromides and greater

than 4 equivalents with alkyl iodides (Table 1, entries 1, 2, and 3). Again, assuming the elimination reactions are leading to partial conversion, this observation makes sense since elimination reactions are more facile with better leaving groups (bromides and iodides).

Hexadecyl chloride did react successfully. Unfortunately, the alkylated imidazolium RTIL could not be isolated in pure form due to difficulties in removing the excess hexadecyl chloride from the RTIL product. Simple extraction methods, which were successful in all other cases, failed as both the RTIL and hexadecyl chloride were freely miscible with a wide range of solvents including hexanes.

This method is not without its limitations. Secondary alkyl halides (such as 2-chloropropane or 2-bromopropane) failed to afford any of the alkylation product. Presumably the increased steric hindrance in these systems results in elimination being the sole reaction pathway. Interestingly, allyl bromide, benzyl bromide, and 4-bromo-1-butene also failed to afford clean alkylated product. In the case of 4-bromo-1-butene, elimination may again be the problem, as starting material was cleanly recovered. For allyl and benzyl bromide, though, the reactions afforded complex mixtures of products, suggesting the alkylation did occur.

Table 1.1. Alkylation Results

Entry	Alkyl Halide	Equivalents	% yield ^a
1	Iodoethane	5	99
2	Bromoethane	4	99
3	Chlorobutane	3	92
4	Iodobutane ^a	3	(50)
5	Chlorohexane	3	85
6	Bromohexane ^a	3	(93)
7	Chloroheptane	3	67

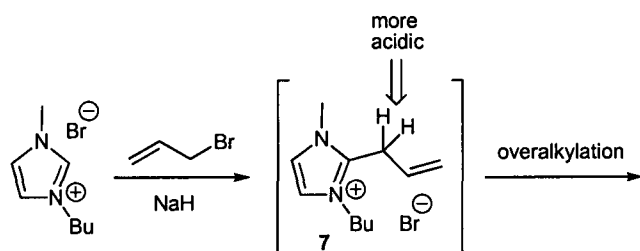
Table 1.1. cont.

Entry	Alkyl Halide	Equivalents	% yield ^a
8	Bromoheptane ^a	3	(70)
9	Chlorodecane	3	85
10	Chlorohexadecane	3	NA ^b
11	Bromobutane ^a	3	(96)

a). % conversion is shown in parenthesis for reactions that did not proceed to completion.

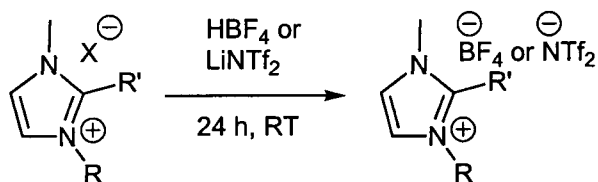
b). Precise yield could not be determined due to difficulties in removing the excess alkyl halide and alkene by-product.

However, since the initial alkylation product (such as **7**) features even more acidic protons than the starting material, it is quite possible that further alkylation occurs, thereby generating the mixture of products (Scheme 1.10). No attempts have been made to see if complete alkylation of all acidic protons can be achieved. Finally, 2-bromoethyl acetate also afforded a complex mixture of products. This is likely due to the same reason that allyl and benzyl bromide failed – overalkylation. As a result, functionalized alkyl groups appear to be problematic substrates for this reaction.



Scheme 1.10. Over-alkylation Problem

Imidazolium halides are typically not room temperature liquids, so it was not surprising that only one of the alkylation products, **BBMIM**, was a liquid. Interestingly, though, all of the remaining halides were relatively low-melting solids. The identity of the halide in these salts has not yet been rigorously determined. It is speculated to be a bromide, since reactions of **BMIM** bromide with either alkyl bromides or alkyl chlorides give materials with identical ^1H NMR spectra, whereas the product of alkylation of **BMIM** chloride with an alkyl chloride gives a material with slightly different chemical shifts for the two imidazolium signals. As a result, it appears that the bromide remains the counter-ion in these alkylation reactions, even when it could be mixed with a chloride. Further work on confirming this observation is underway and will be reported in due course. Still, to demonstrate that the alkylation route could serve to access more conventional materials, a series of tetrafluoroborate and triflimide salts were prepared via anion metathesis reactions. For these reactions, the appropriate imidazolium halide was added to an aqueous solution of either fluoroboric acid or lithium bis(trifluoromethanesulfonyl)imide and allowed to stir overnight (Scheme 1.11).^{21,22}



Scheme 1,11. Anion Metathesis

In general, the tetrafluoroborate RTILs were obtained in modest yields, while the triflimides were obtained in good yields (Table 1.2). The low yield of the tetrafluoroborate reactions is probably due to the product being at least partially soluble in water (see experimental for full details). As a result, washing them to remove excess fluoroboric acid certainly resulted in at least some loss of material. It is probable that better yields can be obtained via other metathesis techniques.^{23,24}

Table 1.2. Metathesis Reaction Results

Entry	R	R'	Anion	% Yield
1	Bu	Bu	BF ₄	53
2	Bu	Hex	BF ₄	64
3	Bu	Heptyl	BF ₄	54
4	Bu	Decyl	BF ₄	56
5	Bu	Bu	NTf ₂	71
6	Et	Bu	BF ₄	44
7	Et	Bu	NTf ₂	83

The viscosities and melting points were measured for each compound and are reported in Table 1.3. It should be noted that the water content of the samples used for the viscosity measurements is not known. All samples were dried in a uniform fashion at 100° C overnight under high vacuum. This procedure afforded materials that consistently gave viscosity measurements that were within a 5% range of the reported values.⁴ Of the trisubstituted butyl-methyl imidazolium halides, the butyl substituted compound was the only one that was a liquid at room temperature, the others were all solids with melting points around 50° C. These salts became liquid when the halogen group was replaced with a tetrafluoroborate group. All BF₄ compounds were liquids at room temperature

with viscosities ranging from 400-1170 cP. For BBMIM, a triflimide salt was synthesized and its viscosity compared to the other BBMIM compounds (Table 3, entries 2, 3, and 4). As expected, its viscosity (224 cP) was less than both the tetrafluoroborate (400 cP) and bromide (1760 cP) analogs.²⁵ For the sake of comparison, 2-butyl-1-ethyl-3-methyl imidazolium iodide (BEMIM I), tetrafluoroborate, and triflimide RTILs were synthesized and the properties measured. It was found that the BEMIM I was a solid with a melting point of 47-55° C. The tetrafluoroborate analog was less viscous (220 cP) than the iodide and the triflimide was even less viscous (48.3 cP). This trend is consistent with the trend observed for the BBMIM RTILs. The regioisomer 1-butyl-2-ethyl-3-methyl imidazolium bromide (BEMIM Br) was synthesized to allow for the comparison of properties with BEMIM I. Like BEMIM I, BEMIM Br was a solid with a similar melting point (46-52° C).

Table 1.3. Physical Properties of Ionic Liquids

Entry	R	R'	Anion	MP	Visc.
1	Bu	Et	Br	46-52	NA
2	Bu	Bu	Br	L	1760
3	Bu	Bu	BF ₄	L	400
4	Bu	Bu	NTf ₂	L	224
5	Bu	Hex	Br	20	NA
6	Bu	Hex	BF ₄	L	1170
7	Bu	Heptyl	Br	48-55	NA
8	Bu	Heptyl	BF ₄	L	963
9	Bu	Decyl	Br	50-60	NA
10	Bu	Decyl	BF ₄	L	380
11	Et	Bu	I	47-55	NA
12	Et	Bu	BF ₄	L	220
13	Et	Bu	NTf ₂	L	48.3

L = liquid at room temperature. NA = not applicable.

It may be beneficial to perform metathesis reaction on BEMIM Br to form its tetrafluoroborate and triflimide salts, and to compare their physical properties to their corresponding BEMIM analogs.

Conclusions

Because of the acidic C2 proton, imidazolium ionic liquids are limited to reactions that do not employ strongly basic conditions. The present study set out to investigate if it is possible to devise a method to add groups other than methyl to the C2 position of imidazolium RTILs and to investigate what effect it would have on the physical properties of these molten salts. Additionally, other counter-ions were prepared to determine if the counter-ion effects would be similar to that observed with unsubstituted imidazolium RTILs. Future work is directed at preparing further triflimide salts as they were easy to synthesize and isolate and are less viscous than either the halide or tetrafluoroborate RTILs. Other work will explore a broader range of functionalized alkyl halides, particularly ones with the functional group further removed from the alkyl halide than in the cases explored in the present work.

Experimental

NMR spectra were collected as solutions in deuteriochloroform on either a JEOL 500 or 300 spectrometer. IR spectra were collected on a Varian 800 FTIR as thin films or, for solid samples, neat using an ATR attachment. All solvents and reagents were used as received and all reactions were run in oven-dried glassware under an atmosphere of

argon. TLCs were performed on Merck aluminum-backed plates coated with silica and visualized using a UV lamp. Viscosities were measured on a Brookfield DV-E viscometer using materials that had been dried overnight under vacuum at 100° C. Melting points were measured on a Fisher-Johns hot stage and are uncorrected.

General procedure for the alkylation of 1-butyl-3-methylimidazolium bromide (BMIM Br) with alkyl chlorides

To a stirred solution of BMIM Br (10 g, 45.6 mmol) in acetonitrile (175 mL) was added NaH (60% in mineral oil) (2.18 g, 54.8 mmol). After allowing the mixture to stir for 4 hours, chlorobutane (16.93 g, 182.9 mmol) was added and the reaction was stirred overnight. The solution was filtered to remove any precipitated NaCl and the resulting solution was then evaporated to dryness to afford a red/orange oil. The resulting oil was washed with ether (3x75 mL) to remove any excess alkyl halide and the residual volatiles were then removed under vacuum.

Synthesis of 1-butyl-2-ethyl-3-methylimidazolium bromide (BEMIM Br)

To a stirred solution of BMIM Br (1.00 g, 4.56 mmol) in acetonitrile (25 mL) was added NaH (60% in mineral oil) (0.22 g, 5.48 mmol). After allowing the mixture to stir for 4 hours, ethyl bromide (2.00 g, 18.3 mmol) was added and the reaction stirred overnight. The solution was filtered to remove any precipitated NaBr and the resulting solution was then evaporated to dryness to afford a red/orange oil. The resulting oil was

washed with ether (3x20 mL) to remove any excess alkyl halide and the residual volatiles were then removed under vacuum.

Synthesis of 2-butyl-1-ethyl-3-methylimidazolium iodide (BEMIM I)

To a stirred solution of 1-ethyl-3-methylimidazolium iodide (EMIM I) (2.00 g, 8.37 mmol) in acetonitrile (50 mL) was added NaH (60% in mineral oil) (0.42 g, 10.88 mmol). After allowing the mixture to stir for 4 hours, chlorobutane (2.33 g, 25.1 mmol) was added and the reaction was allowed to stir overnight. The solution was filtered to remove any precipitated NaCl and the resulting solution was then evaporated to dryness to afford a red/orange oil. The resulting oil was washed with ether (3x20 mL) to remove any excess alkyl halide and the residual volatiles were then evaporated under vacuum.

Representative Anion Metathesis to afford Tetrafluoroborate Salts

To a solution of BBMIM-Br (1.55 g, 5.63mmol) in water (40 mL) was added dropwise HBF₄ (50 wt% solution) (0.742 g, 8.44 mmol). The mixture was then allowed to stir overnight. The resulting solution was extracted with dichloromethane (3x20 mL). The organic layer was collected and then concentrated *in vacuo* and the crude ionic liquid was washed with water until the pH of the extracts was between 6 and 7. The solution was then dried with Na₂SO₄. Any residual volatiles were then removed under vacuum.

Representative Anion Metathesis to afford Triflimide Salts

To a solution of BBMIM-Br (12.24 g, 44.4 mmol) in water (100 mL) was added lithium bis (trifluoromethanesulfonyl) imide (LiNTf₂) (20.38 g, 71 mmol). The mixture was then allowed to stir overnight. The resulting solution was extracted with dichloromethane (3x75 mL) and the extracts were combined and dried with Na₂SO₄. The dried organic layer was then concentrated *in vacuo*.

1-Butyl-2-ethyl-3-methylimidazolium bromide: ¹H NMR (300 MHz, CDCl₃) δ = 7.71 (d, 1H, J = 2.07 Hz), 7.52 (d, 1H, J = 2.07 Hz), 4.11 (t, 2H), 4.09 (s, 3H), 3.07 (q, 2H), 1.97-1.74 (m, 2H), 1.54-1.00 (m, 5H), 0.82-0.62 (m, 3H); ¹³C NMR (75 MHz, CDCl₃): δ = 147.27, 123.36, 121.32, 48.42, 35.86, 32.26, 19.54, 17.39, 13.54, 11.69; IR (neat) 3124, 2961, 2928, 2872, 1637, 1530, 1192, 1033 cm⁻¹ HRMS (EI) calcd for C₁₀H₁₉N₂ 167.1548, found 167.1550.

1, 2-Dibutyl-3-methylimidazolium bromide: ¹H NMR (300 MHz, CDCl₃) δ = 7.79 (d, 1H, J = 2.07 Hz), 7.52 (d, 1H, J = 2.04 Hz), 4.11 (t, 2H), 3.99 (s, 3H), 3.02 (t, 2H), 1.81-1.62 (m, 2H), 1.58-1.43 (m, 2H), 1.41-1.22 (m, 4H), 0.88-0.82 (m, 6H); ¹³C NMR (75 MHz, CDCl₃) δ = 146.49, 123.56, 121.35, 48.46, 36.02, 32.24, 29.29, 23.60, 22.42, 19.68, 13.62, 13.58; IR (neat) 3148, 2924, 2857, 1688, 1530, 1190, 1033 cm⁻¹; HRMS (EI) calcd for C₁₂H₂₃N₂ 195.1861, found 195.1860.

1-Butyl-2-hexyl-3-methylimidazolium bromide: ^1H NMR (300 MHz, CDCl_3) δ = 7.84 (d, 1H, J = 2.07 Hz), 7.59 (d, 1H, J = 2.07 Hz), 4.14 (t, 2H), 3.99 (s, 3H), 3.04 (t, 2H), 1.86-1.73 (m, 2H), 1.64-1.51 (m, 2H), 1.45-1.18 (m, 8H) 0.96-0.78 (m, 6H); ^{13}C NMR (75 MHz, CDCl_3) δ = 146.50, 123.70, 121.34, 48.52, 36.06, 32.29, 31.24, 28.95, 27.33, 23.98, 22.42, 19.74, 13.99, 13.63; IR (neat) 3124, 2935, 2959, 2873, 1665, 1530, 1466, 1033 cm^{-1} ; HRMS (EI) calcd for $\text{C}_{14}\text{H}_{27}\text{N}_2$ 223.2174, found 223.2171.

1-Butyl-2-heptyl-3-methylimidazolium bromide: ^1H NMR (300 MHz, CDCl_3) δ = 7.74 (d, 1H, J = 2.07 Hz), 7.54 (d, 1H, J = 2.07 Hz), 4.06 (t, 2H), 3.89 (s, 3H), 2.96 (t, 2H), 1.75-1.61 (m, 2H), 1.56-1.44 (m, 2H), 1.33-1.07 (m, 10H) 0.82 (t, 3H), 0.72 (t, 3H); ^{13}C NMR (75 MHz, CDCl_3) δ = 146.38, 123.48, 121.33, 48.38, 35.92, 32.19, 31.38, 29.06, 28.65, 27.22, 23.74, 22.41, 19.56, 13.94, 13.51; IR (neat) 3054, 2958, 2934, 2820, 1672, 1530, 1465, 1033 cm^{-1} ; HRMS (EI) calcd for $\text{C}_{15}\text{H}_{29}\text{N}_2$ 237.2331, found 237.2333.

1-Butyl-2-decyl-3-methylimidazolium bromide: ^1H NMR (300 MHz, CDCl_3) δ = 7.65 (d, 1H J = 2.07 Hz), 7.47 (d, 1H, J = 2.07 Hz), 4.00 (t, 2H), 3.82 (s, 3H), 3.33, (t, 2H), 1.72-1.52 (m, 2H), 1.49-1.37 (m, 2H), 1.29-0.98 (m, 16H), 0.78 (t, 3H), 0.68 (t, 3H); ^{13}C NMR (75 MHz, CDCl_3) δ = 146.55, 123.74, 121.33, 48.53, 36.06, 32.29, 31.87, 29.51, 29.39, 29.29, 29.15, 27.38, 24.02, 22.7, 19.76, 14.16, 13.64; IR (neat) 3148, 2925, 2855, 1672, 1531, 1466, 1033 cm^{-1} ; HRMS (EI) calcd for $\text{C}_{18}\text{H}_{35}\text{N}_2$ 279.2800, found 279.2801.

1, 2-Dibutyl-3-methylimidazolium tetrafluoroborate: ^1H NMR (500 MHz, CDCl_3) δ = 7.29 (d, 1H, J = 2.04 Hz), 7.26 (d, 1H, J = 2.07 Hz), 3.99 (t, 2H), 3.75 (s, 3H), 2.90 (t, 2H), 1.84-1.76 (m, 2H) 1.64-1.57 (m, 2H), 1.49-1.34 (m, 4H), 0.92-0.81 (m, 6H); ^{13}C NMR (125 MHz, CDCl_3) δ = 146.40, 122.77, 120.76, 47.87, 34.77, 31.76, 28.76, 22.51, 22.05, 19.25, 13.25, 13.23; ^{19}F NMR (470 MHz, CDCl_3) δ = -150.98; IR: 3127, 2966, 2937, 2866, 1531, 1466, 1033 cm^{-1} ; HRMS (EI) calcd for $\text{C}_{12}\text{H}_{23}\text{N}_2$ 195.1861, found 195.1861.

1-Butyl-2-hexyl-3-methylimidazolium tetrafluoroborate: ^1H NMR (500 MHz, CDCl_3) δ = 7.67 (d, 1H, J = 2.07 Hz), 7.49 (d, 1H, J = 2.04 Hz), 4.05 (t, 2H), 3.87 (s, 3H), 2.92 (t, 2H), 1.76-1.64 (m, 2H), 1.56-1.44 (m, 2H), 1.35-1.11 (m, 8H) 0.87-0.70 (m, 6H); ^{13}C NMR (125 MHz, CDCl_3) δ = 146.55, 122.98, 120.97, 48.05, 34.91, 31.94, 31.11, 28.74, 26.91, 22.94, 22.33, 19.47, 13.88, 13.39; ^{19}F NMR (470 MHz, CDCl_3) δ = -150.98; IR: 3144, 2966, 2936, 2866, 1532, 1469, 1053 cm^{-1} ; HRMS (EI) calcd for $\text{C}_{14}\text{H}_{27}\text{N}_2$ 223.2174, found 223.2173.

1-Butyl-2-heptyl-3-methylimidazolium tetrafluoroborate: ^1H NMR (500 MHz, CDCl_3) δ = 7.39 (d, 1H, J = 2.3 Hz), 7.36 (d, 1H, J = 2.3 Hz), 4.08 (t, 2H), 3.85 (s, 3H), 2.99 (t, 2H), 1.72-1.63 (m, 2H), 1.54-1.44 (m, 2H), 1.34-1.06 (m, 10H), 0.83 (t, 3H), 0.75 (t, 3H); ^{13}C NMR (125 MHz, CDCl_3) δ = 146.26, 122.65, 120.68, 47.76, 34.66, 31.65, 31.11, 28.70, 28.32, 26.70, 22.64, 22.13, 19.14, 13.65, 13.11; ^{19}F NMR (470 MHz,

CDCl_3) $\delta = -151.98$; IR: 3220, 2983, 2940, 2826, 1507, 1318, 1022 cm^{-1} ; RMS (EI) calcd for $\text{C}_{15}\text{H}_{29}\text{N}_2$ 237.2331, found 237.2333.

1-Butyl-2-decyl-3-methylimidazolium tetrafluoroborate: ^1H NMR (500 MHz, CDCl_3) $\delta = 7.38$ (d, 1H, $J = 2.3$ Hz), 7.35 (d, 1H, $J = 2.3$ Hz), 4.06 (t, 2H), 3.81 (s, 3H), 2.97 (t, 2H) 1.84-1.73 (m, 2H), 1.64-1.56 (m, 2H), 1.44-1.20 (m, 16H), 0.96 (t, 3H), 0.87 (t, 3H); ^{13}C NMR (125 MHz, CDCl_3) $\delta = 146.37, 122.82, 120.78, 47.91, 34.81, 31.78, 31.59, 29.24, 29.11, 29.01, 28.94, 28.83, 26.86, 22.82, 22.41, 19.31, 13.86, 13.25$; ^{19}F NMR (470 MHz, CDCl_3) $\delta = -152.01$; IR (neat) 3144, 2960, 2924, 2854, 1532, 1466, 1052 cm^{-1} ; HRMS (EI) calcd for $\text{C}_{18}\text{H}_{35}\text{N}_2$ 279.2800, found 279.2802.

2-Butyl-1-ethyl-3-methylimidazolium iodide: ^1H NMR (500 MHz, CDCl_3) $\delta = 7.32$ (d, 1H, $J = 2.07$ Hz), 7.29 (d, 1H, $J = 2.07$ Hz), 3.94 (q, 2H), 3.63 (s, 3H), 2.76 (t, 2H), 1.34-1.06 (m, 7H), 0.60 (t, 3H); ^{13}C NMR (125 MHz, CDCl_3) $\delta = 146.45, 123.24, 120.75, 43.91, 36.31, 29.21, 23.84, 22.31, 15.23, 13.42$; IR neat 3095, 2966, 2964, 2867, 1637, 1597, 1397, 1010 cm^{-1} ; HRMS (EI) calcd for $\text{C}_{10}\text{H}_{19}\text{N}_2$ 167.1548, found 167.1549.

2-Butyl-1-ethyl-3-methylimidazolium tetrafluoroborate: ^1H NMR (500 MHz, CDCl_3) $\delta = 7.18$ (d, 1H, $J = 2.3$ Hz), 7.17 (d, 1H, $J = 1.7$ Hz), 3.96 (q, 2H), 3.63 (s, 3H), 2.79 (t, 2H), 1.40 (m, 2H), 1.32-1.19 (m, 5H), 0.74 (t, 3H); ^{13}C NMR (125 MHz, CDCl_3) $\delta = 145.96, 122.42, 119.90, 42.86, 34.43, 28.35, 22.16, 21.65, 14.74, 12.88$; ^{19}F NMR (470

MHz, CDCl_3) $\delta = -151.91$; IR (neat) 3148, 2966, 2941, 2876, 1727, 1532, 1361, 1056 cm^{-1} ; HRMS (EI) calcd for $\text{C}_{10}\text{H}_{19}\text{N}_2$ 167.1548, found 167.1546.

2-Butyl-1-ethyl-3-methylimidazolium triflimide: ^1H NMR (500 MHz, CDCl_3) $\delta =$ 7.28 (d, 1H, $J = 2.3$ Hz), 7.25 (d, 1H, $J = 2.3$ Hz), 4.13 (q, 2H), 3.81 (s, 3H), 2.96 (t, 2H), 1.65-1.58 (m, 2H), 1.53-1.40 (m 5H), 0.97, (t, 3H); ^{13}C NMR (125 MHz, CDCl_3) $\delta =$ 192.51, 112.71, 120.09, 119.28 (q, $J = 316$ Hz, 2C), 43.33, 34.86, 28.66, 22.71, 22.05, 14.82, 13.09; ^{19}F NMR (470 MHz CDCl_3) $\delta = -79.03$; IR (neat) 3148, 2972, 2943, 2876 1712, 1532, 1350, 1183, 1055 cm^{-1} ; HRMS (EI) calcd for $\text{C}_{10}\text{H}_{19}\text{N}_2$ 167.1548, found 167.1546.

1,2-Dibutyl-3-methylimidazolium triflimide: ^1H NMR (500 MHz, CDCl_3) $\delta =$ 7.19 (s, 2H), 4.00 (t, 2H), 3.77 (s, 3H), 2.90 (t, 2H), 1.81-1.72 (m, 2H), 1.60-1.52 (m, 2H), 1.45-1.14 (m, 4H), 0.96-0.77 (m, 6H); ^{13}C NMR (125 MHz, CDCl_3) $\delta =$ 146.26, 122.69, 120.69, 119.61 (q, $J = 320$ Hz, 2C), 53.38, 48.09, 34.99, 31.64, 28.72, 22.78, 22.11, 19.28, 13.19; ^{19}F NMR (470 MHz, CDCl_3) $\delta = -78.97$; IR (neat): 3143, 2937, 2922, 2876, 1667, 1464, 1531, 1349, 1135, 1054 cm^{-1} ; HRMS (EI) calcd for $\text{C}_{12}\text{H}_{23}\text{N}_2$ 195.1861, found 195.1860.

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Part II. Organic Chemistry Textbook Survey and Analysis

Chapter 2. Organic Chemistry Textbooks: the Core, the Extraneous, and the Uncertain

Submitted for publication to *Journal of Chemical Education*

Introduction

The discipline of chemistry continues to evolve and as a part of this evolution textbooks have continued to change. For the most part, change in chemistry textbooks simply means “grow larger.” As more and more discoveries are made, more and more material has been added to books, but little if anything has been removed. Consequently, they are becoming more like encyclopedias than textbooks. For example, the 2nd edition of Bruice released in 1998 contains 1256 pages, and the 5th edition released in 2007 has 1440 pages.^{1,2} Brown, Foote, and Iverson’s second edition of their organic chemistry text contained 1232 pages and the 5th edition contains 1272 pages.^{3,4} Textbook prices have risen considerably during this time due in part to the increasing size, making it harder for students to afford them. A brief survey of Amazon.com in 2009 revealed the average list price of an organic chemistry textbook alone was around \$200. The problem of increasing size and costs of organic chemistry textbooks was first brought to light by Kerber in 1988, who noted that even at that time, textbooks had grown larger and more expensive.⁵ Additionally, Cohen noted that bigger isn’t necessarily better when it comes

to textbooks.⁶ If anything is going to be done to stem the unwieldy growth of organic chemistry textbooks, we must determine what material is absolutely essential. As the amount of material expands, the question then becomes: what material do you keep in the book and what should be removed?

Data Collection

In this study, we set out to find what material organic chemistry professors feel is essential and what they feel is extraneous. To explore these topics and find out their opinion about textbooks, a short ten-item survey was created using Survey Monkey, an online survey program. The survey was sent to professors at various institutions across the United States. Schools were selected using Yahoo's college directory and every 2nd and 5th school was selected from the list and the professors who were identified as organic chemistry at those institutions were sent the survey. Of the 2417 surveys that were sent out, 489 responses were received. The professors commented on what they believed to be the core material of organic chemistry and also provided feedback on things they wanted to see changed in the textbooks. Full written comments can be found in Appendix A.

The Participants

The ten questions in the survey can be found in Table 1. The first five questions were used to collect the demographic information of the professors. Survey responses were received from professors in every state of the Union except Nevada (Figure 1). Not

surprisingly, the highest percentage of respondents came from California (9.2%), New York (6.3%), and Texas (5.9%). The participants taught at a wide variety of institutions and institution types with the majority of participants teaching at 4 year public institutions with graduate programs (36%), followed by 4-year private schools (25%), 16% of respondents were from 4 year public institutions, 14% were from 4-year private schools with graduate programs, 8% were from 2-year schools and 2% came from private colleges. The professors also represented every academic rank from instructor to full professor with the largest percentage being full professors (38%), followed by 29% of respondents who were associate professors, 22% of those responding were assistant professors, and 6% were instructors/non-tenure track faculty . The experience level of survey participants also varied widely and ranged from 20-plus years (34%), 10-15 years (18%), 6-10 years, (16%), 3-6 years (14%), 15-20 years (11%), and 0-3 years (8%). We concluded that our group of participants was diverse and represented many different types of organic chemistry instructors across the country.

Table 2.1. Survey Questions

1. In what state do you teach?
2. At what institution do you teach?
3. At what type of institution do you teach? <ul style="list-style-type: none"> • 2-year • 4-year public • 4-year public with a graduate program • 4-year private • 4-year private with a graduate program • Private college • Other (please specify)

Table 2.1. cont.

<p>4. What is your present rank?</p> <ul style="list-style-type: none"> • Instructor/non-tenure track • Assistant professor • Associate professor • Full professor • Other (please specify)
<p>5. How many years have you been teaching?</p> <ul style="list-style-type: none"> • 0-3 • 3-6 • 6-10 • 10-15 • 15-20 • 20 +
<p>6. What textbook do you currently use in your class?</p> <ul style="list-style-type: none"> • Bruice • Carey • Ege • McMurry • Morrison and Boyd • Smith • Solomons & Fryhle • Sorrel • Vollhardt & Schore • Wade • Other (please list)
<p>7. How long have you used your present textbook?</p> <ul style="list-style-type: none"> • 0-3 years • 3-6 years • 6-10 years • 10-15 years • 15 + years
<p>8. How often do you change textbooks?</p> <ul style="list-style-type: none"> • Every year • Every 2 years • Every 3 years • Every 4 or more years • Other (please specify)
<p>9. To what extent do you cover the topic listed below? (see table 3 for full list of topics)</p>
<p>10. If you could change anything about organic chemistry textbooks what would it be?</p>

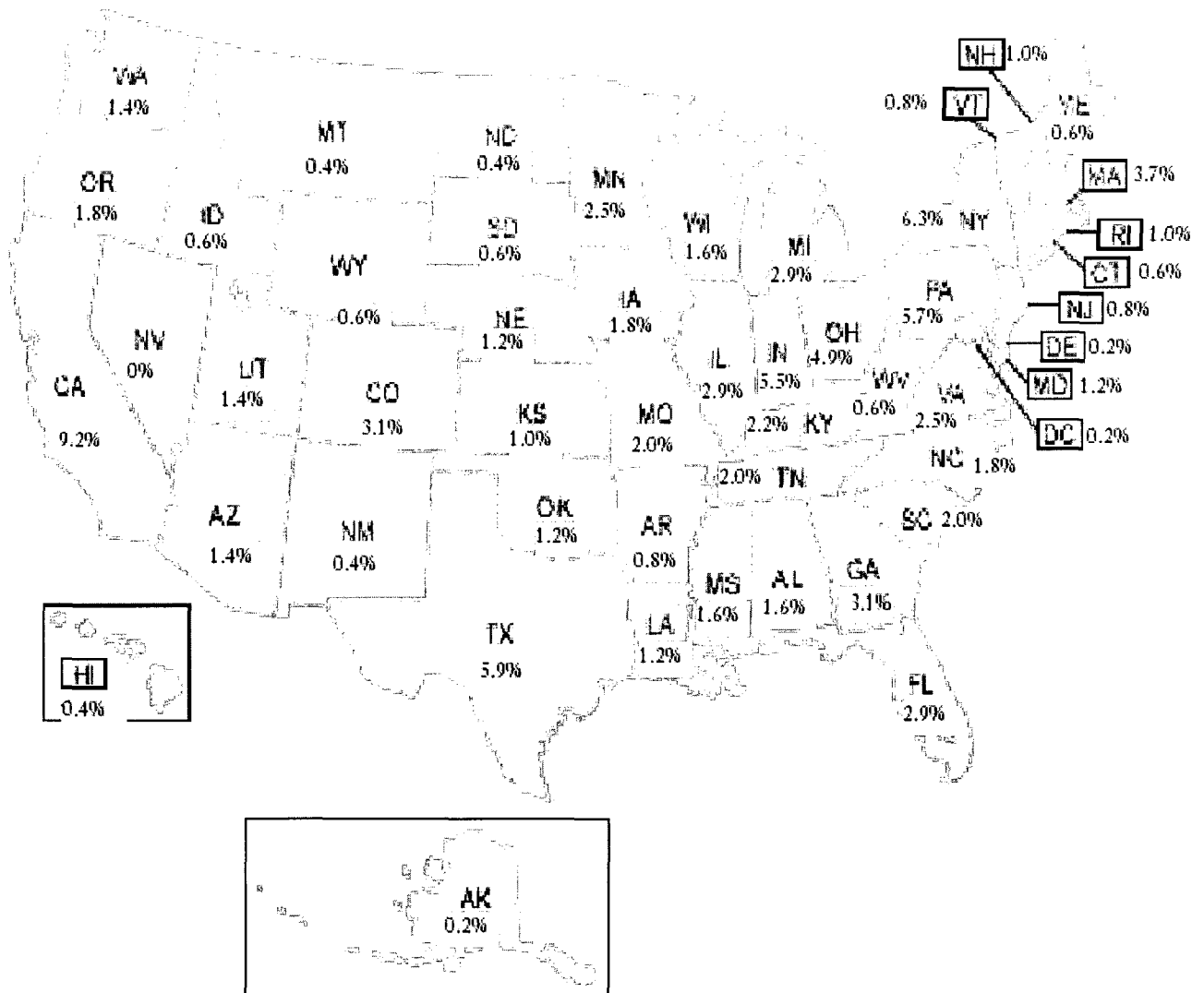


Figure 2.1. Survey Responses by State (percentage of total is shown)

The Textbooks

Questions 6-8 focused on which book an instructor uses and their pattern of book use and replacement. The professors generally reported a pattern of frequent book

replacement but the specific book used varied greatly. Respondents cited 22 different textbooks with McMurry⁷ being the most popular at 18%, followed closely by Bruice² and Wade⁸ with 14% each, and Carey⁹ with 13% (Table 2.2). Of those responding, 45% said they keep an organic textbook for 4 years or more while another 25% said they used it for 3 years or less. While most professors change books in six years or less (76%) that change is often catalyzed by the release of new editions of their current textbook.

Table 2.2. Textbooks and their Frequency of Usage

Book Author(s)	Number of users
McMurry ⁷	86 (18%)
Bruice ²	68 (14%)
Wade ⁸	67 (14%)
Carey ⁹	63 (13%)
Vollhardt & Schore ¹⁰	39 (8%)
Solomons & Fryhle ¹¹	38 (8%)
Smith ¹²	33 (7%)
Brown, Foote, & Iverson ⁴	24 (5%)
Hornback ¹³	14 (3%)
Maitland Jones ¹⁴	10 (2%)
Ege ¹⁵	9 (2%)
Loudon ¹⁶	7 (1%)
Morrison & Boyd ¹⁷	4 (1%)
Other*	21 (4%)

*Other books included: Fessenden and Fessenden,¹⁸ Fox and Whitesell,¹⁹ Straumanis,²⁰ Clayden, Greaves, Warren & Wothers,²¹ McMurry-A Biological Approach,²² Streitweiser & Heathcock,²³ Sorrell,²⁴ Brown & Poon,²⁵ Hart,²⁶ Reingold²⁷

The Concepts

Table 2.3 shows the extent to which professors cover each of the listed concepts. We arrived at the topics selected for the list by first anticipating the core material from first semester organic. Then selected topics from a typical second semester organic class we felt most professors would cover, and some that we thought fewer people would cover. For example, we believed that most professors would teach the Diels-Alder reaction, but that not everyone teaches other pericyclic reactions. There are eight topic areas that at least 90% of professors surveyed cover in detail or at least briefly mention: free radical reactions (94 %), IR spectroscopy (93%), electrophilic aromatic substitution (99%), the Grignard reaction (99%), other organometallics (91%), amines (94%), the Diels-Alder reaction (95%), and protecting groups (91%). Topics which fewer than 50% or less of respondents cover in detail or at least mention briefly are: 2-dimensional NMR (33%), lipids (50%), nucleic acids (38%), transition metal catalysis (48%), and pericyclic reactions other than the Diels-Alder (48%).

The biochemistry topics (amino acids, carbohydrates, lipids, and nucleic acids) have their own chapter(s) in the majority of the organic chemistry textbooks on the market today, but according to the surveyed professors, the majority of professors cover them briefly if at all. Carbohydrates are an exception and are covered by ~ 67% of respondents; this could be due to the fact that they can be used to teach stereochemistry concepts.

Table 2.3. Organic II Topics and the Extent to which they are Covered by Respondents

Topic	Extent to which professor covers the listed topics			
	In detail	Briefly	If I had time	Never
Free Radical reactions	262 (54%)	196 (40%)	17 (4%)	13 (3%)
Mass spectrometry	107 (22%)	280 (58%)	49 (10%)	48 (10%)
2-D NMR	42 (9%)	118 (24%)	126 (26%)	198 (41%)
Infrared spectroscopy	306 (63%)	141 (29%)	18 (4%)	18 (4%)
UV/Vis spectrometry	55 (12%)	288 (60%)	64 (13%)	72 (15%)
Electrophilic aromatic substitution	450 (93%)	27 (6%)	4 (1%)	3 (1%)
Benzyne	102 (21%)	227 (47%)	85 (18%)	67 (14%)
Grignard reaction	456 (94%)	26 (5%)	1 (0.2%)	2 (0.4%)
Other organometallic reactions	203 (42%)	239 (49%)	29 (6%)	13 (3%)
Amines	343 (71%)	114 (24%)	25 (5%)	3 (1%)
Amino acids	127 (26%)	194 (40%)	108 (22%)	55 (11%)
Lipids	54 (11%)	187(39%)	146 (30%)	98 (20%)
Carbohydrates	147 (30%)	164 (34%)	108 (22%)	65 (13%)
Nucleic acids	36 (8%)	147 (31%)	174 (36%)	125 (26%)
Transition metal catalysis	32 (7%)	198 (41%)	130 (27%)	124 (26%)
The Diels-Alder reaction	373(77%)	88 (18%)	13 (3%)	9 (2%)
Pericyclic reactions other than the Diels-Alder reaction	58 (12%)	172 (36%)	154 (32%)	99 (21%)
Polymers	60 (12%)	259 (54%)	99 (21%)	65 (14%)
Carbenes	70 (15%)	275 (57%)	61 (13%)	78 (16%)
Protecting groups	119 (25%)	316 (66%)	34 (7%)	11 (2%)
Heterocyclic compounds	83 (17%)	304 (63%)	70 (14%)	28 (6%)
Heteroaromatics	110 (23%)	305 (63%)	51 (11%)	16 (3%)

The final question of the survey asked the professors to provide comments on any aspect of textbooks they would like to see changed. Of the 489 respondents, 386 gave written comments. The suggestions the professors made to improve textbooks were incredibly varied and many of the respondents made multiple suggestions for improvements. The top 15 responses (with 14 or more people agreeing) are listed in Table 2.4.

Table 2.4. Most Commonly Cited Changes Professors would make to Textbooks*

1. Textbooks have become too long and need to be shortened (39)
2. Textbooks are way too expensive for students (29)
3. Organize the book around a mechanistic framework rather than the present functional group format most texts use (28)
4. Make the book more reader friendly by eliminating excessive use of color, complicated drawings, and other extraneous distracters (22)
5. Use more modern reactions to teach the fundamentals (22)
6. Introduce spectroscopy in the early chapters and integrate it throughout the book (21)
7. Problems are either too hard, too easy, or need improving (21)
8. More coverage of multi-step synthesis and the strategies used (20)
9. Make the text more bio-organic themed because most of the class is premed majors (18)
10. Spend more time on the basics of organic chemistry (18)
11. Completely reorder the whole book (16)
12. Add more problems (15)
13. Don't release new editions so frequently (15)
14. Place more emphasis on reaction mechanisms (15)
15. Omit the chapters on biochemistry since most schools have a junior level biochemistry class (14)

* Number of responses is listed in parenthesis

The second most commonly cited change the professors would make is for the book to be cheaper for students. Some of the other suggestions they made could go a long way to making this a reality such as: shortening the book, not releasing new editions so frequently, eliminating excessive use of color, and removing the biochemistry topics. A few respondents commented that switching to an electronic version of the text would be favorable since it could reduce costs to consumers and would also be good for the environment.

Summary/Discussion

One of the strengths of our survey is that it featured a large and diverse sample of participants representing differences in teaching environment, textbook, and geographic location. Like many open-ended surveys, the responses are subjective and open to interpretation. For example, the question regarding how long participants had used their present textbook could have been interpreted as how long have they used their present edition or how long they used a book by a particular author which would yield different results. In either event, it appears as though professors change every 4 years, about the length of time it takes publishers to come out with new editions.

By focusing on what is really being taught in organic chemistry courses, textbooks could be greatly reduced in size and scope which may have the added bonus of reducing the price. As knowledge in the field of organic chemistry continues to expand, textbooks grow larger and larger with little material being removed even though the time to learn this material has not changed for students. With alternative methods of material delivery becoming more and more popular, textbook authors and publishers need to take

a hard look at the way in which material is selected for inclusion in their books. Since textbook choice does not appear to have a strong link to topics covered, the book may be becoming less and less important in the instruction of organic chemistry.

The purpose of this survey was to catalogue what organic chemistry professors believe is the core material for the year long organic chemistry course found at most institutions. In addition, the professors were asked to make suggestions for textbook improvements. We found that professors typically tend to change texts every 4 years, about the same length of time it takes publishers to release new editions. There are eight areas that professors of organic chemistry feel are core material: electrophilic aromatic substitution, the Grignard reaction, other organometallic reactions, amines, the Diels-Alder reaction, protecting groups, free radical reactions, and IR spectroscopy. Additionally, in the open-ended section a few themes emerged: books are too expensive, they need to be shortened somehow, and respondents had suggestions about ways to reorganize the book and would like to see it switched from the current functional group organizational pattern to a more mechanistic approach. Lastly, respondents felt that something needed to be done with the problems such as adding more, or adjusting the difficulty of the existing problems.

A textbook analysis is underway to clarify the similarities and differences in the most commonly cited books in the survey. Preliminary results indicate that there is very little difference between the most popular textbooks in terms of content coverage and organizational pattern. This study illuminates the topics valued by a large number of organic instructors at a wide variety of institutions. It will be interesting to see if there is an author or publisher willing to use this information to produce a textbook that is truly

different from others on the market by focusing on the core material that appears to be widely agreed upon by those participating in the study.

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Chapter 3. An Analysis of Organic Chemistry Textbooks

Introduction

A brief search of the *Journal of Chemical Education* reference shelf reveals a wide variety of textbooks appropriate for any type of undergraduate organic chemistry class. With such a large number of textbooks to choose from, how does a professor (or department) choose a textbook that will fit the needs of both the professor and the students? An analysis of organic textbooks would be helpful since it appears that such a study has never been undertaken.

Textbook analyses have been performed on high school and college general chemistry texts and have focused on analogies,^{1,2} presentation of material,^{3,4} explanations,⁵ misconceptions and their sources,^{6,7} visual aids,⁸ social relevance,⁹ and equity and diversity.^{10,11}

Two general chemistry textbook analyses have focused on types of problems found in the text. Gillette and Sanger^{12,13} analyzed gas law problems in high school and college general chemistry textbooks and the accompanying test banks using a variety of parameters, including Bloom's Taxonomy. They looked for associations among four variables—Book Type (high school, college), Question Format (multiple-choice, short answer), Question Placement (in-chapter, end-of-chapter, test-bank), and Representation (macroscopic, particulate, symbolic). They found that Book Type, Question Format, and Question Placement appeared in several significant associations, but none of the associations involving Representation were significant. Another recent work by Davila & Talanquer¹⁴ conducted an analysis of the three most popular general chemistry

textbooks: Chang, Silberburg, and Brown et al. They analyzed the end-of-chapter problems in the 17 chapters typically covered in a year-long general chemistry course using Bloom's Taxonomy. The study revealed the similarities and differences between the end-of-chapter problems in the three most popular general chemistry textbooks.

It has been established that textbooks have a major influence on what material is taught in a course and on student learning.^{15,16} The book serves to guide students through the learning process and communicates what is expected of them.^{7,17} Therefore it is important to understand what professors think about textbooks, and how the books do or do not meet their needs.

Survey of Organic Chemistry Professors

A survey of organic chemistry professors on the state of organic chemistry was done in the summer of 2007.¹⁸ The survey, which included 492 responses from a variety of institutions, asked the professors to comment on various aspects of organic chemistry textbooks: What book they used in the course, what topics they covered, and at what level of depth. Further, they were invited to leave written comments about things they would change in organic chemistry textbooks. The top 15 comment areas from these professors can be found in table 3.1.

From this list, it was clear that many professors wanted to see the organization of the book changed, the type and number of problems altered, the excessive use of color and graphics addressed, the location and integration of spectroscopy spread throughout the book, and various topics that either needed to be added or removed. Using this list as

a starting point, a textbook analysis template was created. We also conducted a survey of 275 students at our institution to see what they valued in a textbook. The survey revealed that students were concerned about the number of example problems and the number of problems with answers in the back of the text. With this information in hand, we analyzed the books for: the number and types of problems, the number of worked out example problems, the percentage of problems with answers in the back of the textbook, the number of extraneous distractors, the location of the spectroscopy chapter(s) and how many spectroscopy problems occur outside these chapters. Based on these categories, we were able to make comparisons of the 13 most popular (widely used) organic chemistry textbooks.

Table 3.1. The top 15 Issues Identified/Changes Suggested by Respondents on the Subject of Organic Chemistry Textbooks*

15. Omit the chapters on biochemistry since most schools have a junior level biochemistry class (14)
14. Place more emphasis on reaction mechanisms (15)
13. Don't release new editions so frequently (15)
12. Add more problems (15)
11. Completely reorder the whole book (16)
10. Spend more time on the basics of organic chemistry (18)

Table 3.1. cont

9. Make the text more bio-organic themed because most of the class is premed majors (18)
8. Give more coverage of multi-step synthesis and the strategies used (20)
7. Change the problems to make them harder, easier, or better (21)
6. Introduce spectroscopy in the early chapters and integrate it throughout the book (21)
5. Use more modern reactions to teach the fundamentals (22)
4. Make the book more reader friendly by eliminating excessive use of color, complicated drawings, and other extraneous distractors (22)
3. Organize the book around a mechanistic framework rather than the present functional group format most texts use (28)
2. Make the books less expensive for students (29)
1. Make the book shorter (39)

*The number of individuals who suggested the changes is given in parenthesis

Methodology

Initially, we sought to classify the problem types based on Bloom's taxonomy since it is a system that is widely accepted to classify questions based on complexity. At the same time, using just Bloom's taxonomy does little to address the professor's comments about things like the practice problems in the textbooks. Specifically, professors mentioned that they wanted to see more synthesis, mechanism and spectroscopy problems, so we designed a classification system that would address these aspects of the professor's comments. Therefore, we classified problems into the following categories: Mechanism, synthesis, and spectroscopy problems that appeared in the chapters after it was introduced. Problems that didn't fit into any of the previous categories were classified as either lower-order "drill" (LOD) problems, or higher-order

conceptual (HOC) problems (Table 3.2). A majority of the problems included multiple sub-problems which were individually coded and classified.

In addition to problem types, the books were also evaluated based on the number of worked-out example problems contained in the text, number of problems that contained answers in the back of the book, and total extraneous distractors. An extraneous distractor was defined as anything that could potentially distract the reader from the text, such as an icon, interest box, or anything that one could skip over if they were reading the text verbatim. An item was not counted as extraneous if it served to reinforce the material in the actual text or gave students a concrete representation of what was being discussed. Tables of data were not counted as extraneous either. To quantify the amount of extraneous material, we calculated the average occurrence of extraneous items in the book per chapter.

To ensure the reliability of our classification system, an inter-rater reliability analysis was conducted. The problem definitions were developed by the researcher and shared with two of his faculty advisors. The researcher did all of the original classifying in the texts; and to check reliability, the 2 faculty advisors looked at the aldol reaction chapters from four randomly selected textbooks. The results were compared and the inter-raters agreed with 82% accuracy. The primary differences came from the synthesis category, where some of the problems were classified as drill problems since they were only one step. So the definition was revised to include synthesis problems that were any number of steps in the synthesis category. After modifying the scheme, the inter-rater procedure was repeated with four different randomly selected textbooks and the amine chapter. Accuracy improved from 82% to 91%.

Table 3.2. Problem Classification, Definitions, and Examples

Category	Definition	Examples from textbooks
Lower Order "Drill" (LOD)	Problems primarily testing recall of information, commonly known as drill and practice problems. Problems that are designed to reinforce concepts.	Provide a name for the following molecule... What is the product of the following reaction..., Rank the following compounds in terms of reactivity in an S_N2 reaction...
Higher Order Conceptual (HOC)	Problems that test students' higher-order thinking skills or require multiple thought steps to solve. Requires students to think about a given reaction rather than simply recalling different aspects of it. This category does not include mechanism or synthesis problems which also require higher order thinking skills.	Explain why butyl lithium is an effective base for converting alkynes to acetylide anions.
Mechanism	Problems asking students to explain a reaction with a mechanism, or propose a mechanism for a given transformation using the arrow pushing formalism.	Draw a step-wise mechanism for the following reaction...
Synthesis	Problems asking students to propose a synthesis of a target molecule from given starting materials and any other reagents. Retrosynthesis problems (problems that ask students to work backwards from a target molecule to establish possible starting materials) were also included in this category. One-step synthesis problems were classified under this category as well.	Synthesize the above molecule from the given starting materials...

Table 3.2. cont.

Spectroscopy post-chapter	Problems involving spectroscopy (IR, NMR, MS or UV-VIS) which are not present in the spectroscopy chapter. Problems in the spectroscopy chapter were classified under either drill or higher order.	Establish a structure based on the given spectral data...
Problems with answers	Problems which have answers in the back of the textbook.	
Examples	Problems worked-out in the chapter, above and beyond what is in the discussion in the text.	

A Brief History of Organic Chemistry Textbooks

Before Morrison & Boyd, textbooks covered the chemistry of the various functional groups, showed their reactions and paid little to no attention to mechanisms. When Morrison & Boyd wrote their book, they took the accepted functional group format and added mechanistic details. This approach revolutionized organic chemistry textbooks, and is still used in the majority of textbooks today.¹⁹

The 13 books we analyzed are shown in table 3.3. All of the books used in the analysis were those cited in the survey that we were able to obtain a copy of from the publishers. They represented most publishing companies and included the texts used by 90% of the respondents in our earlier survey. They ranged in price from \$112.95 USD to \$228.95.

Organization

Most of these books follow the accepted functional group organization. The two exceptions are Fox & Whitesell²⁰ and Clayden et al.²¹ which both follow a more mechanistic approach.

Another aspect of how a book is organized is what reactions students are introduced to first. The first reaction introduced in each of the books included: radical reactions, addition to alkenes, and substitution and elimination. Clayden et al. introduces carbonyl chemistry first and is the only textbook to use this approach.

Table 3.3. List of Textbooks Analyzed

Author(s)	Publisher	Edition Analyzed
William H. Brown, Christopher S. Foote, Brent L. Iverson, Eric V. Anslyn ²²	Brooks/Cole	5 th
Paula Y. Bruice ²³	Prentice Hall	5 th
Francis A. Carey ²⁴	McGraw Hill	7 th
Jonathan Clayden, Nick Greeves, Stuart Warren & Peter Wothers ²¹	Oxford	1 st
Mary A. Fox & James K. Whitesell ²⁰	Jones & Bartlett	3 rd
Joseph H. Hornback ²⁵	Brooks/Cole	2 nd
Maitland Jones ²⁶	W.W. Norton	3 rd
John McMurry ²⁷	Brooks/Cole	7 th
Robert T. Morrison & Robert N. Boyd ²⁸	Prentice Hall	6 th
Janice Smith ²⁹	McGraw Hill	2 nd
T. Graham Solomons & Craig B. Fryhle ³⁰	John H. Wiley & Sons	9 th
Peter K.C. Vollhardt & Neil B. Schore ³¹	W.H. Freeman	5 th
L.G. "Skip" Wade ³²	Prentice Hall	7 th

In our survey, professors noted they wanted to see spectroscopy introduced earlier in the text and integrated throughout the whole book. With the exception of Solomons & Fryhle and Clayden et al., textbooks introduce spectroscopy in the middle of the book. Solomons covers IR in chapter 3 and carbon-13 NMR in chapter 4; Clayden et al. introduces IR and MS and introduces NMR in chapter 3, covers NMR in more depth in chapter 11, and covers spectroscopy in more depth in chapters 15 and 32. Overall, 11 of the 13 books use a functional group organization and introduce spectroscopy in the middle of the book. Clayden et al. is an exception to both of these cases. Generally, it appears books have stayed close to the organizational approach used by Morrison & Boyd.

Results

Table 3.4 shows the full results of our textbook analysis with respect to problem types. We looked at problems in two ways: the total number and percentage of problems of a particular type in a book.

Table 3.4. The Number (percent) of Questions by Problem Type in the 13 Textbooks

Book	Total LOD	Total HOC	Total mechanism	Total synthesis	Total "other" ¹
McMurry (<i>N</i> = 3870)	2203 (57)	631 (16.3)	280 (7.2)	628 (16.2)	0
Bruice (<i>N</i> = 4825)	3069 (63.6)	899 (18.6)	207 (4.3)	606 (12.5)	0
Wade (<i>N</i> = 5512)	3092 (56)	632 (11.5)	389 (7.1)	776 (14.1)	527 (9.6)
Carey (<i>N</i> = 3362)	2002 (59.4)	510 (15.2)	129 (3.84)	487 (14.5)	176 (5.2)
Vollhardt & Schore (<i>N</i> = 4270)	2522 (59)	614 (14.4)	248 (5.8)	471 (11)	331 (7.8)
Solomons & Fryhle (<i>N</i> = 3658)	1895 (52)	643 (17.6)	166 (4.5)	746 (20.4)	256 (7)
Smith (<i>N</i> = 5775)	4100 (71)	571(10)	183 (3)	810 (14)	0
Brown et al. (<i>N</i> = 3844)	2271 (59)	570 (15)	199 (5)	763 (20)	0
Hornback (<i>N</i> = 3551)	2094 (59)	600 (17)	221 (6)	478 (14)	131 (4)
Jones (<i>N</i> = 2430)	1176 (48)	558 (23)	352 (14)	242 (10)	0

Table 3.4. cont.

Book	Total LOD	Total HOC	Total mechanism	Total synthesis	Total "other" ¹
Morrison & Boyd (<i>N</i> = 5040)	2689 (53)	1265 (25)	215 (4)	772 (15)	0
Fox & Whitesell (<i>N</i> = 3100)	1847 (60)	572 (18)	217 (7)	415 (13)	0
Clayden et al. (<i>N</i> = 1617)	283 (18)	611 (38)	481 (30)	212 (13)	0

1. Wade contains definition problems, Solomons & Fryhle contain learning group problems, Vollhardt & Schore and Carey both contain MCAT practice problems. Hornback contains problems requiring an internet connection.

Smith had the most total overall problems with 5775, followed closely by Wade with 5512. Bruice was next with 4825 and Vollhardt & Schore had 4270 problems. Clayden et al. had the fewest number with 1617. The average number of problems in the books analyzed was 3979. Figure 3.1 shows the number of questions in each textbook. In all of the figures, the books are listed from left to right based on popularity.

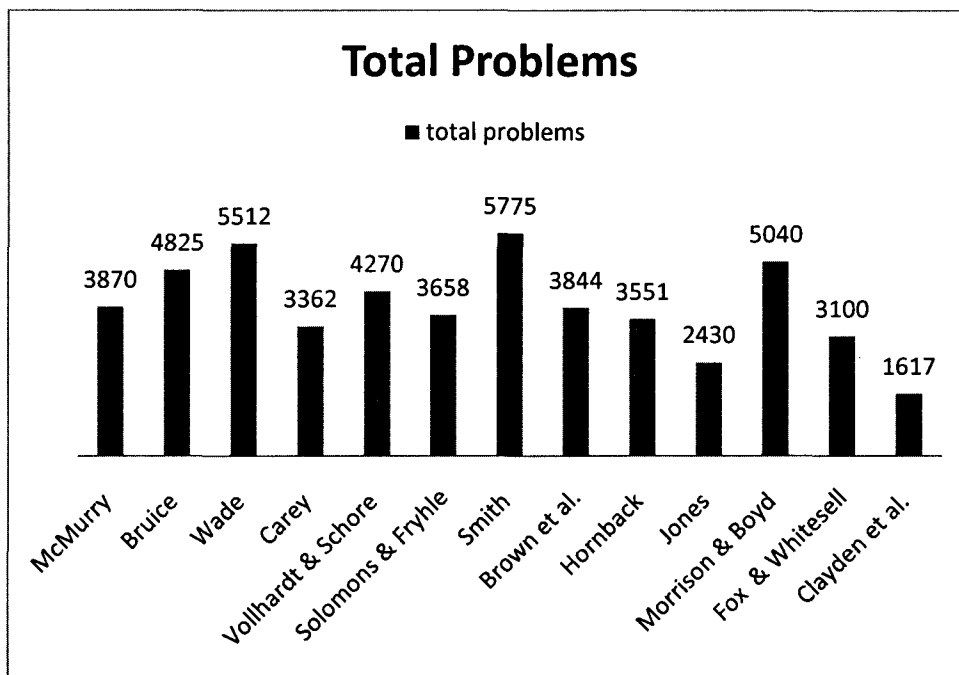


Figure 3.1. Total Number of Problems in each Textbook Analyzed

Smith's book had by far the most lower order drill problems (LOD) with 4100; the next closest was Wade with 3092. It is interesting to note that Smith had more LOD problems than the total number of questions in some other books. In terms of percentages, Smith was the leader with 71% of the problems being LOD followed by Bruice with 64%. Clayden et al. had the fewest LOD problems with 283, and also the lowest percentage with 18%. With the exception of Clayden et al.'s text and Maitland Jones, all books have 50% or more of their problems belonging to the LOD category (Figure 3.2).

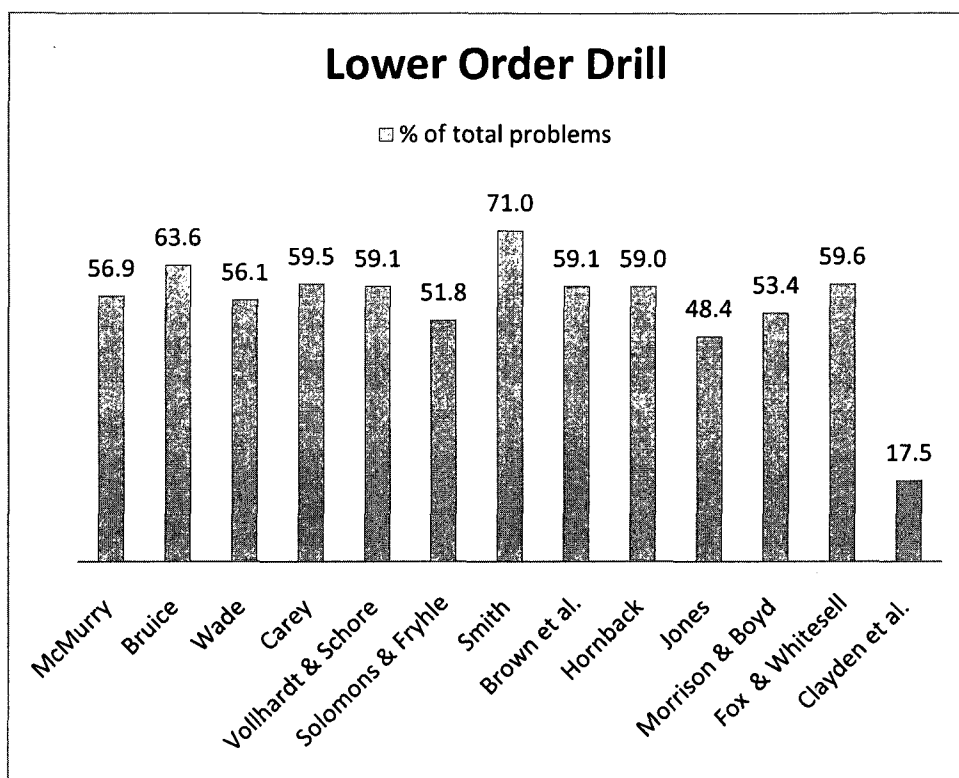


Figure 3.2. Percentage of Lower Order Drill Problems by Textbook

Morrison and Boyd, last printed in 1994, had the most higher order conceptual (HOC) problems with 1265 followed by Bruice with 899. The other texts analyzed had similar numbers of HOC to each other. In terms of percentages, Clayden et al. contained significantly more HOC with 38% of its problems. Morrison & Boyd and Jones contained the next highest percentages with 25 and 23% respectively. The rest of the books contained between 10 and 18% of their problems devoted to HOC (Figure 3.3).

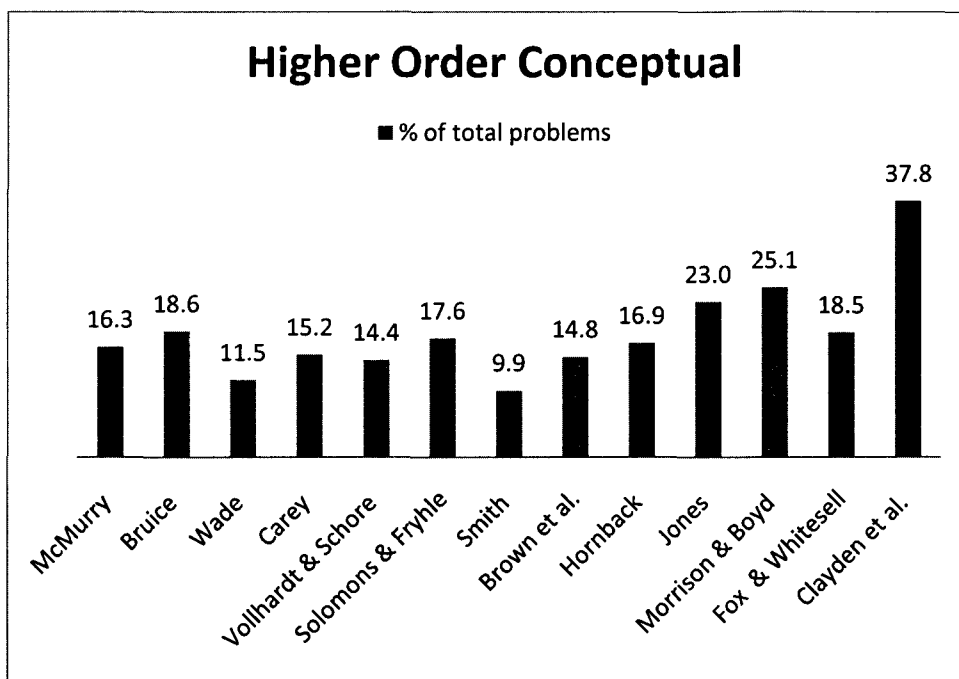


Figure 3.3. Percentage of Higher Order Conceptual Problems by Textbook

Clayden et al. had both the highest number and highest percentage of mechanism problems with 481 and 30%, respectively. Jones had the next highest number and percentage with 352 and 14%. The other texts analyzed had similar numbers and percentages of mechanism problems, ranging from 3 to 7% (Figure 3.4).

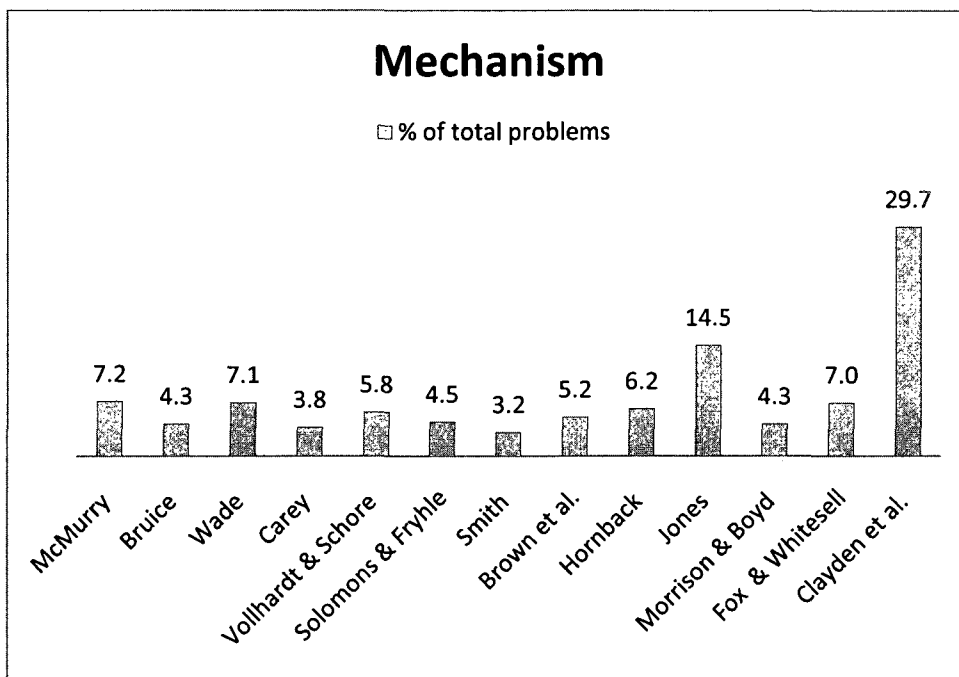


Figure 3.4. Percentage of Mechanism Problems by Textbook

Smith had the highest number of organic synthesis problems with 810 followed by Wade (776), Morrison & Boyd (772) and Brown et al. (763). Brown et al. and Solomons & Fryhle both had the highest percentage of organic synthesis problems with 20% followed by McMurry with 16%. Jones contained the lowest percentage of organic synthesis problems with 10%. Other books analyzed had 11-15% of their total problems devoted to organic synthesis (Figure 3.5).

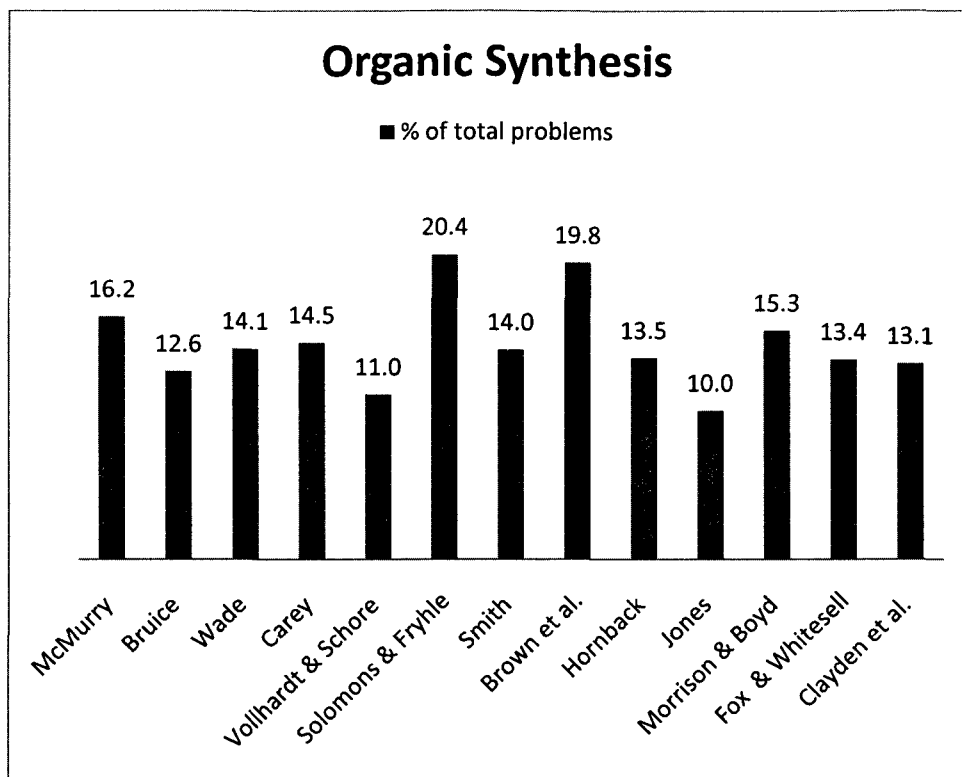


Figure 3.5. Percentage of Organic Synthesis Problems by Textbook

Solomons & Fryhle had the most post-chapter spectroscopy problems with 167, followed by Vollhardt & Schore with 157, Smith with 111, and Jones with 102.

Generally, all books contained roughly the same percentage of total, ranging from less than 1 to 5% (Figure 3.6).

While the professors in the survey were concerned about spectroscopy problems appearing in subsequent chapters after they were introduced, we also decided to look at spectroscopy problems in the entire book to obtain a more complete picture of the state of spectroscopy in organic chemistry textbooks. Table 3.5 shows the location and number of spectroscopy chapters, the number of problems contained in these spectroscopy

chapters, and the number of spectroscopy problems located in chapters following the introduction of spectroscopy. With the exception of Solomons & Fryhle, Fox & Whitesell, and Clayden et al., all books introduced spectroscopy in the middle. In terms of spectroscopy problems in the whole book, Vollhardt & Schore contains the most problems with 508 and Solomons & Fryhle is next with 422, followed by Bruice with 412. Vollhardt & Schore and Solomons & Fryhle contain roughly the same percent of total spectroscopy problems (11.8% and 11.5%, respectively) followed by Jones with 10.3% and McMurry with 9.9% (Table 3.5).

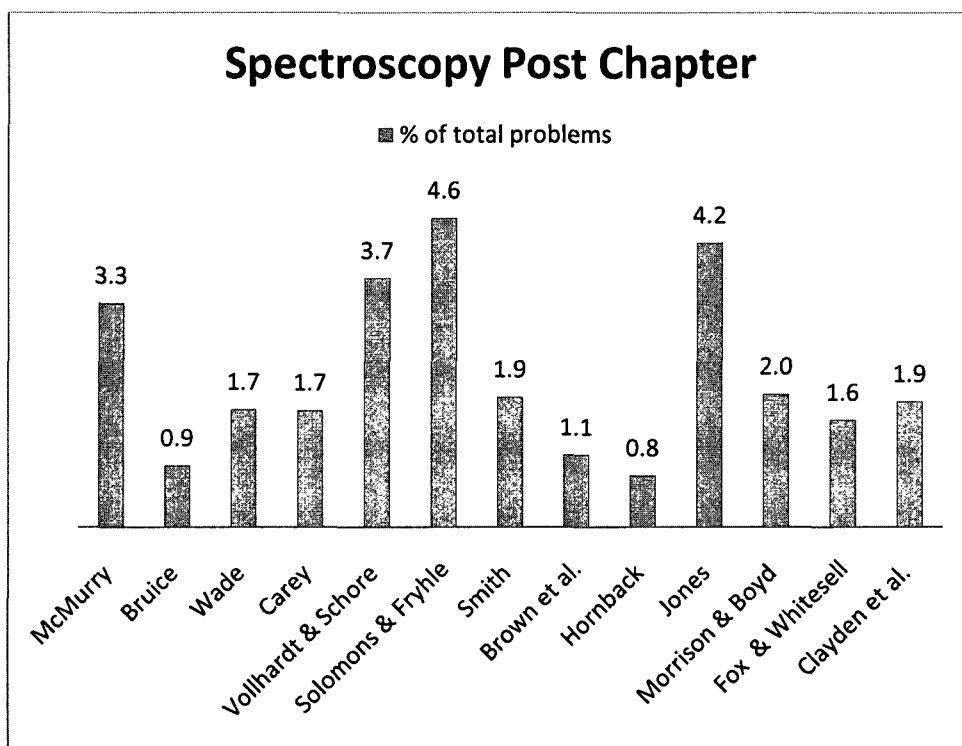


Figure 3.6. Percentage of Spectroscopy Problems Post-Chapter by Textbook

Table 3.5. Spectroscopy Chapter Locations and Number of Problems (percentages) Located in and Outside the Spectroscopy Chapter

Book	Spectroscopy chapter locations	Spectroscopy problems in-chapter(s)	Spectroscopy problems in chapters after spectroscopy	Total
McMurry	12,13	257	128 (3.3)	385 (9.9)
Bruice	12, 13	368	44 (<1)	412 (8.5)
Wade	12, 13	261	96 (1.74)	357 (6.5)
Carey	13	123	58 (1.72)	181 (5.4)
Vollhardt & Schore	10, 11	351	157 (3.6)	508 (11.8)
Solomons & Fryhle	3, 4, 9	255	167 (4.5)	422 (11.5)
Smith	13,14	297	111 (2)	408 (7.1)
Brown et al.	12,13,14	178	41 (<1)	219 (5.7)
Hornback	13,14,15	213	27 (<1)	240 (6.8)
Jones	3,15	149	102 (4)	251 (10.3)
Morrison & Boyd	17	192	99 (2)	291 (5.8)
Fox & Whitesell	4	149	49 (2)	198 (6.4)
Clayden et al.	3, 11, 15, 32	92	30 (2)	122 (7.5)

Values of Students

An informal survey of 275 organic students at our institution revealed that they valued example problems and problems that have answers in the back of the book. As a result, this feature was included in our analysis. The analysis revealed that Brown et al. contained the highest average of example problems with 16 per chapter. They usually had some examples followed immediately by practice problems to help reinforce the concepts being taught. In each chapter, there is an average of almost one example for

every practice problem. Vollhardt & Schore, Bruice and Jones were next with 7 examples per chapter (Table 3.6).

When problems with answers in the back of the book were quantified, Vollhardt & Schore had the most with 71%. Bruice was next with 51% of total problems containing answers in the back of the book, followed by Morrison & Boyd with 47% (Table 3.6).

Table 3.6. Examples, Problems with Answers and Extraneous per Chapter by Textbook

Book	Example Problems/chapter	Percentage of problems w/ in-text answers	Extraneous/chapter
McMurry	3.52	30	9.7
Bruice	6.87	51	33.3
Wade	5.31	27	14.5
Carey	3.52	0	16.7
Vollhardt & Schore	6.93	71	16.4
Solomon's & Fryhle	2.24	17	11.2
Smith	6.1	0	16.5
Brown et al.	16	0	19.2
Hornback	3.8	43	10.7
Jones	6.7	0	19.3

Table 3.6. cont.

Book	Example Problems/chapter	Percentage of problems w/ in-text answers	Extraneous/chapter
Morrison & Boyd	0	47	0
Fox & Whitesell	0	0	13.08
Clayden et al.	0	0	26.3

Extraneous Material

Since a large number of respondents in our survey mentioned that books over-used graphics and color, the textbooks were analyzed for how much “extraneous material” they contained. This was defined as anything that could easily be skipped over when reading the main text without losing meaning. Bruice’s book had the most extraneous material with 33.3 instances per chapter. It contains many biographies of famous scientists and stories about the discoveries. The next highest book was Clayden et al. with 26.3 instances per chapter (Table 3.6). Clayden et al. uses boxes for many things other than interest topics such as margin notes, and key concepts. We are not suggesting that extraneous material is a problem; we were merely analyzing to see how often it occurs based on the discussion of the survey respondents.

Statistical Analysis

As a means of comparing the books statistically, chi square analysis was conducted using an alpha-level of 0.05. The chi square analysis revealed that there is a statistically significant difference in the way the problem types were distributed in the books analyzed: $\chi^2(48) = 4015.5, p < 0.0001$. The problems classified as “other” were not included in our chi-square calculation as the amount ranged from 4-9% of total problems and not all books contained problems classified as “other”. A test of standardized residuals was conducted to investigate the ways in which the books differed from the calculated expected values for each category analyzed. These differences included:

- McMurry contains more synthesis and spectroscopy problems
- Bruice contains more drill, and fewer mechanism, synthesis and spectroscopy problems
- Wade contains fewer lower order, HOC, and spectroscopy problems
- Carey contains fewer HOC and mechanism problems
- Vollhardt & Schore contains fewer HOC, and synthesis problems, and more spectroscopy problems
- Solomons & Fryhle contains fewer lower order and mechanism problems, and more synthesis and spectroscopy problems
- Brown et al. contains fewer HOC, mechanism, and spectroscopy problems and more synthesis problems
- Clayden et al. contains fewer lower order, mechanism, synthesis and spectroscopy problems

- Smith contains more lower order and fewer HOC and mechanism problems
- Morrison & Boyd contains fewer lower order and mechanism problems, and more HOC problems
- Hornback contains fewer synthesis and spectroscopy problems
- Fox & Whitesell contains fewer synthesis and spectroscopy problems
- Jones contains fewer lower order and synthesis problems, and more HOC, mechanism and spectroscopy problems.

Pair-wise comparisons were performed to see if there were statistically significant differences between individual books; a family-wise alpha level of 0.0005 was used on all tests. We chose this lower p-value to avoid making a type one error. The analysis revealed that all books were statistically different with the exception of Jones and Hornback ($\chi^2(4) = 11.32, p = 0.0232$).

Discussion

There is a notion held by many that all organic textbooks are the same and that books are interchangeable. After performing this analysis, we determined that this notion was false and the books are statistically different with respect to problem type and frequency of occurrence. If one looks at newer textbooks, it appears that more emphasis is being placed on LOD and practice than on conceptual understanding. This is observed with the increase in LOD problems and a decrease in HOC in the modern books compared to Morrison & Boyd.

First published in the 1950s and now out of print, Morrison & Boyd has a higher percentage of HOC problems than all but one of the books analyzed (Clayden et al. with 38%, which is the only book used predominantly outside the US). In terms of other categories, it has a comparable percentage of mechanism problems to the other books (again Jones is higher with 14%). Morrison & Boyd does however contain a smaller percentage of synthesis than the modern books. A test of chi-squared standardized residuals was conducted to examine how the modern books differ statistically from Morrison & Boyd. The analysis found that Morrison & Boyd contained fewer LOD problems than most of the books analyzed. Clayden et al., Solomons & Fryhle, and Jones which all contained more LOD problems were the only exceptions. Morrison & Boyd also contained statistically more HOC problems than every book analyzed except Clayden et al., which was not statistically different. With the exception of Carey and Smith which contained statistically more mechanism problems than Morrison & Boyd, the other books analyzed all contained statistically fewer mechanism problems. McMurry, Wade, Solomons & Fryhle, and Brown et al. all contained statistically fewer synthesis problems than Morrison & Boyd, while the other books analyzed statistically more synthesis problems. Generally speaking, the focus of the majority of modern books has shifted to lower order drill problems and synthesis problems and away from HOC and mechanisms.

For a book comparable to Morrison & Boyd in terms of LOD and HOC problems, Jones, which is now known as Jones & Fleming³³, is the closest. The only differences are that Jones contains more mechanism and synthesis problems. Jones maintains the advanced tone and focus of Morrison and Boyd, yet still has a reasonable amount of

lower order problems so students can practice the basic material and gain a deeper understanding of it through HOC questions.

Conclusions

Based on this data, it appears that the emphasis of at least the majority of American texts has shifted away from higher order conceptual problems and more to lower level thinking and synthesis problems (which can require either lower or higher order thinking depending on the number of steps they contain). Since many students are taking organic chemistry as part of pre-professional programs, the books are trying to cater to the interests of these students by adding content that shows how organic chemistry is related to the health professions. Two of the books, Carey and Vollhardt & Schore, have added MCAT practice questions. Brooks/Cole has even published a textbook that is marketed towards classes for pre-health majors and tries to look at organic chemistry from a biological angle: Organic Chemistry: A Biological Approach by John McMurry³⁴ which is in its second edition. While it was not fully analyzed, it does not appear to differ too much from McMurry's original organic chemistry textbook.

Our analysis primarily focused on problems, examples, extraneous materials, and problems with answers in the back of the book. While problems are one aspect of a textbook professors look at, another aspect is readability. Indeed, to some, readability is more important than problems, since a professor wants to make sure his or her students will read and benefit from the book he or she selects. Given the high cost of books, this analysis will allow professors to evaluate if the book they have chosen is useful for their

students. Other equally important aspects of books that could be evaluated in the future include: sources of misconceptions, content errors, cost, physical size, ancillaries, integrations with technology, and the number of changes between editions to name a few.

This study provides a snapshot of organic textbooks in relation to the characteristics valued by professors. The present work reveals that textbooks are different in terms of distribution of problem types which might be helpful for professors and departments as they go through the textbook selection process. This analysis provides a basis for what books a professor could select based on what they value and the needs of their students. If you value a large amount of drill and practice problems for your students, Smith would be a good choice. Solomons & Fryhle would be a good choice for the professor who values synthesis problems, an early introduction of spectroscopy, and its integration throughout the whole text. If one values examples for students and synthesis problems, Brown et al. would be a good choice. Vollhardt & Schore would be a good choice for professors who value a good number of spectroscopy problems and problems with answers in the back of the book. Clayden et al. and Jones are good choices for a more advanced book that contains many HOC and mechanism problems. As can be seen from the analysis, a professor can find a book that fits reasonably well for their course based on what type of problems and learning he or she values. Still, to effectively choose a book, a professor needs to know the needs of their students and what they hope to accomplish.

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Chapter 4. Conclusions and Future Research Directions

Conclusions

The purpose of the survey was to catalogue what organic chemistry professors believe is the core material for the year long organic chemistry course found at most institutions. In addition, the professors were asked to make suggestions for textbook improvements. We found that professors typically tend to change texts every 4 years, about the same length of time it takes publishers to release new editions. Professors identified eight areas of organic chemistry that they believe constitute the core material including: electrophilic aromatic substitution, the Grignard reaction, other organometallic reactions, amines, the Diels-Alder reaction, protecting groups, free radical reactions, and IR spectroscopy. Additionally, in the open ended section a few themes emerged: books are too expensive, they need to be shortened somehow, and respondents had suggestions about ways to reorganize the book and would like to see it switched from the current functional group organizational pattern to a more mechanistic approach. Lastly, respondents felt that something needed to be done with the problems such as adding more, or adjusting the difficulty of the existing problems.

This study provides a snapshot of organic textbooks in relation to the characteristics valued by professors. The present work reveals that textbooks are different in terms of distribution of problem types which might be helpful for professors and departments as they go through the textbook selection process.

The organic chemistry survey and textbook analysis gave us some insight into what material professors think is important, what changes they would make to textbooks if they were so enabled, and how the problems in organic textbooks are distributed. Like many survey studies, these data provide more questions than answers. It is hoped that chemistry departments are able to take this information and use it to make more informed decisions about what textbook they select for their students. Also, textbook publishers have already taken this information and are using it to improve the way their books are marketed. In addition to using it to market their books, the present work would be useful to them to help change their books so they line-up better with what professors want. An author (or publisher) could use this information to make their book different from the other books on the market. The present work is the only work on organic textbooks and there is still much work that can be done.

Future Research Directions

According to the textbook analysis, modern books have a different emphasis with respect to problems than the classic Morrison & Boyd text. It would be interesting to obtain out-of-print textbooks from the time of Morrison & Boyd (such as Cram & Hammond) and compare them to both Morrison & Boyd and modern organic textbooks. An analysis of this nature would allow us to see how similar or different Morrison & Boyd was to the other books of its era. It would also allow us to make more comparisons between older and newer textbooks.

It would be interesting to look longitudinally at the multiple editions of the same text to see exactly what they contained in the past and what they contain at present. Such an analysis would reveal differences between older and newer editions of the books and

show when (or if) the books started to emphasize more drill and practice problems at the expense of higher order conceptual problems. Also, if we were able to analyze subsequent editions of multiple textbooks, we could see if the changes in these books are similar and if they happened at about the same time. The changes might then be correlated to what was happening in educational theory at that time or what was taking place in the chemistry market place over the same time span. By evaluating the books over time and correlating them with education theory and practice and the happenings in the chemistry marketplace, we could then start to obtain a better picture of what was driving any changes in the textbooks.

One of the things that jumped out repeatedly was how different Clayden et al. was from the other books analyzed. To date, the differences between foreign and domestic textbooks have not been evaluated. It would be insightful to administer this survey to professors in other countries to find out what they feel is core material, what textbooks they use, and what changes they would make to textbooks if they were able. From this work, we could find out what books are used and obtain English translations (if needed) of the most popular foreign textbooks and analyze them in the same manner as our analysis of domestic textbooks. Performing our survey and an analysis of foreign textbooks could give us insight into what those professors think is important and any differences between foreign and domestic textbooks.

The present textbook analysis categorized the questions as mechanism, organic synthesis, spectroscopy post chapter, lower order drill, and higher order conceptual. However, the questions in the mechanism, synthesis, and spectroscopy categories could be further classified as lower order or higher order based on Bloom's taxonomy. Such a

project would allow the varying difficulty of the problems to be clarified. It would allow for a detailed comparison between the number of higher order and lower order problems in each category between textbooks instead of just stating that there are a certain number of each type of problem per textbook. Using both our present classification system and Bloom's taxonomy would allow a more detailed comparison of the textbooks and allow professors using the information to make an even more informed decision about what book they select. It would also provide more data on the difficulty of the problems overall.

How do the questions on standardized tests in organic chemistry compare to those in textbooks? It would be informative to obtain the first semester ACS organic exam, the year-long organic chemistry exam, and possibly the DUCK exam and compare the proportions of problems on the exams to those found in the textbooks. The study would show if the level of problems on exams is similar to the level of problems found in the textbooks, and would show which textbooks were aligned with the questions on the ACS standardized tests. In addition to studying the ACS exams, one could also evaluate professional school tests such as the MCAT and PCAT and perhaps review materials from test preparation companies like Kaplan or Princeton Review.

Most publishers currently seem more interested in developing and "selling" their ancillaries, many of which are online. It would be interesting to analyze the problems contained in these online resources based on problem types. After establishing the make-up of the ancillaries, a possible future project would be to evaluate whether or not all of these elaborate online learning resources have any effect on student learning. Any information about these online ancillaries and their effectiveness will help professors

make a more informed decision about what textbook they choose to use. Because the textbook being used influences what is taught and how students learn, it is important to select one that will meet the needs of both the students and the professor teaching the course. This work, and the proposed future work, could go a long way in helping departments select textbooks for their courses, and helping publishers improve their textbooks.

Appendices

Appendix A

Professors' Full Written Comments

1. include only what is possible to cover in a normal (not accelerated, honors) course in 2 semesters - there is too much information in organic texts

3. Make them smaller; they have gotten so large that it becomes impossible to get through it all. Moreover I think many of the problems in the books are too advanced. This leads to confusion with the students. In short. More isn't always more. Sometimes less is more.

4. I would like to see a greater amount of emphasis placed on organometallic chemistry. An introductory section on these compounds (as is found in one of Solomons/Frhylye's 'Special Topics' sections) would be quite useful.

5. Stop the functional group approaches.

6. Don't do new editions so often.

7. Cover stereochemistry earlier. It is currently placed as Chapter 7. Ideally, it should be right after conformational analysis

8. Base them on a mechanistic approach rather than functional group

9. 1. Have more problems 2. Show more arrow pushing 3. Show more natural products 4. 10. shorter more biological

11. I would definitely change the order of presentation of the topics from the traditional "Morrison and Boyd" approach that has dominated the field throughout my career. The addition reaction would be the first important focus of organic reactivity--not the SN2 substitution/E2 elimination conundrum that frequently serves as the students' introduction to organic reactivity. The addition reactions to alkenes, epoxides, and many carbonyl compounds should be the unifying theme. Unsaturation begets reactivity. Oxidations and reductions are the next most important reactions followed by substitution/elimination. The reason that substitution/elimination should be considered later in the course is that the theory is not well supported by the facts. After years of trying to explain why secondary alkyl halide sometimes give substitutions and other times eliminations, I have come to hate the topic. Putting this topic so early "poisons the well" of student interest. If things are this complicated, why am I supposed to know this? The addition reaction is simple; as I tell my students $1+1=1$ (in terms of the numbers of molecules involved). Why not start with something simple and predictable to give the students some confidence in the electronic theory and later work in the more complicated cases?

12. define concepts clearly and provide several examples

13. Get rid of the biochem stuff to leave more room for pure organic chemistry that has been deleted over the years to make room for the biochem stuff. Organic chemistry is NOT biochemistry! Most schools have a biochem course to cover this stuff. There is more to organic than applications to biology/biochem. Not everyone in the course is a pre-med!

14. Better ancillaries, ie easier to use and more useful

15. Order of topics

16. To organize the book introducing "structure" and the ways of knowing structure first which means putting spectroscopy up front. Then move into "function" which would include mechanisms and reactions that would lead to synthesis.

18. Simplify SN1 and SN2 just a bit so students can understand it better overall.

19. More emphasis on Organic Qualitative Analysis with major emphasis in Lab Techniques

20. I think we all understand that organic textbooks have more material than can be covered in two semesters. I think it would be impossible to get a consensus on what not to include in the textbook. Therefore, under the circumstances most organic textbooks are fine and it's up to the instructor to decide what not to cover. I can't think of a way to change that.

21. There is nothing I would change.

22. Include carbonyl chemistry in the first semester

23. More reader friendly

24. They have become too busy, with too many competing sidebars and unnecessary color graphics; they should be visually simpler

25. Have a longer period for expiration of editions. I will not consider any book with less than four years between new editions.

26. I would like to see more synthesis problems as well as a stronger emphasis placed on mechanisms.

27. Talk about spectroscopy earlier before getting into functional groups. Include guides to help with synthesis. "Between chapter" synthesis sections to help the students put together all the reactions learned

28. Approach to nomenclature

29. Cover spectroscopy earlier.

30. I would move the spectroscopy chapter to earlier in the text.

31. The order that material is presented in. I can never understand why textbooks choose to present stereochemistry after reactions have already been presented. Stereochemistry should be discussed before any reactions that are stereospecific are discussed. I prefer to discuss all organic structure material before starting reactions

32. More empirical results, not just theory.

34. More examples connecting organic chemistry to the real world (i.e. biology, medicine, materials science)

35. more rearrangements

36. 1) There should be some organic photochemistry 2) The Moebius-Hueckel alternative to the W-H many rules is needed 3) The Frost-Musulin mnemonic needs detailing 4) A little MO theory would not hurt 5) Text-book errors need better checking 6) The Hammond Postulate needs presentation 7) A simple presentation of carbonyl excited state structure would help

37. Better chapter end practice problems.

38. Make them smaller and cheaper

39. I would give them much more bio-organic focus.

40. Not have ALL the problems answered in a "study guide" or the text so that homework problems would force the students to study and to think and apply what they have seen,

rather than just copy the answers blindly with no real value to their learning. As it is today, we can get this ONLINE type of homework but not in the standard text(s). We need both.

42. Lower the price. They are too expensive!

43. Alter the order in which reactions are taught to promote understanding rather than memorization. Increase emphasis on bioorganic chemistry.

44. Organized by reaction type, not by functional group.

45. Length

46. More intermediate and advanced problems. More integrated problems. More synthesis problems. More problems.

47. Add more challenging homework problems

48. The sequencing and logical organization of topics. Because most books are focused on the functional group approach, there is little or no linkage of similar or complementary topics or linkage of common mechanistic themes. This produces books that are segmented and illogical. All the major reaction topics should be given detailed treatment drawing on fundamental concepts, but many of the other topics are not that important other than they are covered on ACS exams, MCATS's, etc and the students need to at least see them. I would love to see books that take ideas such as SN2 reactions and at least show that enolate alkylations and amine alkylations are part of SN2 chemistry in the initial chapter. For example, because amine alkylations are not covered until the "amine chapter" much later in the year, the true Hofmann elimination of quaternary ammonium ions can't be covered with the Zaitzeff eliminations so the distinction of the two is not made clear (most books slide over Hofmann eliminations in the early chapter on eliminations just using a bulky base such as t-butoxide which misses the mark. Other areas where there is little or no linkage is in reactions that involve resonance stabilized carbocations of the R_2C^+-X type where the lone pair on the heteroatom stabilizes the C^+ . This is part of pinacol reactions, acetals, carboxyl reactions, etc. Its one mechanism with several variations. This commonality is not clearly pointed out in most books. A third example that is not clear is the difference in conditions required to form an acylium ion for a Friedel Crafts acylation vs the addition-elimination of a carboxyl reacton such as esterification. In many texts, aromatic chemistry is covered first and carbonyl/carboxyl chemistry is much later. So, since students have seen the acylium ion for the F-C reaction, they automatically use it when writing an esterification and the books do not point out clearly that the conditions for the two pathways are significantly different and that the acylium ion can only form under the very non-nucleophilic environment of the F-C reaction where the only nuc is the relatively unreactive benzene, compared to the highly nucleophilic environment of the acyl group that is swimming in nucleophiles (i.e. ROH). The commonalities of the nucleophilicity of an alcohol in an SN1 reaction vs an acyl transfer should be made clear to the students from the beginning. The compartmentalization of most books makes it very difficult to get these kinds of ideas across to students in lecture since they most still rely much more on the book for their studying than their class notes. The irony however is that I have seen that many of the very best students rely almost exclusively on their notes and rarely use the books because for them the books are filled with too much information that makes it harder for them to see the main mechanistic points. I have a number of specific criticisms of the

organization of the first 5 chapters in Wade as well that I won't discuss here. I have just retired after 25 years of teaching organic and am glad that I no longer have to deal with this issue. I have run out of ideas about how to get this complex but very logical subject across to the students.

49.No mention of functional groups until they are presented in full. In other words, if the alcohol proceeds the carbonyl chapter, then oxidation of alcohols is not presented until the latter chapter

50.I would make them shorter.

51.the text stresses the octet rule (and rightfully so) but it then violates this when dealing with compounds such as DMSO by giving the qualification that it can have an expanded octet due to empty "d" orbitals. I wish that the valid resonance form that is octet rule obeying is emphasized and used more instead of how it is handled. (Same applies for compounds like phosphine oxides)

52.Better explanations in Student Solutions Manuals.

53.Cost!!!! I'm changing To Daley & Daley next fall. The text is complete and best of all it is FREE! Look at it at www.ochem4free.info. It's a good text!

54.I would like to see amines presented earlier in a textbook since all of the major prescribed drugs contain an amine functional group. It is almost always the last chapter before the mandatory biochem sections.

55.I do change it as I wish since I write it.

56.I am very satisfied with McMurray

57.To develop a more active learning from the student rather than memorization. Another professor and I are working on conceptual change theory which holds some promise.

58.They should contain a more manageable set of topics that could be covered in the sophomore level course. Most books try to be "all things to all people". As a result one gets a monstrous textbook that is visually and mentally overwhelming to the "average" sophomore college student.

59.Better presentation/ readability

60.I would modernize the content.

61.Clear, straightforward, easy to read. Good, logical organization of topics.

63.Integration of organic chemistry with disciplines such as biology (some of the newer textbooks are doing a very good job of this, but I am the only one in my department that likes this approach, so for a multi-section course) we have to choose a textbook by consensus.

64.Overall, I would choose a more complete physical background for organic chemistry. I find that the "review" sections are largely inadequate, especially b/c most students have never seen molecular orbital (MO) theory before. I would also like to see more MO theory worked in throughout the sections on reactivity/reactions.

65.Clear description of proven ways to learn reactions, and clear description of proven ways to do retrosynthetic analysis. Earlier into to retrosynthetic analysis in a way that demonstrates to students that they can in fact master it.

66.More data! More original literature!

67.Make them more mechanistically organized. That's why we use Hornback.

68.Give more worked sample problems within the text.

- 69.No practical examples organic chemistry is a practical subject. If you can't make anything you're useless as an organic chemist!
- 70.less material; focus on most important topics and have more practice exercises
- 71.Cheaper Better integration of molecular models (computer & plastic) More environmental/green content
- 72.Add a Suzuki coupling. Add a reaction of alkyl lithiums with carbonyls - possibly replacing copper-lithium reagents.
- 73.I would bring in spectroscopy gradually over the course of the first semester. I would introduce ideas from Gen. Chem. on a just-in-time basis instead of all at the first couple of chapters.
- 74.to have as many problems as possible.
- 75.I like Bruice so far I would not have any comments
- 76.eliminate the wide margins and spacing that makes the books be longer and more daunting than they have to be
- 77.Make them shorter
- 78.Include more example reactions. Improve end-of-chapter summary. Provide study (flash) cards or other similar resource to help students memorize reaction types and conditions.
- 79.I would prefer to teach topics to their fullest rather than jumping around.
- 80.Not having a focus on functional groups but on the Big Ideas of Chemistry themes: http://chemistry.csuci.edu/big_ideas.htm
- 81.Having the free radical halogenation mechanism as the first mechanism they learn (which is common in most, but not all textbooks) is a mistake: this reaction and mechanism are unlike anything they will see in future chapters, and should be presented later as a "special case" - it's a bad introduction to mechanism.
- 82.Include references to web sites with animations and applications for as many topics or reactions as possible within the body of each chapter.
- 83.They would cost less!!
- 84.the cost to students and I would like to see an increase in online problem solving
- 85.Would introduce spectroscopy (IR/NMR/MS) very early - after the functional groups are introduced. In fact, using the Solomons text, after Ch 2 I skip ahead to Ch 9, the spectroscopy chapter. When I present Ch 3-8, I come up with my own spectroscopy probs. Our students have hands-on experience in the lab with acquiring H NMRs beginning in October; typically every lab involves acquiring/interpreting NMR spectra.
- 86.each textbook is different. This is a poorly formulated question. There are specific changes I would see for specific textbooks. For example, Smith doesn't introduce Grignards until the third quarter of the class: this is unfortunate, as it is a main method for C-C bond formation.
- 87.Include larger selection of more thought-provoking mechanism problems. Eliminate some of the traditional reactions that are not so important (such as OsO₄ hydroxylation), so as to make room for more biologically relevant material.
- 88.make them readable to students
- 89.There are many good texts out there. Bruice is a bit verbose and still has some errors.
- 90.Have them come out LESS frequently with new editions.
- 91.increase relevance to biological chemistry

92. Give more multiple choice questions at the end of the chapters. Add a chapter at the beginning of the book which tells how to learn organic chemistry, teaches about deductive reasoning, reasoning by analogy, etc. and makes the point that you can not learn organic chemistry by only memorization.
93. more examples
94. I really like McMurry and wouldn't change a thing except maybe the price students pay for it.
95. Easier to read. Convey concepts in a context interesting to young people
96. Make them less expensive
97. (a) Mechanistic organization as opposed to functional group approach (Hornback is ok with this, as is Bruice, which would be my preferred choice) (b) Problems that require mechanistic thinking as opposed to memorization (c) Introduction of retrosynthetic pathway (i.e. disconnection) for every new reaction whenever that reaction is introduced
98. I would put Spectroscopy at the beginning of the text to make lab more relevant.
99. Less fluff and more practice problems.
100. fewer reactions, more strategy
101. Eliminate all of the specialty chapters such as carbohydrates, amino acids, nucleic acids, pericyclic reactions, etc. that one never has time to cover.
102. Integrate NMR spectroscopy more into the text (after it is introduced)
103. There should be more diverse offerings available. It seems as though the textbook companies each want to follow what the other is doing. Books like Hornback and Fox/Whitesell offer a mechanistic approach. However, I would like to see more differences between Carey, Volhardt, Wade, Louden, Solomons, etc., so that instructors choosing between these texts would have more of a rainbow of choices using the functional group organization. This isn't likely to happen because all authors/publishers want to have the best seller.
104. less biochem and more medical applications
105. There are too many reagents for any one transformation, especially oxidations/reductions -- they should emphasize the concept over memorization of reagents.
106. I liked the way Pine was organized, namely carbonyl addition first and group by type of reaction rather than functional group.
107. I would like to see citations of original literature
108. More difficult problems!!!
109. A greater number of "organic unknown" spectroscopy problems in which students must assign identity based on elemental analysis, mass spectrum, IR, and ^1H NMR. It's hard to find problems that are suitable in difficulty.
110. More problems in each chapter for more practice for my students
111. lower the price; maybe make them online texts
112. that they stop coming out with new editions so frequently. so little changes with each new addition.
113. Integrate more biochemistry, as the interface between chemistry and biology is the future of chemistry departments.

114. The need to be more clearly written for the sophomore organic reader. Sometimes they are written too compactly and students have a difficult time reading it on their own. Also, the costs of these texts have gotten way out of hand.
115. begin with carbonyl reactivity as the first reaction chemistry
117. The fact that they update every 3 years. I don't see any advantage to the students except it cost them more money.
118. Too many new editions too quickly that have only superficial changes - we've been through 3-4 editions of Carey in about 6 years.
119. They are much better than they used to be. It is a good thing that quite a few good ones, using different styles, are available. The principal thing I would change is the price. Older, cheaper editions should be made available in quantity. Loose-leaf versions will be coming out I hear, but will they be cheaper?
120. Separate Organic I from Organic II and make the textbooks smaller.
121. Students always request more biological references to show more applied organic. Less focus on obscure reactions.
122. Less dumbing down.
123. I would shorten the length of the textbook. I think that 1,300 page textbooks are overwhelming. Janice Smith has a new organic text out on the market that is about 1,000 pages. My colleagues and I have discussed possibly changing to that text.
124. Include more modern reactions involving transition metal catalysis, etc.
125. More transition metal catalysis (2nd semester topic). Get to organic reactions more quickly - many are all structure for first half of semester 1. Postpone discussion of multi-step synthesis a few chapters, then explain more fully and at higher level.
126. Better questions at the end of the chapters
127. the inclusion of MO theory early
128. I would emphasize the acid-base character of organic reactions and connect to medical and living systems reactions as much as possible. That is why I am changing to Smith for Fall. Still not perfect in my mind, but closer to what my students need.
129. This is our first semester with Bruice. We used McMurry for several edition cycles...just got tired of it. But Bruice has turned out to be awful. Less material. More thought to having fewer and well designed end-of-chapter questions. Providing 60-90, whatever, isn't helpful. Also, easy-to-use on-line HW capability.
130. McMurry introduces ^{13}C NMR before it discusses proton NMR. That is a good approach -- I wish other textbooks would do so, as well.
131. more problems and more modern reactions
132. To have them entirely as PDF files so students would not have to lug around those heavy texts. (And neither would I.)
133. Better publisher-produced Powerpoint slides
134. Green chemistry is an approach to conducting chemical synthesis that takes into account issues of efficiency and safety. I would like to see more (or any!) green chemistry incorporated into organic textbooks.
135. I believe there is a niche for a text that covers the critical reactions needed in an introductory course. There is too much unnecessary information in most texts.
136. move away from Named reactions, toward redox and energy surface process explanations. ex, Wolff-Kishner is only one of a vast array of reductions CO to CH_2 (or

CHOH)but explaining reduction and energy requirements combined with modern reaction searching demo explains the "pathways" of ochem. students will need to be able to deconstruct the knowledge body to be our best future researchers.

137. More mechanisms and more interactive comparisons. Much less emphasis on rote learning.

138. I can't really comment what I'd change about organic chemistry books in general except that they are all SO expensive! Especially since the students also buy a solutions manual, a model set, a lab manual and lab notebooks. Specifically, I am very happy with the Carey textbook. The format is excellent and the students find it very readable (not the case with all books). They especially like the in-chapter sample problems (with worked solutions) and the way important mechanisms are highlighted and boxed. It has a good emphasis on mechanisms and theory behind why reactions occur the way they do. The end-of-chapter problems are also good (combination of naming, straight-forward reactions, synthesis, mechanisms, and theory. Spectroscopy problems are included as chapter problems in the latter half of the book). I also like how Carey introduces SN2/SN1/E2/E1 in a early chapter and re-visits the topic after the students have learned some stereochemistry. That is a novel approach that I hadn't seen before. The only problem I have with the book (and it's extremely minor) is that Carey makes a strong point about carbocation rearrangements in an early chapter, but the possibility of rearrangements is disregarded in solutions to problems in later chapters. Also, the 6th edition introduced Sharpless epoxidation (not discussed in the 5th ed)---but there is not really enough information (ex. about the mechanism) given in the chapter to be able to do the associated book problem. Again, a minor issue. I LOVE this text book and the students like it too.

139. I think they need to be modernized a little. That's one reason I chose Brown, Foote, and Iverson. They've included new and important reactions (Sharpless Epoxidation, Suzuki coupling, for example), and they place a smaller emphasis on reactions that just aren't used much anymore, but continue to be covered in orgo course for essentially historical reasons. I also think that authors of organic texts need to pay very close attention to the problems they include in their texts. There should be a comprehensive array of problems for all chapters, including routine drill type problems, and more challenging problems that involve critical thinking

140. answer some of the questions in the homework assignments.

141. I have many ideas here. The key ones are moving to mechanistic approach and changing the emphasis in the first semester to carbonyl chemistry. I will be implementing this new approach next fall with Bruice's book.

142. lower cost - possible online version at very low or no cost to student

143. Always put IR in the first or second chapter with functional groups.

144. 1. Increase the treatment of MO theory and cover it throughout the text as done in Maitland Jones 2. Have more texts with a biological emphasis as McMurry 3. Update descriptions of basic concepts to reflect current understanding e.g. source of hindered rotation of C-N bonds of amides, MO description of rotation of ethane, improved description of carboxylic acid acidity

145. improved coverage of pericyclic reactions

146. Introduce the carbonyl group a very early topic

147. work more on the fundamentals. students suffer from poor understanding of bonding and electronics.

148. there should be two different content for chemistry majors and others who have to take 2 semester organic chemistry.

149. Brevity is essential.

150. There needs to be more explanation of some nomenclature rules.

151. Regarding question 10, many of the items are unchecked for two reasons. First, we teach spectroscopy in a laboratory course associated with the lecture course. Second, I only teach first semester organic chemistry and many of the topics are in our second semester course. Regarding question 11, in general, the most important change I would make in organic texts is to have them more epistemologically based, i.e.

hypotheses/theories should be presented AFTER key experimental observations are described. There are many reasons for this. First, it is how science generally works, so to present it backwards gives student a false impression of what really happens. Second, it is much more interesting to ponder the meaning of experimental observations and to propose possible explanations (i.e. multiple hypotheses). This illustrates one of the underappreciated, creative aspects of science. As a result, the advantage of multiple hypotheses (what John R. Platt called "Strong Inference") becomes clear. Finally, it provides an opportunity for students to try to construct their own understanding of the chemical facts. Thus, they become actively engaged with the material.

152. Remove the chapters on Biochem (which belong in an introductory biochem course).

153. I would put NMR / IR / MS much earlier, after the first introduction to alkanes and cycloalkanes. This way, the spectroscopic information for each functional group could be introduced as each new functional group is introduced.

154. I am pretty happy with McMurry!

155. Less focus on detailed reactions and more focus on explaining how the reactions work.

156. I would add a section on Fischer projection structures to explain chirality.

157. More synthesis

158. No changes in the textbook

159. Make a wide range of difficulty level of the problems at the end of the chapters.

160. Less written explanation and more pictorial or bulleted information

161. Organizing the subject matter by functional groups is OK, but within each functional group framework, more stress should be placed on teaching reactions according to reaction types: redox, acid-base, addition, substitution, elimination, and isomerization.

Also, The order of concepts should follow a more logical order. Here's an example of "cart before the horse": Textbooks usually present aldehydes/ketones chapter before the chapter covering acyl-C substitution, and yet they describe ketone synthesis reactions that entail acyl-C substitution (or acyl-like C substitution): for instance (1) reaction of Corey-House reagent with acyl chlorides or (2) reaction of nitriles with Grignard reagent. Tue,

162. I would place the spectroscopy chapters right after stereochemistry.

163. Eliminate the inclusion of so much biochemistry. This material should be left for a Junior level biochem. class. Much more on the use of pKa, general mechanism, and use of spectroscopy at an earlier stage than most books. Mc Murray waits till chapter 12 to introduce NMR.

164. I like the McMurry text and I can not think of any changes to it.
165. More synthetic problems.
166. Better correlation between chapter material and problems
167. I would make sure a chapter on polymers was included.
168. The cost!!!!
169. Add topics in wave mechanics and topicity
170. more challenging problems that focus on critical thinking more synthetic problems throughout the course order of topics should be rearranged to introduce structure determination early and the first reactions encountered should be carbonyl reactions. (We should spend the most time reinforcing the most important reactions...carbonyl reactions!)
171. More problems for which answers are not available
172. Better problems including more basic problems to reinforce concepts and more application-based problems.
173. Decrease the number of reactions we expect students to know. In particular, decrease--possibly to zero--the time spent on obsolete or useless reactions, such as free radical halogenation, several electrophilic addition reactions, essentially all electrophilic aromatic substitution reactions. Focus on carbonyl, alcohol, and amine chemistry, with some attention paid to organometallics.. Emphasize--and test--the reasoning and problem-solving processes in the subject, specifically, reasoning to mechanisms; critical analysis of a proposed mechanism in light of experimental evidence, retrosynthetic planning of synthesis, deducing structure from spectroscopic evidence. Of course, that means we need to give students a sound foundation in the principles of the subject.
174. Too much for the student to master in a year. Books are too long, too heavy, and much too expensive. Decide on what is important and cut to the chase. Cover that material in detail. Stop the endless process of coming up with new edition simply to outgimic the competition.
175. I would eliminate the chapters related to biochemistry and bioorganic chemistry (e.g. lipids, a part of the carbohydrate chapter, amino acids). Polymers can be a section of the alkene chapter.
176. Make more relevant still to biologically-oriented students
177. More use of acidity/basicity principles, thermodynamics, kinetics in explaining basic reactions- whatever is needed to minimize memorization. More emphasis on synthetic chemistry. Connections to biological and material science with explicit explanations - not just cartoons, like most books have it today.
178. Less Expensive Web answers instead of big solutions manual
179. I would place greater emphasis on the critical role that the understanding of mechanisms plays in really understanding organic chemistry.
180. Have more textbooks use electrophilic addition to alkenes as the first reaction, because I think that's a kinder, gentler approach to learning organic chemistry.
181. Geared more towards the pre-med students (our largest group in sophomore organic)
182. Faster to reflect major changes in field. For example olefin metathesis (2005 Nobel) is now a routine method, but not even mentioned in most organic texts. Less emphasis on nomenclature rules, more on mechanistic understanding. Most books are now linked with

online resources - a good step, as long as the resources are done well. They have to include gradebook capabilities, because few students use them if they're not required.

183.MANY details. One very important thing - phosphorus acids are so important in Biochemistry, and should be covered along with carboxylic acids. The reactions are identical, EXCEPT that base hydrolysis of phosphate esters is very slow past the first step, because of charge-charge repulsion. ATP doesn't phosphorylate unless locally acidified by an enzyme. HYDROGEN BONDING! Critically important in biochemistry.

184.I would like more color involved in bond changes and I think it is important to very difficult problems- most of the problems in the book on show one concept at a time. Frequently, there are several things to worry about in organic chemistry reactions and the book should provide a few examples where the student needs to choose one functional group reacting over another.

185.More emphasis on acid-base chemistry; all nomenclature in one chapter --- nomenclature is a great way for students to learn functional groups..... More emphasis on similarity between reaction mechanisms.

186.focus on conditions of reactions and how slight change may cause different results.

187.The fact that new editions come out every two or three years.

188.Cost

189.more current oxidizing agents and reagents in general

190.Lower price!! I no longer require my students to buy a textbook the prices are so high. I would prefer good depth on fewer topics. Texts seem to include everything that might be someones favorite topic. Good multi-step synthesis problems are rare in text books.

191.Higher quality problem sets at the ends of the chapters. Clayden et al. currently has the most rigorous problem sets at the ends of the chapters and that is why I am currently using this text.

192.More emphasis on retrosynthesis Integrating NMR with mechanism problems

193.Up to date chapters on mass spec, nucleic acids, carbohydrates.

194.Bruice is a decent text. The amount of material in all texts are difficult or imposible to cover in two semesters. Ege was difficult to teach from due to its approach, but could be an good text with an honors or integrated lecture-lab course.

196.~the enormous size due to unnecessary glossy thick pages ~the numerous pictures that require the use of glossy thick pages ~I would prefer a simple paperback, in black and white (maybe a bit of color here and there for emphasis) ~too much waste and resources are being used on these textbooks that students don't even use, but are required for a course so they purchase them. ~I don't want to see textbooks disappear. They are a good reference to look at and in paperback form students might use them more. For those that do use them, it will make them cheaper, lighter weight. ~I would like to see textbooks come out with new editions LESS OFTEN!!!!!!!!!!!!!! In the time that I've been teaching, Carey has gone through 4-5 editions. In the time that I was in grad school, about equal time, Carey only changed editioins once. This needs to change. It increases waste on our planet, it decreases the reusability of an object, that is not really used in the first place, and it makes more work for an instructor who remains faithful to a book (we have to go through all the problems each time a new addition is put out and reassign them for our classes).

197. Include more biochemistry. Almost all of my students are pre-med., dent., pharmacy, bio., or biochem. majors.

198. I now teach from a reduced intensity book for nurses and textile people. A few years ago I taught mechanistic Organic chemistry. The students should learn more about light and its effect on matter.

199. Make them shorter and less expensive. Stop making solutions to problems so readily available to students... many do not take the time to work through the material and develop problem-solving skills. Rather they memorize the material, start the problems--encounter difficulties--look at the solution--memorize it, and THEN bomb the exam because they (perhaps) understand the material, but never learned how to apply it.

200. There is always something

201. Change the NMR spectroscopy section so that students actually learn how to predict and interpret NMR spectra. No textbooks teach this so I must rely on lecture notes for it.

202. They would be about 1/2 the size and most of the 19th chemistry would not be covered. Actually, at WSU we require all students to take a 1 semester survey course in organic that covers the functional groups from alkanes to amines. This course has an associated laboratory (required). The second semester, for those students who need it, covers at somewhat the discretion of the instructor these topics in depth. Last semester I taught asymmetric catalysis, organometallic catalysis, nucleic acid and amino acid synthesis and left out lots of old chemistry. Spectroscopy is taught in depth in a separate laboratory course for chemistry and biochemistry majors.

203. Detail and problems are lacking. Add newer chemistry.

204. Cut out reactions that are rarely used and try to relate the chemistry to everyday life.

205. (Note: I only teach the first semester course; I have answered the above questions based on my knowledge of the entire year course, some of which is taught by a colleague.) More consistent and explicit use of mechanism for ALL steps; introduction of a few more "modern" reactions at the expense of some classical chemistry that nobody uses anymore (would require a change in standardized exams (e.g. MCAT, GRE, ACS test, for this to work!)).

206. lower the costs

207. I would make them more readable.

208. put radical chemistry at the end and not at the beginning more carbonyl chemistry earlier in the book

209. Split them into smaller portions, similar to lit anthologies used in HS. Easier on the back, students will bring to class, etc. Get used books off the market so that companies are not forced to put out new editions every 3 years. Encourage publishers to lower cost. Introduce incentives such as longer term commitments to a book involving bookstores, departments, etc.

210. New reagents have replaced the challenges of carbocation rearrangements.

211. Rearrange Clayden for a US market

212. More concept & less memorization

213. I think they should cover less material and place more emphasis on *teaching* the basics of organic chemistry in depth. More emphasis should be placed on development of critical thinking skills. Organic textbooks should not be as "chemocentric" as they are.

They should show more about how organic chemistry interacts with other areas of chemistry and other scientific disciplines.

214.I would like spectroscopy to be covered early (perhaps in chapter 1). Conformational analysis and computational modeling (Spartan software) should also be introduced early and integrated with spectroscopy (ie. determining vicinal dihedral angles via molecular modeling and ^1H NMR).

215.Reduce the cost. More classification of reactions and rules according to general concepts.

216.There are so many organic texts, you can find a text that is fairly suitable. For example, I usually like texts that do nomenclature in different ways for different classes. Chemistry majors - 2 chapters of nomenclature, 1 for the first semester, 1 for the second semester. Service course (biology majors, etc.) - nomenclature in each chapter. Some texts are strictly by functional group, others are more mechanistically organized.

217.I would include a greater emphasis on applications of organic chemistry, mixed intermittently throughout the text.

218.Easier for the students to read with better end of chapter summaries.

219.Note for the question above (#10): Some of the topics indicated are covered in the lab. Much more spectroscopy is covered in another course.

220.The incredibly high cost of textbooks in general.

221.I am very unhappy with the current textbook used: I would rather use Bruice

222.I would change to a 7th edition of Morrison and Boyd if it was available. M&B was the best.

223.More examples of the reactions in context include physiologically active molecules in the examples more "road-map" problems at the end of the chapters as a means of review of previous material

224.Each chapter should have a list of facts that must be known, concepts that must be known and problems that involve applying, not regurgitating the facts and concepts. End result: Students who unhappy and lost.

225.More emphasis on real synthesis; more development of big ideas and how the details relate to these themes.

226.1. Delete the biochemistry chapters, and incorporate small amounts of this material into the appropriate functional group chapters. 2. Do more on how to plan an organic synthesis. 3. Group reactions by similarity in mechanism.

227.More polymer chem. and material properties vs molecular structure. More Pd coupling and metathesis emphasis in the main stream of the text.

228.Add a section on carbenes. Discipline the authors to include only full compound formulas in writing reactions, and to give actual yields of reactions.

229.NEVER use H^+ , always H_3O^+

230.In general I'm fairly happy with most organic textbooks. They cover the basics that provide the foundations for further advanced studies. However, I think that the fundamentals could also be covered by using more modern reactions. I think that hydroboration is the most modern concept that is covered in most textbooks, and that is 50 years old.

231.more examples and applications from everyday experience and fewer from exotic, frontier research

- 232.Reduce the emphasis on synthesis and reactions that are important only for organic synthesis and increase the emphasis on reactions that are more general and take place in nature as well as in the laboratory.
- 233.Put acid/base chemistry early, to introduce all the parameters affecting reactivity. Use biological examples wherever possible.
- 234.More mechanisms
- 235.Reduce number of chapters
- 236.Better illustrations
- 237.They are much too large and cover too much material. Cover the fundamentals and leave everything else out.
- 238.Include modern synthetic reactions; i.e. what reactions do chemists most commonly do. Include green chemistry
- 239.It is good
- 240.Most textbooks are equally good. I would not change much.
- 241.more discussion of green chemistry more focus on design and the creative nature of synthesis
- 242.inclusion of more reactions that are currently used in organic synthesis
- 243.Accurate representation of MO's with accurate descriptions of orbital coefficients. Delete old reactions never used, update with more current reactions (Mitsunobu, for example)
- 244.Less focus on learning numerous reagents for reactions. More focus on learning basic principles of reactivity, predicting reactivity trends, etc.
- 245.Too detailed; return to earlier editions of 20 years ago (this applies to most chemistry textbooks, not only organic) Get rid of CD roms; get rid of study guides; keep full solution manuals Narrow the number of end-of-text problems
- 246.Problem sets carefully planned to drill skills, including reaction recall and electron-pushing mechanisms, as well as continually review older material, including stereochemistry and proton nmr interpretation, and introduce satisfying puzzler problems.
- 247.Streamline more, fewer name-reactions; more biochemical applications for pre-med students
- 248.I would have Solomon's books banned. I would get the prices down! I would probably cut biochemical molecule type references down to interest peaking tidbits.
- 249.Throw away the functional group organization and divide material into large units on structure/spectroscopy/physical properties and reactivity
- 250.Loudon is not my choice and I think we will drop it ASAP, now that the makeup of the faculty has changed. It is too detailed and too comprehensive for a beginning course.
- Tue, 5/22/07 7:19 AM
- The books are too bio-oriented. Because the ACS said to cover biochem in other courses things like tm organometals get no coverage. With the new ACS stds, the organic books will need to drastically change.
- 252.Take out all the biochemistry chapters. Who really has the time to teach this content?
- 253.include transition metal chemistry and exclude archaic reactions such as mercury-based reactions

254. include less--somehow they need to be shorter and lighter

255. earlier introduction of spectroscopy; some discussion of chromatography

256. Length

257. Make them more geared toward Chemistry majors and less toward pre-med Majors. Provide the detail, physical organic underpinnings that allows a student to know, not just the reactions, but the mechanisms in detail and why we know the mechanisms to be what they are. Also have the book be up to date on asymmetric catalysis

258. I see too many inconsistencies in the mechanisms that they show. For example, impossible four-membered transition states, two or three steps condensed into one (presumably to "save time" for the student), etc.

259. The books need to get a focus that is relevant to the student population they serve. The books are written for the instructor. Also, pedagogically the books do very little review of earlier topics even though that is extremely important learning. Only do reactions and mechanisms that students will see more than once. For example, dehydration of alcohols is part of reactions of alcohols and formation of alkenes, the mechanism is general to elimination..... Good reaction to include.... Hoffman rearrangement of amides - goofy mechanism, not necessary to include.....

260. More history of problem solving. How were things figured out. Students need to see (1) the process of successive approximations/hypotheses evolving and (2) the fact that humans, using relatively simple logical steps, were able to sort out the incredible richness of organic chem.

261. too long

262. Get rid of outdated information. Don't just keep adding more and more and more.

263. Change the order of topics so that carbonyl chemistry is introduced early. This would allow earlier presentation of bioorganic molecules.

264. make them shorter and more focused on basic concepts and problem solving

265. Include more references to current literature and publications. Include real procedures from org syn

266. Better problems

267. less "bling", more content better intro to arrow-pushing and retro-synthetic analysis strategies

268. I need to footnote many of these responses (1) spectroscopy and MS are covered in the lab course, which is separate; I have answered according to the lecture course (2) the Honors course covers Diels-Alder and all pericyclics in detail, as well as organometallic chemistry: I have answered for the mainstream course (3) the polymers that we cover are biopolymers only (4) 50% of the second term course is bio-organic What changes? (1) in general, better explanations (2) in general, better problems (3) in general, more honesty that life is not simple (4) in general, far less synthesis and synthetic methods

269. I would make them more useful to the student. More emphasis on problem solving skills. Less fluff.

270. I would move IR, NMR, and MS earlier in the book, probably right after alkyl halides

271. I like the idea that some are starting to use of organizing around reactivity rather than functional group. I am also attracted to the idea of the guided inquiry approach. I have always said that students learn by doing and not by just listening. Overall, I'd say that

textbook writers need to remember that it is a textbook and not a reference book. The focus should be on the basic principles of reactivity, without worrying about minutiae.

272.I suppose I would drop the biochemistry structures (proteins, lipids, carbohydrates, etc.) only because I never get to those chapters. However, I would drop them only if that would lessen substantially the cost of the text.

273.improve the End-of-Chapter problem sections ... most texts have questions that are far too easy relative to the type of exam questions I use.

274.Change from functional group approach to a more mechanism-based approach thereby emphasizing common themes, avoiding redundancy, and allowing concepts/problem-solving techniques to be covered in greater depth.

275.Make a greater effort to show how the underlying principles apply to all aspects of organic chemistry.

276.Cover carbonyls first. Ditch mercury-mediated reactions. Cover Pd-catalyzed reactions.

277.Most students in my class are pre-med, pre-pharm and other health related fields. Giving a textbook more 'bio-relevant' insight would be great. I think McMurry is going in this direction already.

278.More real-life examples involving organic chemistry, such as the organic chemistry of biological pathways since most of our students go on to some sort of professional schools.

279.I would rather change the entire chemistry curriculum than just the text book

280.I would like to see modern methods for organic synthesis covered to a larger extent.

281.Well thought-out problem sequences that start with drill and increase in cognitive thinking and problem solving skills. Summary of reactions need to have generic structures, simple examples and complicated examples for students to generalize the reaction and its use.

282.switch to mechanistic approach

283.I would have them include 'newer' reactions/topics such as the Suzuki and enzyme catalyzed synthesis---essentially provide a sense of the more modern trends in synthesis. I would also like to see more follow thru on IR and NMR practice problems outside of the chapter actually dealing with spectroscopy

284.Have more textbooks with the chapters in the order that McMurry uses. I REALLY like that order, because I think it makes it easier for students

285.I would do them more biochemically oriented. Stuedents ask for the relevance of organic chemistry in their lives, because they do not see in the text books.

286.I would include a greater number and variety of more challenging problems.

287.have better problems

288.I realize that beginning organic students need examples of reactions that use very basic organic molecules, but I think it would benefit them if there were specific examples of how these reactions were applied to real scientific problems. For example, show how the oxidation of an hydroxyl group using PCC is used in a synthetic organic chemistry laboratory. Give a reference to the actual paper that this information was published.

Basically, students do not receive enough "real world" examples of how the information they are learning is actually applied.

289.Make it simpler

290. Better ancillaries that would provide a more balanced alternative to learning the material in a largely text-based approach.
291. The responses above are for an intermediate-level organic chemistry class (recently established). The emphasis is on developing strategy for organic synthesis, and specific classes of organic reactions with reactive intermediates (e.g. nitrenes). A survey of other organic chemistry topics is included at the end.
292. Reduce the cost. This may require deleting a moderate amount of the "extra" material which bulks up most textbooks.
293. Authors trying to put their (successful) classroom personalities in the text. This is almost always unsuccessful.
294. Include photochemistry and supramolecular chemistry
295. While it is important to show how organic chemistry applies to other sciences, I think the growing emphasis on biochemical applications in organic texts is becoming excessive.
296. Most books are quite good
297. I currently enjoy Smith very much. I would change the test bank, the questions are boring, repetitive and contain many mistakes. We are switching to the Aris program and hope that will help our problems. The topics you have listed above are many of the more advanced topics. Our school only has a 2 semester sequence for organic, so we will never get to advanced topics (we leave many of them for biochem). All books are adding them but we simply don't have the time to teach them. I do everything I do in detail and that means we don't get to lipids, advanced polymers etc... that's the way it is.
298. The cost for the students! In terms of content, all textbooks have their positives and negatives... There are things that I would both change and keep about each one.
299. Text questions tend to focus on drill or single-skill exercises. I wind up writing most of my own problem sets, although I may assign book problems as a warm up. A conspicuous exception to this is Ege's book, which uses real examples from the literature.
300. different approach to emphasize arrow pushing
301. Include more ANNOTATED electron pushing mechanistic detail for those who want to learn it.
302. Stop organizing them by functional groups and organize them by mechanism. McMurry is a fine book, but not my personal first choice. We choose by consensus/committee.
303. More difficult problems
304. I would... (1) write more succinctly. (2) come out with a new edition every 5 years rather than every 2 to 4 years. (3) do away with cost-elevating multi-colored illustrations. (4) make a pulp paperback version available for less than \$50. (5) include all unshared electrons on an atom involved in a mechanism (for example, show 8 electrons on a bromide ion rather than just 2). (6) always start electron-pushing arrows at electrons rather than at a negative charge. (7) do away with confusing and often misleading "concept maps." (8) include tables that contain numerous examples that illustrate nomenclature rules. (9) include more end-of-chapter questions that include lots of examples of fundamental reactions (for example, a couple dozen saponification reactions that differ from each other by having some of them as lactones rather than simple esters,

some with the ester group pointing up rather than to the right, some have the ester group buried in the middle of a large molecule, etc.).

305.nucleophilic aromatic substitution should be taught with conjugate addition chemistry

306.The use of multistep synthesis problems as a learning tool for reactions, and a better teaching dynamic for learning synthesis strategies

307.Include online content that shows a real person performing the particular reaction in a You-Tube kind of way in ~5 mins with start to finish including work-up

308.get rid of some details

309.Most are pretty good. I would prefer that everything be justified by mechanistic arguments. It helps the students get to the "why" of things

310.cost weight lack of interactivity

311.Less material and more emphasis on the unifying mechanistic framework

312.some are way too distracting, with lots of different boxes and special sections or MO diagrams of compounds interspersed throughout the text, that i'm not sure help the students. also it seems that students are less and less willing to read the book, and perhaps the writing style/approach could capture them better. also i think more reinforcement of basic concepts throughout the book could be done - you have a chapter on Newman projections and then they never appear again. incomplete mechanisms are also annoying.

313.Most organic chemistry textbooks present everything far too fast (e.g., all functional groups at once). I use V&S (and before that, Streitwieser & Heathcock) because it presents only a small number of functional groups initially, and then introduces others a small number at a time.

314.More history

315.more work problems

316.Drop the biochemistry and focus on organic chemistry. Mechanisms, reactions, molecular orbital theory. Why do text spend 3-6 chapters on biomolecules? It is not organic chemistry

317.Make is a mechanistic approach instead of functional group.

318.Better problems

319.Easier to abbreviate coverage when time is short. Better coverage of synthesis, particularly building in retrosynthetic analysis from the beginning.

320.price and size

321.Introduce spectroscopy with functional groups in chapter 1 or so and then provide problems throughout the semester.

322.Better connection with general chemistry! I must bridge the language gap with them. Organic is easy for students who truly learned general chemistry if they can figure out what the organic chemists are saying.

324.A longer time between editions.

325.Better coverage of different types of spectroscopy, better discussion of physical properties, more about heterocyclic compounds, reduce the number of detailed reaction mechanisms and discuss selected mechanisms in more detail, some descriptive chemistry (the physical state of aggregation of different compounds, their color, etc.)

326.Solutions manual should give the approach to solving the problem rather than just giving the answer.

327. more physically correct
328. More emphasis on the type and mechanisms of synthetic organic reactions
329. Include more vignettes relating the course material to everyday occurrences. Of course I do that in my lectures so in some ways it's fine to add this to the textbook notes.
330. More mechanisms, fewer reactions. More student friendly, readable, visually appealing.
331. less introductory material that is supposed to be known from general chemistry
332. In general, they're very well written. I'd like to see more attention to mechanisms (orbital theory) and their presentation as organizing principles for Organic Chemistry.
333. More challenging problems More discussion of the research that led to the information Most need better organization to make the all of the different topics relate better
334. Move Diels-Alder coverage into 2nd semester (currently placed in 1st).
335. Lower cost and lighter weight
336. More conciseness is needed. Students will not learn as much as we learned.
337. The sequence of the materials presented.
338. More up to date discussion of carbohydrates
339. Equal treatment of laboratory and bio synthesis. Lab synthesis is a great way to develop problem solving skills and to think forwards and backwards through a problem. Multi step synthesis should be more of a focus in chapters as well as end of chapter problems. This should assume complete understanding of reagents, which students should master in each chapter.
340. I would make them less expensive.
341. More emphasis on correct arrow pushing and a stronger mechanistic foundation behind all the reactions.
342. Clearer presentation. It reads as if it was designed for the attention-deficit child. More examples of real reactions and conditions. More literature references.
343. Organic texts traditionally contain much more material (and go more deeply into some topics) than can be covered in two semesters with average students. There is a lot of debate about what content is in the texts, but serious thought should be given to how much the students can master in the time allotted. On-line homework and supplemental materials are now a must for all texts if they wish to be competitive. While I support having extra material in the text for students who can do more, the basic text should be "basic". I do not mean watered down... just "basic"
344. remove many things that are included for historical reasons and replace them with modern reactions like RCM. include more molecular orbital theory (e.g. show appropriate phases in orbital pictures)!
345. Change the order of Vollhard's book to introduce more reactions earlier
346. Different organization of material Inclusion of transition metal-catalyzed reactions
347. More focus on mechanisms and general reactions and synthesis. Less coverage of the more unique rxns that are somebodies pet research area. Majority of students are medical or pharmacy students and they get little exposure to lipids , carbohydrates amino acids etc. They need more on biological molecules.
348. More quantitative tables

349.making first semester material reaction type themed rather than functional group themed

350.Instead of spending valuable textbook space talking about nmr theory, authors should provide students explicit strategies for determining molecular structure augmented by an adequate number of worked-out problems.

351.That they would be cheaper and new edition every five or more years.

352.In other texts, I do not like the emphasis on radical rxns and polymer chemistry. I like more bio-organic focus, but not exclusively. I would like to see more pulling together of all of the topics - stereochemistry, reactions and spectroscopy seem to be treated as 3 distinct areas of organic chemistry without conveying how they are all intricately related anywhere except the most difficult homework problems. This gives a false impression, because combining these ideas in real life make our jobs easier, not more difficult.

353.Stick to reactions that have general applicability in organic synthesis and mechanisms.

354.Cut out chapters that deal with biochemistry - there isn't time in 1st year Organic and most students take biochemistry anyway. Put in some more real-life applications or articles of interest for most important("name brand") reactions. Introduce some famous organic chemists/Nobel laureates and importance of their contributions.

355.incorporate aspects of biochemistry into the basics ie look at d sugars when doing stereochemistry

356.how much they cost

357.More detail in basic kinetics and mechanisms before attacking general organic chem mechanisms. More focus on the salient underlying generalities;ie, Lewis acid/base reactions.

358.In general, I think they are pretty well optimized. I would like to see more emphasis on mechanisms. In particular, more mechanistic questions at the end of chapters would be helpful. There is a similar need for multistep synthesis problems.

359.Completely reorganize. They still follow the Type Theory model of books from the 1870's

360.I like the wording in the organic texts from 25 or more years ago when they didn't have the nice graphics to help them out. I like the graphics and charts provided, but the wording is not as easy to follow as it used to be.

361.I would change the order of the McMurry text so that redox reactions, Sn1/Sn2 and E1/E2 were presented earlier on in the content.

362.shorten by 20-30%

363.I would place major spectroscopy (IR, NMR, MS) very early in the text, right after the presentation of functional groups and constitutional isomers. Students do not need to know any reactions in order to use spectroscopic methods (IR for functional groups, NMR for connectivity, MS for exact mass = molecular formula). In presenting spectroscopy in this way, it can be integrated into every reaction starting with substitution and elimination, addressing a very important question often asked by students: How do you know that's the product of a particular reaction? Other changes I would make would be to get back to basics, and not try to cover all of the newest methods unless they are truly paradigm. Students at this level need concepts more than a compendium of methods. I've been trying (unsuccessfully) for years to have O-Chem a three-semester

course, given how much has been added to the bulk of knowledge just in the last 15 years alone.... Most of the texts nowadays are all about presentation: multicolor, trying to make a cold prickly science into a warm fuzzy. It doesn't work, and I've witnessed firsthand the decline in student learning outcomes over the years as texts try to become friendlier. I'm all for increased accessibility (however, our peculiar demographics is such that any text written at a high level, like Fox and Whitesell, simply would not work here: most of our students cannot read or write coherent English....), but (for example) the Smith text, adopted by a committee vote excluding mine -- the only dissenting vote of five -- is so badly organized, so broken up, choppy, it has no aesthetic flow, and frankly gave me a five-alarm headache when I tried to go through the first few chapters in writing the course syllabus. Textbooks should return to very, very modest use of color, and stop trying to 'do it all'. A three-semester course can have the third semester build on the first year with its own text for more advanced synthetic methods, strategy of synthesis, and mechanisms. The first year for pre-health professions and biology majors, and the third semester for chem/biochem majors. The bulk of knowledge in the sciences alone has made it totally unrealistic for a science major to complete a solid degree program in four years and still have enough breadth and depth, liberal-arts courses to keep the students human. I could go on for pages, but this is not the time nor the place in which to do so.....

364. Introduce carbonyl chemistry much earlier (this applies to nearly every text, not just to Vollhardt & Schore!)

365. More mechanisms. Bruice is REALLY weak on mechanisms. However it has a nice bent toward biology which the pre-meds like.

366. All would cover electrophilic addition to alkenes BEFORE covering SN1, SN2, E1, & E2. Students need softer introduction to mechanisms.

367. Spectroscopy should be taught as soon as possible with additional sections on spectroscopy as each functional group is introduced. Most texts do one or the other, but not both. More discussion of protecting groups and strategies for using them in total syntheses.

369. more detailed mechanisms

370. More explanation questions on homework problems. In addition to simply getting the right product, also probing "why does this happen?"

371. get rid of emphasis on electrophilic aromatic subs. A reaction that nobody uses and that takes up time better spent on transition metal catalysis and pericyclic reaction

372. Spectroscopy introduced earlier Stereochemistry earlier

373. Make a hybrid between the mechanistic approach and the functional group approach for example, use the first 7 or so chapters of Bruice's text then use Carey's approach for the rest of the year.

374. I would want them to go to an organization based on mechanistic themes rather than functional groups.

375. Mechanistic approach + more problems solved within the text

376. Introduce stereochemistry early, as well as NMR. I also think that most authors put too much detail in their texts. You can always add detail in lecture, but you can't take it out of the book, where it can cause confusion to many students.

377. More emphasis on mechanism and understanding concepts instead of memorization, particularly in the problem sets.

- 378.** Much less fragmentation in sections and fewer "extra" boxes. In my opinion, you also need to have attention-deficit disorder to effectively go through an organic chemistry book today. Clearer mechanisms would also be nice. My ideal organic chemistry book would be more conversational and would have more flow, just as a good lecture should.
- 379.** Have online drilling programs available to the students free of charge. Best program on the market, I feel, is ACE Organic. Providing students 24/7 feedback on their proficiency using the web can offer many a change to build upon their successes.
- 380.** Cover carbonyl reactivity in the first sections of the book rather than the last
- 381.** Move stereochemistry earlier
- 382.** more problems, less text
- 383.** More basic proton NMR spectral examples.
- 384.** More multi-step synthesis problems! More multi-step synthesis problems integrated across large sections of the text. More mechanism problems!
- 385.** A lot of organic texts have radical reactions early, which confuses students later when they get to reactions. I would like to see more detail in explaining mechanisms and more problems working through the smaller detail-oriented problems.
- 386.** use color only to highlight important concepts and not make a comic out of them

Appendix B. IRB Approval

April 18, 2007

Elliot Ennis, Amy Phelps, & Dr. Michael J. Sanger
Department of Chemistry
ege2a@mtsu.edu, aiphelps@mtsu.edu, misanger@mtsu.edu

Subject: "Organic Chemistry Textbook Content Coverage"
IRB # 07-236, Exempt Research

Dear Investigator:

Based upon my review, I have found your proposed study to be exempt from Institutional Review Board (IRB) continued review. The exemption is pursuant to 45 CFR 46.101(b)(2) and is based on the fact that the research is involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior; no identifiers will be used; and, any disclosure of the human subjects' responses could not reasonably place the subjects at risk.

You will need to submit an end-of-project report to the Office of Compliance upon completion of your research. Complete research means that you have finished collecting data and you are ready to submit your thesis and/or publish your findings. Should you not finish your research within the three (3) year period, you must submit a Progress Report and request a continuation prior to the expiration date. Please allow time for review and requested revisions. This study will expire April 18, 2010.

Any change to the protocol must be submitted to the IRB before implementing this change. According to MTSU Policy, a researcher is defined as anyone who works with data or has contact with participants. Anyone meeting this definition needs to be listed on the protocol and needs to provide a certificate of training to the Office of Compliance. **If you add researchers to an approved project, please forward an updated list of researchers and their certificates of training to the Office of Compliance before they begin to work on the project.**

Also, all research materials must be retained by the PI or faculty advisor (if the PI is a student) for at least three (3) years after study completion. Should you have any questions or need additional information, please do not hesitate to contact me.

Sincerely,

Tara M. Prairie
Compliance Officer