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EXPERIMENTAL HIGH SCHOOL ORGANIC CHEMISTRY

An Interactive Qualifying Project Report
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by

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Abstract

This project investigated teaching techniques of organic chemistry. A general overview of science and chemistry teaching methods is discussed in this report. This project comprised of designing and testing a hands-on approach to teaching introductory organic chemistry, involving concept-related laboratories. Working with St. Croix Country Day School (CDS), located on St. Croix, US Virgin Islands, this approach was explored with 11th and 12th grade students. We encountered many obstacles in our project. However, it was successful.

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Introduction

Whether we are the teacher or the student, teaching is an important part of our lives. The method by which we are taught (or teach) is just as important as the subject matter. WPI's philosophy has always been that of theory and practice. Students at WPI are taught the conceptual material and they must then apply it to real world situations. This method of encouraging application to go along with facts is one the most effective methods of teaching. Application is an excellent way to reinforce information that has been learned.

One of the subjects that can benefit greatly from this application of facts is organic chemistry. Organic chemistry has earned a bad reputation among students. It is often thought to be one of the greatest obstacles for chemists and biologists in college. From personal experience and observation we have found that students are not interested in pursuing organic chemistry after an introductory course. Introductory organic courses can feel like a flood of rules for naming compounds, and memorizing reactions that seem to have no possible useful application. This could not be farther from the truth. As a result of the reputation organic chemistry has earned very few students are aware of the large range of the applications of organic chemistry.

There have been studies performed testing the effectiveness of teaching the applications of organic chemistry in introductory courses. These studies have shown that science courses in general are understood more thoroughly when appropriate laboratories are integrated into the curriculum. More specifically, studies of methods of teaching organic chemistry have shown that students who took an introductory organic chemistry course with a regular step-by-step laboratory class did not learn the material as well as students who took the introductory organic class along with a laboratory course that focused on problem solving.

Based on such studies many improvements have been made in recent years to increase the quality of introductory organic chemistry courses in colleges, but there is little done to provoke an interest in the topic in younger students. High school students usually have little exposure to organic chemistry, therefore there is little to interest them in the field before entering college. The declining interest in organic chemistry and other "older sciences" may also be a result of today's technological society. In today's technological society students are more interested in sciences relating to computers and other more technical fields.

In order to interest students in organic chemistry it must be taught through application rather than memorization. We planned to introduce basic concepts of organic chemistry to high school students, to give them an overview of what this field is really about. Working with St. Croix Country Day School we develop and taught a laboratory-based class in organic chemistry. Through integrating laboratories and other interactive teaching techniques into this class we hoped to effectively present the material to students and stimulate interest in the subject matter.

Literature Review

1. Chemistry

1.1. History of Chemistry

The field of chemistry has gone through many changes and advances throughout the course of history. Early stages of the development of this field involved increasing familiarity with the environment, like the discovery of the difference between liquid, solid, and gas. As the years progressed more sophisticated advances were made, allowing people to manipulate their environment. Finally chemists began understanding the composition of matter, including the discovery of elements. This progression of chemistry may be divided into three major time periods. These stages may be referred to as the Prehistoric – Christian Era, Alchemy, and Modern Chemistry.

1.1.1. Prehistoric – Christian Era

From prehistoric times until near the beginning of the Christian Era mysticism and superstition dominated over all "scientific" thought. Even though true "scientific" principles were lacking, application of chemical principles may be traced back into this era. As far back 1000 BC ancient peoples were applying their knowledge of chemistry to produce embalming fluids. Techniques of refining ores to use in making weapons and ornaments were also developed during this time (http://library.thinkquest.org/2690/hist/black.html, 12/11/00).

Around 400 BC, the Greek philosophers Aristotle and Thales were among the first to explore the nature of chemical changes. They developed the theory that matter was composed of four basic elements: fire, air, earth, and water. Other Greek philosophers inquired whether matter could be infinitely divided into smaller portions, or if would eventually be broken down into very small, definite units. Democritus called these units *atomos* (to later be known as atoms). In these ancient times there were no methods to test these ideas, therefore no conclusions could be drawn.

Nearing the end of this era it was discovered that bronze could be made through combining tin and copper. The idea of combining two substances to form a new product interested people. From this discovery people were inspired to think that perhaps if they could find two substances that each had a characteristic of gold (for example luster and malleability) then these could be combined to form gold. This brought about a new era: Alchemy.

1.1.2. Alchemy

Nearly 2000 years of chemistry history was dominated by alchemy. Alchemists believed that there was a way to turn common metals into gold. In the late thirteenth century alchemists realized that they could be of more use to the world by discovering new products and new methods to improve life. One alchemist, Theophratus Bombastus, felt that the object of alchemy should be to cure the sick (http://library.thinkquest.org/2690/hist/alchemy.html 12/12/00). Alchemists made many important discoveries in the field of chemistry, like the discovery of the elements antimony, sulfur and mercury. They also learned how to prepare mineral acids (Zumdahl, 1998).

1.1.3. Modern Chemistry

The use of quantitative experiments by Robert Boyle may be marked as the foundation of modern chemistry. Boyle performed experiments that explored the relationship between the pressure and volume of gases. From his results of these experiments he wrote the book *The Sceptical Chemist* (published in 1661). The publishing of this book may be classified as the birth of the quantitative sciences of chemistry and physics. Boyle aided in the dismissal of the Greeks' theory of four elements, by proposing that "a substance was an element unless it could be further broken down into two or more simpler substances," (Zumdahl, 1998). Boyle's definition of an element became the standard definition.

Antoine Lavoisier (1743–1794) was the next chemist to raise revolutionary ideas. He also performed quantitative experiments, keeping careful track of all quantities consumed and produced. Lavoisier's field of study was combustion (an area of great interest at the time). By comparing the carefully measured quantities of the products and reactants he was able to develop the law of conservation of mass: "Mass is neither created nor destroyed" (Zumdahl, 1998). *Elementary Treatise on Chemistry* (published by Lavoisier in 1789) was the first modern chemistry textbook.

Many chemists adopted Lavoisier's methods in the 1800's. These methods of carefully monitoring quantities allowed chemists to follow the progress of reactions, as well as determine the composition of various compounds. One of these chemists was Joseph Proust (1754-1826).

Proust studied the substance copper carbonate and found that it always contained the same proportions of copper, oxygen, and carbon. From this work he developed the law of definite proportions: "A given compound always contains exactly the same proportions of elements by mass" (Zumdahl, 1998).

Proust's theory led John Dalton (1766-1844) to the conclusion that elements could further be broken down into smaller units (atoms). Dalton questioned how elements could always appear in the same proportions in a given compound. The only explanation was a definite unit. Dalton's theory of atoms had to be tested. This led him to experiment with carbon and oxygen. From these experiments he developed the law of multiple proportions: "Elements will always react together in simple, whole number ratios" (Summerhayes Notes, 9/8/97). Another very important contribution Dalton made to chemistry was to develop the first table of relative masses. A great deal of his data was based on incorrect assumptions about formulas of certain compounds, but the idea was a very important step in the development of what chemistry is today.

In the next great advance in the development of modern chemistry, Dmitri Mendeleev (1834-1907) collected data from researchers around the world and constructed the first periodic table of elements. From Mendeleev's table he was able to organize known elements and even predict properties of elements that were not yet discovered (http://www.woodrow.org/teachers/chemistry/institutes/1992/Mendeleev.html, 12/12/00).

1.2. Organic Chemistry

1.2.1 What is Organic Chemistry?

A difference between compounds that were derived from living sources and non-living sources had been noticed as far back as the early eighteenth century. Compounds from non-living sources (minerals) could be easily isolated, but compounds derived from living sources decomposed easily, and were therefore difficult to isolate. These differences led chemists to apply the term "organic" to compounds that came from living sources. However, over the years it has been discovered that the true distinction between organic and inorganic compounds is that organic compounds contain carbon.

1.2.2. History and Development of Organic Chemistry

In order to rationalize this difference between organic and inorganic compounds the theory of "vitalism" was formed. The basis of vitalism (or the vital force theory) is that "organic compounds contain a peculiar vital force because of their origin in living sources" (McMurry, 2000). This theory explained why organic compounds could not be synthesized or manipulated in the laboratory like inorganic compounds.

The chemist Michel Chevreul (1786-1889) discovered the first fault in the vitalism theory. Chevreul was able to manipulate organic compounds in his laboratory. He was able to take animal fats (organic compounds) and convert them to soap and glycerin. From these products of soap and glycerin, he could then make "fatty acids." Although this is a fairly simple reaction today, at the time this experiment was a breakthrough.

The next chemist to discover fault in the vital force theory was Friedrich Wöhler (1800-1882). Wöhler was able to convert a compound that had previously been thought to be inorganic (ammonium cyanate) into a known organic compound (urea). Although this experiment proved the fault in vitalism, this was not the discovery that interested him most. The real interest to him was the fact that there was no change in the amounts or types of elements presents. The elements present had simply been rearranged (this is now known as isomerism).

Through the nineteenth century there were great amounts of proof against the vital force theory. In 1848 William Brande (1788-1866) wrote, "No definite line can be drawn between organic and inorganic chemistry... Any distinction... must for the present be merely considered as matters of practical convenience calculated to further the progress of students" (McMurry, 2000). Therefore, we now define organic chemistry as the study of carbon containing compounds.

2. Teaching Principles

2.1. History of Science Teaching Principles

In the 1960's the space race sparked a national interest in science and technology education. At the time higher educators thought that the best way to teach was through instructor-centered classes. The focus of this plan was to produce the best individuals in the fields of science and technology, thus staying out in front in the technological race. During this time the overall effects of this instructor-centered style had not been fully explored (McNeal, 1997).

While this style did produce students who excelled in their fields, it did not help the majority of the students; this shortcoming was not discovered until the mid-80's. As a result of this shortcoming many students were switching out of science majors (McNeal, 1997). The problem was not rooted just in the lectures but also in the lab classes being taught. Step by step instructional labs or "cookbook labs" were turning away students who wanted to inquire about things on their own. With this new information drastic changes were needed to counteract this downward trend.

2.2. Modern Teaching Principles

2.2.1. Student-centered Teaching

Until the development of student-centered teaching techniques classes were designed to be instructor-centered. Instructor-centered classes focus on the instructor as the expert in a particular field and the student has a passive role. In the instructor-centered teaching style, the student is usually just asked to recall the facts that have been presented to them. Instructor-centered teaching is not as effective as student-centered teaching because it relies on memorization of facts, but in student-centered teaching students are taught the *methods* to get to the right answer rather than just being given the answer. However, student-centered teaching focuses on getting students to understand the subject matter. The *process* of getting to the answer is stressed more than getting the right answer (National Research Council, 1997).

Incorporating students into the learning process is very important as is shown in student-centered teaching. Allowing students to become involved with what they are studying has proven to be very effective in helping them learn. Some student-centered teaching methods that can be used are group discussions, short exercises, demonstrations, and games.

2.2.1.1. Group Discussions

Group discussions are a good way for students to expand on concepts they have learned in class and develop their problem-solving skills. These discussions may be instructor-centered or student-centered. In instructor-centered discussion the questions are devised and asked by the instructor to the students. When engaging in student-centered discussion the students formulate questions among themselves and the instructor only provides guidance as to the important points that should be covered. The problem with the student-centered discussions is that the direction is unpredictable and therefore constant guidance is needed. Instructor-centered discussions may be favored because they are more likely to flow in a structured manner (National Research Council, 1997). Either method produces the desired result: the students will think about the material instead of just plugging numbers into equations or memorizing facts.

2.2.1.2. Exercises

Short exercises can be a good way to quickly reinforce a concept that has just been introduced. Students will retain information more readily if they apply it after learning it. This may be accomplished through doing exercises or problems on the material. These exercises may be as simple as changing the numbers in an example problem presented in the lecture. Psychological studies have shown that generating an answer yourself increases your recall of that material. This effect is known as the self-generation effect (Matlin, 1998).

2.2.1.3. Demonstrations

Demonstrations are another method used to help students understand the ideas presented in class. Visualization of concepts is very important. It gives the students a mental picture that they can apply to a particular concept. One way to involve students in demonstrations is to have them predict what is going to happen. To imprint the demonstration on the students' mind, it may be performed with everyday items. A few basic principles of cognitive psychology provide some basis for these ideas. Recall of facts is easier when information is related to familiar items (especially a visual stimulus); this gives the students a visual image to call up to help them remember the concept (Matlin, 1998).

2.2.2. Lecturing

Even though interactive methods are favored over lecturing there still will be times when lecturing is the only way to teach certain subject matter. Studies have shown that lecturing to a group of passive students contributes little to the learning process (National Research Council, 1997). When subject matter requires lecturing there are some methods that can be used to produce more active student involvement and therefore more effective learning. These methods include pausing, varying of the teaching medium, and asking questions.

2.2.2.1. Pauses

When lecturing, a pause should be taken every 10-12 minutes. The reasons for stopping is that studies have shown that a student's attention increases steadily up to ten minutes but after this time it starts to decline and drift (McKeachie, 1999). During these pauses students are given a chance to do something else so that they may deal with all the other stimuli that would have affected their attention span before. These stimuli are the physiological and psychological responses that would keep them from effectively listening for longer periods of time. Another thing students may do during these pauses is to catch up and compare notes with others. This comparing notes and discussion will increase the amount students learn because two students will take better notes than just one. This pause also provides the opportunity for students to process the information that they just passively absorbed (Bonwell, 1996).

2.2.2.2. Variations of Teaching Medium

Varying the medium through which the material is presented can help create a more effective lecture. Videos, films, slides, and computer programs help the students' attention to stay focused on the material because, as was previously noted, a student's attention span is short and variation tends to increase it. Multimedia also allows the instructor to appeal to the multiple learning modes of the students (auditory and visual) thus reaching a greater number of students (McKeachie, 1999).

2.2.2.3. Questions

Asking questions is a way to make a lecture more effective. The students' answers give the instructor an indication of how the students are interpreting the material being presented. The process through which students arrive at the answer is what's important, not the answer. This shows that the students understand the methods to get to the answers rather than just memorizing the answers to particular problems. To get good answers the instructor should wait 5-30 seconds after asking the question before demanding the first answer (McKeachie, 1999). Waiting for a response will indicate to the students that they need to think about the question. If there is trouble getting answers the instructor can ask the students to write down preliminary thoughts about the question. An important point to pay attention to when asking students a question is that an instructor's questions should build confidence, rather than induce fear (National Research Council, 1997). Also, questions must be phrased in the correct way in order to get the response wanted. Bloom's Taxonomy helps us understand how to use different types of questions.

Bloom's Taxonomy divides learning into six different levels: knowledge, comprehension, application, analysis, synthesis, and evaluation. Knowledge may be the recall of previously memorized facts or general concepts. An example of the type of question that would be asked to retrieve this information from a student would be "What is…?" or "Which one…?" The second level of learning is comprehension.

Comprehension is achieved when an understanding of material is exhibited through comparing, organizing, and interpreting facts. Examples of questions that will lead students to recall this type of information would be “How would you classify…?” and “Will you state in your own words…?” At this level an individual demonstrates the lowest level of understanding. Here the individual can use the material being communicated but does not necessarily relate it to other material or see its full implication. The next level, application, is the third level described by Bloom’s Taxonomy. Application requires that previously learned material be applied in a new way to solve problems. “What other way would you plan to…?” and “What would result if…?” are examples of questions that may be asked to use this level of learning. Analysis is the fourth level in Bloom's Taxonomy. Analysis is the breaking down of information into its constituent parts. In this level the relationship between ideas is seen and the organization of information is understood. The types of questions to test for this level of learning are "What conclusions can be drawn from ...?" and "What is the relationship between ...?". The fifth level is synthesis. At this level an individual demonstrates an ability to put elements together to form a whole that was clearly not present before. The types of questions that can be asked to test on this level are "What do you get if you combine ...?" and "How would you create ...?". The sixth and final level of Bloom's Taxonomy is evaluation. Evaluation is an ability to make judgments about the value of ideas and methods. The individual is also able to compare and discriminate between ideas to satisfy a set of criteria. Examples of the type of questions that can be used lead to this level of learning are "Which is more important ...?" and "Which is more appropriate ...?". (http://www.utexas.edu/student/lsc/handouts/1414.html, 12/27/00).

2.2.2.5. More Lecturing Tips

Other tips for improving lectures are: first, avoid lecturing right out of the book. The textbook should be available for the student to get alternative information about the subject to enhance what was taught in class. Second, try to link the material to everyday phenomena and events. Studies in cognitive psychology show that information may be recalled more readily when it has some meaning that the students may apply to their world. The delivery of a lecture is also important. The instructor wants to be able to hold the students' attention while speaking. There are several techniques that may be used to accomplish this: maintaining eye contact with students in all parts of the room, moving around, and varying the intensity of the instructor's voice (National Research Council 1997). All of these approaches to improving the lecture are consistent with the principles of student-centered teaching. Each of these lecturing techniques will allow the student to become more involved in the learning process.

2.3. Teaching Chemistry

The mystery of the field of chemistry is what often draws students to it, but students often become disenchanted by introductory courses. What is the problem with these courses? Part of the problem is that instructors tend to try to cram all the facts into a short period of time, so the more interesting concepts are never reached. Also due to the fact that they are introductory courses, they must accommodate a large number of students. As a result of having to accommodate a large number of students they are typically not student-centered courses.

Since many courses are taught as a series of facts to be memorized, students are never allowed enough time to work with the information presented. Students cannot learn to apply concepts in these instructor-centered situations; instead it is all rote memorization. It often becomes the practice of professors to pack facts into lecture, forcing students to busy themselves with constant note-taking. Therefore the student has little or no time to process to the information and they must rely solely on recall, with no understanding of the material.

These courses that force recall on students causes the information to be short-lived in their memory because it has only gone through a shallow level of processing, rather than deep processing. The terms "shallow processing" and "deep processing" refer to the "levels of processing" approach. This is a model of memory that states people achieve a greater depth of processing when they extract more meaning from a stimulus (Matlin, 1998).

In order for a student to understand chemistry information they must think like a scientist, this will aid students when concepts to be learned become more complex. To think like a scientist means that a student must be able to look at a practical problem and try to solve it through scientific principles. Students should be able to process and evaluate all information received including their own answers.

2.4. Teaching Organic Chemistry

"Organic Chemistry courses have a well-deserved reputation for difficulty, memorization, and information overload" (McNeal, 1997).

Since organic chemistry is such a vast field there are so many facts that the instructor must try to present in a year. This overloads students with content and allows very little time to understand the application of the material, which is an example of information previously noted, is common in most chemistry courses. Organic chemistry is usually treated as a difficult stepping-stone for students preparing to begin a career in biology or medicine, but there have been recent attempts to make it more understandable (McNeal 1997).

To teach organic chemistry in the most effective way the instructor must provide the student with the basic tools needed to solve problems. Many of the problems that need be solved are similar, but at the same time they are also different. So either students may learn the principles needed in order to reach the similar solutions, or they can try to memorize all the answers. Students have to get a feel for this type of material. The essence of the field must be presented: "the conceptual tools, the general rules, the trends, the modes of analysis..." (Scudder, 1997).

2.4.1. Material Presentation

Teaching organic chemistry is generally found to be most effective when basic concepts of first year chemistry are reviewed first to reestablish principles of reactivity and recognizing active sites on molecules. After this has been mastered then the instructor can move on to generalized reactions and writing generalized mechanisms. Mechanisms are diagrams that show the pathway through which a product is reached. They show the flow of electrons from one site to another. The mechanism for each reaction is somewhat different however. Therefore learning a generalized format and some basic rules to follow for mechanisms helps to increase understanding. This approach is more effective than trying to teach students every possible mechanism that they may need to learn. Then they have the tools that they will need in order to move on and learn more complex reactions. This approach was explored by Paul H. Scudder at New College (McNeal, 1997).

When lecturing in an organic chemistry course it is important that the instructor present topics from a problem solving point of view. An example of this would be the procedure that may be used to synthesize isoamyl acetate (the alarm pheromone of honey bees). This is an example that may be used to introduce the topic of Fisher Esterifications (the acid catalyzed formation of an ester from an alcohol and a carboxylic acid). In the particular case of isoamyl acetate, isoamyl alcohol is heated with acetic acid along with sulfuric acid as a catalyst. After the students had learned the concept they could be given a different ester and asked to design a plan to synthesize it. In the beginning it may be solely the instructor forming the examples, but as the course progresses students may be able to participate in this process more.

Organic chemistry is a highly experimental science. Before the invention of spectroscopy the only way to identify functional groups was through classification tests. Therefore introducing students to it through a problem-solving perspective will help to develop practical problem solving skills that they need in order to understand this subject.

2.5. Teaching Science Labs

Teaching laboratories is an integral part of learning and understanding science, because experimentation is the key to all the developments in science. Theories and laws in all scientific fields must be tested through experimentation. Thus an excellent environment in which to learn science is a laboratory. In a laboratory students are given the opportunity to manipulate a problem so that they may think about it and eventually solve it.

2.5.1. Problems with Introductory Labs

The problem with introductory chemistry labs is that they generally follow the "cookbook" format, or step by step instructions. This eliminates a large portion of the understanding process because students are too busy trying to reproduce exact results and get the right answer. Laboratories are often costly and complicated to design. Laboratories that provide students with step-by-step instructions instead of allowing them to devise their own procedures reduce the number of mistakes that may occur in the lab, reducing the need to replace chemicals and the amount of supervision necessary in the lab. These step-by-step instructions also reduce the amount of time needed in the lab because students already know exactly what needs to be done. Therefore the reduction to "cookbook" labs seems more efficient. However, introductory labs often make science seem less interesting than it really is, and they leave little discovery to be done. Students usually feel that introductory labs are boring or useless (National Research Council, 1997).

2.5.2. Teaching Organic Labs

Like most chemistry labs the organic chemistry lab has been reduced to the simple "cookbook" formula. Following the directions is not, however, the most important part of organic laboratory. The important part of an organic laboratory is learning how to think like a chemist. Thinking like a chemist includes being able to form experiments from concepts and understanding the function of laboratory apparatuses. (Browne, 1999).

A student's understanding of the material may be enhanced by focusing the lab on the problem to be solved, rather than on the technique. This approach may be applied by giving students a problem to solve. Also giving them a list of chemicals and apparatus that they may use in order to solve it. This will apply their knowledge of the actual chemistry and it will also demonstrate their understanding of the lab techniques (Browne, 1999).

Projects in which students identify unknown compounds in the lab have become an integral part of organic laboratories. Such projects help to eliminate the cookbook approach and encourage students to develop their own methods, enhancing their understanding. The students are actively involved in the learning process when they perform such experiments like this one. This is yet another example of student-centered teaching methods. Although organic laboratories are a great way to reinforce concepts, there are always bound to be problems (Browne, 1995).

2.5.2.1. Problems with Organic Labs

One of the most common problems with organic labs is that students have trouble relating the material in lecture to what they have done in lab. By relating the labs to the current lecture topics, the instructor can enhance the students' understanding of the material presented. One way to keep the material in the lab and classroom related is to make a custom designed laboratory manual. In a custom designed manual the instructor may present topics in a similar fashion as in the classroom, therefore the relationship between the two will be clear. In contrast, a published text book manual may vary from the order and way concepts are presented in the lectures (Browne, 1999).

2.5.2.2. Example of Problem Solving Learning

A study was done comparing students taught with the traditional approach to teaching organic chemistry and those taught with the problem solving approach. A traditional approach to teaching organic chemistry includes regular lectures and "cookbook" laboratories. In the problem-solving course students were presented with material, for example a functional group and its reactivity. They would then engage in a discussion about this topic. In this example they might discuss the functional group's reactivity and how that property may be tested. In the lab portion of the class, students were given a practical problem and a list of available chemicals and apparatus. The students then had to develop a series of experiments to solve the problem, for example a way to test for a functional group's reactivity (Browne, 1999).

The problem-solving lab not only improved students' performance but also helped students see the connection between the material presented in class and the work done in the lab. For example, if the reaction being discussed in class was E1 (unimolecular elimination) then students in the laboratory studying the dehydration of cyclohexanol (an E1 reaction) would have a more in-depth understanding of the material. It was also found that working with partners helps students learn more and embrace the problem-solving approach more readily (Browne, 1999).

Overall the problem solving lab students outperformed the students involved in the traditional style of teaching. When tested with standard course tests the problem solving students scored higher than the traditional students did (Browne, 1999).

3. Evaluation

To effectively teach a class the instructor must obtain feedback from the students. Through this feedback the instructor is able to assess the effectiveness of the teaching style of the course, difficulty the students are having with the material, and structure of the course.

In most cases, students fill out evaluation forms at the conclusion of a course. Though this is helpful in seeing if the course was successful overall, it does not help the students who just took the course. A better practice is to solicit students' opinions throughout the course. By starting early in the term an instructor can make reasonable changes to the course suggested by the students. The instructor can also get a better feel for how the students are doing with the material and therefore predict the difficulty they will have with future material (National Research Council, 1997).

3.1. Methods of Evaluation

There are more ways to evaluate a course than through written course evaluations. Other evaluation methods that give the instructor an idea of how the students are learning are one minute papers and short quizzes.

3.1.1. One Minute Papers

The one-minute paper is a good gauge of how well the students are following the material presented in class. At the end of a class the students are asked to write down the most important thing they learned, and a question, or any point of the day's lecture that was not clear to them. From this approach an instructor may see how well students are absorbing the material. The instructor may also be able to identify faults in his/her explanations based on what students write, then these problems can be addressed in the next day's lecture (National Research Council, 1997).

3.1.2. Short Quizzes

Short quizzes can be used to gain helpful information in many areas of student learning. An ungraded and anonymous quiz given at the start of a course it can be used to determine how many of the students have had the proper prerequisites for the subject material that will be covered. This gives the instructor a general idea of the pace at which the subject material should be taught at and also if additional background information should be added for better understanding (National Research Council, 1997).

If this method of short quizzes is continued frequently throughout the term it can be used as a tool to measure the students' progress. With frequent checking the students are more likely to stay on track and see connections between the material than if they are tested midway through the term and at the end of the term. With this method any indications of problems can be quickly addressed before the problems become serious learning gaps (Angelo, 1993). Thus frequent testing has two benefits: first, it helps keep the students on track with the material; and second, it helps the instructor to respond to problems quicker.

Quizzes can be used at various times for various purposes. A quiz given before the subject material is taught can establish where the students are and where the instruction should begin. Placement of a quiz during a class provides the instructor with how the students are following and processing the subject matter currently being taught. Ending a class session with a quiz reinforces the lesson covered that day. No matter what the particular placement of the short quiz is, it allows the instructor to quickly evaluate where the students are and if they need more help in a particular area to get to where they should be (Angelo, 1993).

The evaluation process is very important for judging how students are learning, for "Teaching without learning is just talking" (Angelo, 1993).

Methodology

4. Objectives

Our major project activity is to design and teach a hands-on organic chemistry class to 11th and 12th grade students, mainly through the use of laboratory experiments. We hope to achieve the following objectives. (1) To give a general overview of basic organic chemistry. (2) To prepare the students for college chemistry. (3) To stimulate an interest in organic chemistry. (4) To create an awareness of what organic chemistry is. (5) To familiarize the students with more specialized laboratory techniques than they are used to. (6) To give students a broader view of chemistry and science in general. (7) To complete the project in a cost-effective manner.

5. Methods

5.1. Selecting Course Material

We selected the course material through a careful process. Although some general concepts were selected early on for this course, such as naming and the understanding and identification of functional groups, there are still many details that needed to be addressed. There were several guidelines that we followed when selecting the material.

Since the students we taught were seniors and juniors in high school, we designed the curriculum and the lectures to make sense in the context of their previous knowledge of chemistry. Therefore, material that is too advanced, which may normally be presented in an introductory organic course, were eliminated from our course.

Organic chemistry is full of detailed rules and concepts. Not all of these are necessary to gain a fundamental understanding of organic chemistry. Therefore some of these concepts were also be eliminated from the scope of our course. Each little rule is not important; our purpose was simply to open up the students' minds to this subject.

Although it was not the sole method of selection, material also had to be able to be presented through laboratories as well. Concepts that have no direct practical application were either left out or only discussed briefly. Subject matter that involves laboratories that would be too dangerous or too costly for the situation were not included. Luckily this method of selection did not severely limit our selection of material, because organic chemistry is highly experimental, and therefore the search for hands-on applications was easily satisfied.

5.2. Selection of Laboratories

Six main elements were factors in selecting the laboratories done in for this course. These factors were relevance to material, price, simplicity, interest, environmental factors, and safety. By following these guidelines we hoped to design an effective and engaging lab program.

The most important of these factors is clearly the relevance to the material being covered. Laboratories that could not be directly associated to the material presented in lecture was not used. We discovered in our research that one of the main problems with most introductory laboratory courses is that students often have trouble relating the material covered in class to the material covered in the lab. Our labs were selected carefully, so they aided the student in understanding, rather than confusing them.

Our travel to the island of St. Croix made price an issue. Laboratories needed to be chosen and/or altered in order to make this project as cost efficient as possible. Chemicals that were readily available in the chemistry lab at Country Day School were preferred over those that needed to be purchased. This was also true for equipment. The bare essentials were be used for these labs in order to avoid large shipping charges, since materials had to be shipped both ways.

The labs that we selected had to be relatively simple. By simple we mean that the labs did not include multiple steps involving techniques that the students have never seen before. Using only a few steps that involve new techniques eliminated the need for students to rush to get an experiment done. Also, with few steps, if mistakes were made they can be fixed without fear of losing the whole experiment. Simplicity also means that the labs needed to be somewhat short (or at least each of the steps must be relatively short) in order to fit into the constraints of the forty-five minute class periods. Although an experienced student may be able to perform many of the steps in a short period of time, a beginner may have trouble learning how to use the lab equipment, therefore this had to be figured into the time constraints of the lab. Students were exposed to new equipment and new procedures in order to understand the applications of what they are learning.

One of the most important aspects is that labs must be interesting! This is often a challenge in organic chemistry. Many organic compounds are white solids or clear-colorless liquids. Therefore, it was important to choose experiments in which the reactants and products were easily distinguished from one another. We included labs that result in changes that may be identified by elementary methods. Long periods of boiling and reflux were common in organic chemistry, however these types of long reaction periods are not practical for our purposes. Perhaps one experiment involving this type of procedure may be used to make the students aware of them, but multiple experiments would not be practical considering the time constraints.

Our last guideline for selecting labs was that they needed to be flexible enough to work in a tropical environment and appropriate for the facilities we were using. Products of reactions must be stable at an elevated temperature (85-90°F). Windows ventilate the lab that we were working in; therefore chemicals and products could not attract any type of insect. One of the most important environmental concerns is that reactions could not be moisture sensitive. The high humidity in the air would not have allowed these reactions to take place. The final concern in this area was that disposal of the waste chemicals had to be relatively simple, for example they needed to be able to be washed down the drain, or disposed of in a similar manner.

5.3. Planning Classes

Class periods were carefully planned, so that class time would be used efficiently. However, we avoided trying to cram large amounts of facts into a small amount of time. Research has shown that this not an effective method. Instead, we tried to simplify the facts to clearly stated explanations. These structured and well-planned classes included lectures, interactive classroom exercises, and laboratories.

The style of lecture that we planned to use was based on the research that we have done. We tried to avoid lecturing continuously for an entire period. Lectures we planned to be short and direct, explaining the subject matter. In our plan, the material would be expanded upon in the classroom exercises and laboratories. Classroom exercise designs were be based on our research, possibly including techniques such as the one-minute paper and instructor-centered discussions. Post-lab exercises were also to be assigned to insure that students understand the purpose of the lab work.

5.4. Data Collection and Analysis

Our data was to be based on the progress of the students in our class. Students were expected to keep laboratory notebooks, which were to be collected and graded. There will also be numerous classroom assignments, and possibly two "exams". However, since the focus of this class was to teach an understanding of organic chemistry and interest the students, we hadn't planned to make examinations long or harshly graded.

Students were also to be given several evaluations in order to determine their opinion of this course and its instructors. We had planned to monitor ourselves and the students throughout the course of the project by videotaping select class periods. Upon reviewing the tapes we had planned to critique our teaching methods more accurately.

5.5. Selection of Site

The site of St. Croix Country Day School was chosen for this project. We would like to take time to explain why this site was a choice location to begin a project design such as this one. St. Croix Country Day School is a small private school located on the island of St. Croix, Virgin Islands. There is a student body of approximately 500 students from Kindergarten – 12^{th} grade. This allows small class sizes. The class size for this project should have consisted of eight students. A small class was important in a course like this one so the students may be monitored carefully, especially during laboratory experiments.

Country Day School (CDS) had shown a great deal of enthusiasm and support for this project. They had offered us equipment, a lab, a 45-minute class period every other day, and a faculty advisor. In addition to these great advantages, CDS is also the school which project partner Starla Richter attended from K-12^{th} grade. Therefore she was very familiar with the atmosphere, which proved to be a great advantage in a small school like this one.

The final aspect of the selection of this site was the students. The students who took this class had volunteered. The motivation of the students was to be very important for a project such as this, in order to develop a foundation for the material that was presented without the distraction of trying to make students pay attention. Most students are motivated only by grades and a drive to graduate; this type of student would not be helpful in a short study like this one. It was best to try to offer this class to students who wish to broaden their academic horizons. We hope that in future years this project may be continued with a larger variety of students.

Introduction to Results and Discussion

After several months on St. Croix and seventeen classes in an extra warm classroom with more students than originally anticipated we returned to Worcester and have drawn some conclusions about our project. But before we get to that we will discuss how our project progressed, including writing the manual and a summary of our daily journal. Following this is our evaluation of the project and how close we came to satisfying our original objectives.

When reading this report keep in mind that we feel no amount of research or preparation could have ever made us ready for this experience. Theories about lesson plans and one-minute papers sound good on paper, but getting students to actually do the things you want them to is a completely different story. As for student-centered discussions, they never would have worked in our classroom, we're sure the discussion would have just turned into a soccer tournament-centered discussion faster than we could have controlled it. Somewhere between writing the methodology and the results for this report our students became real people, and all the theories in the world couldn't help us out then.

At the end of our results section we have included our own personal reflections, to let our readers have a better understanding of our motivations for doing this project and how the experience has affected us.

Results and Discussion

6. Material Selected

This section includes a description of the manual (See Appendix C) that we designed and the reasons why we wrote it the way we did. The manual was used almost like lecture notes for the class, so that the students wouldn't have to spend all their time writing. However, material covered in the manual was more detailed than in lectures. This section of our paper is somewhat technical, including quite a few organic chemistry terms. So if you are not interested in organic chemistry terminology you may wish to skip this section.

6.1. Lectures

Many people tend to think of chemistry as just one simple field. They do not realize that there are many different fields of study within chemistry. This is the first thing that our students needed to understand. Therefore the opening material selected for our manual was a brief description of some of the different fields of chemistry (Physical, Inorganic, & Biochemistry). This was followed by the definition of organic chemistry, the study of carbon-containing compounds. An explanation of what kinds of compounds may be considered organic was also included in the manual.

Next, a description of the element carbon was added, including its atomic mass, atomic number, the number of valence electrons, and bonding properties. This description was selected to refresh the students' memories, and to explain some of the unique bonding properties of carbon, such as its ability to form single, double, and triple covalent bonds with itself, and its ability to form long chains and rings with itself.

After this we chose to add a section on trivalent carbon species, carbon species that only have three bonds. Trivalent carbon species are not very stable and generally only exist as intermediates in reactions. This section was selected to start students thinking about these intermediate stages in reactions rather than just the reactants and products. The term "carbocation," (a positively charged carbon species) a term that they will need to be familiar with later in the course, was also introduced here.

Now that we had introduced the properties of carbon, it was then necessary to include a section on the other elements found in most organic compounds. We chose to give them a longer list of these elements for their general knowledge, but specified in the manual the few elements they would be seeing in this course.

Once all the structural basics were covered, we then needed to select material on the "communication" of organic chemistry (drawing, reading, and naming compounds). This is an area with a lot of information to sift through. The material we began with explained that in organic chemistry molecular formulas, which include only the numbers and types of atoms, are not enough to tell the whole story. We must use structural formulas, which give information about the elements in the compound as well as the structure. But before discussing this further we explained *why* different structures would make a difference. So we selected our next topic, a brief description of isomerism.

Isomerism deals with the arrangement and position of atoms within a molecule. For this section we elected to add in examples to give them an idea of how these compounds could really be different. We chose to use the structural isomers cyclopropanol and acetone. Acetone is a compound most are familiar with. Cyclopropanol is not common and is not very stable. This contrast makes acetone and cyclopropanol a good example. One compound is something that students are very familiar with and the other, which has the same number and types of atoms, simply in a different arrangement, has drastically different and unfamiliar properties. This example was also chosen because it introduced functional groups. Although functional groups would be discussed in more detail later in the course we opted to mention them briefly at this point, and clarify which functional groups we would be working with in the duration of this course.

Once this discussion was completed we then selected material describing the types of structural formulas (full structures, condensed structures, and skeletal structures) and how to draw them. This material was necessary because the students needed to be able to read, write, and understand the structures in order to be able to communicate in the classroom. If students can't comprehend condensed and skeletal structures then they will simply waste a lot of time trying to draw all structures as full structures.

Once the background information on isomers, functional groups, and structures had been introduced we then proceeded to have a more detailed discussion of isomerism. We chose to discuss only constitutional isomers in this class, just mentioning that stereoisomers exist. A discussion of the different types of constitutional isomers was then added to the manual. We discussed both positional isomers and structural isomers. The example stated earlier (acetone and cyclopropanol) was chosen to represent structural isomers. Models were used to give the students a deeper visual understanding of the structures. As examples of positional isomers we chose two compounds the students would be working with later in the course, isopropyl alcohol and n-propyl alcohol. We selected to compare these alcohols via written structures, models, boiling points, and test tubes of them. More information on isomerism was included in *Supplemental Materials* (See Appendix C).

Since all the material involving the drawing of structures has been covered, we then needed to select the material on naming organic compounds. This is a broad topic that could take the entire length of the course to cover if not abbreviated properly. Therefore, we chose to simplify it as much as possible, and to use as simple structures as possible for examples in order to avoid the more complex rules of naming. We began the discussion by introducing the simple hydrocarbons. This also introduced the term "alkane" to the students. Instead of including all the rules of naming in the *Lecture Notes* we included our abbreviated version of naming rules in the *Supplemental Materials* section of the manual (See Appendix C).

After the basics of structures, drawing, and naming had been selected, chemical reactions were the next topic to cover. We decided that nucleophilic substitution reactions were definitely something the students needed to learn in this course. In order to introduce students to S_N1 and S_N2 reactions we determined that the best route to take would be to discuss it via the conversion of alcohols to alkyl halides reaction.

A description of alcohols was the first topic in this section. This description included the classification of alcohols as methyl, primary, secondary, or tertiary and the definition of an "R" group. We chose to include information about inductive effects and sigma bonds here as well.

After the discussion of alcohols, we then included a shorter description of alkyl halides. The description was shorter than that of alcohols because the properties of alcohols and alkyl halides are similar in the areas that we covered.

The next topic introduced to discuss reaction mechanisms was electrophiles and nucleophiles. We chose to introduce these terms by comparing them to acids and bases, something the students would already be familiar with.

Now that we had introduced all the tools that we needed to begin discussing mechanisms, it was time for us to explain what a mechanism is. It is impossible to explain this in words alone. Therefore we opted to begin this section with a sample reaction: the protonation of water, using hydrochloric acid and water. We presented the reaction taking two possible pathways, in order to differentiate between unimolecular and bimolecular rate-determining steps in a reaction. Our sample reaction was also selected because it was a substitution reaction, the type of reaction we wished to introduce to the students. In addition to the facts covered in these examples, we were also able to show students how to write a mechanism, including drawing in lone pairs of electrons, and drawing the arrows indicating the flow of electrons.

Then came our next challenge, choosing how the alcohol to alkyl halide reaction should be presented. An explanation using words alone would have been too lengthy, and in reality, insanely complex. We chose to teach this through example. Our example presented students with the following situation: *"Suppose we have an alcohol, t-butyl alcohol (2-methylpropanol) for instance, and we would like to convert it to the corresponding alkyl chloride, t-butyl chloride (2-chloro-2-methylpropane) how would we do this?"* First we introduced a pathway that would not work: the alcohol and sodium chloride. Following this we showed a pathway that would work: the alcohol and hydrochloric acid. This allowed us to explain that the proton in the hydrochloric acid is necessary for the reaction to proceed. Once we explained this we felt it would be appropriate to insert a brief explanation about the relative reactivites of H-X acids and alcohols.

The presentation of the mechanism for the reaction of t-butyl alcohol with hydrochloric acid to form t-butyl chloride and water was the next material included. This mechanism was selected in order to show students many things, including: more about the flow of electrons in organic reactions, deciding which step is the rate-determining step, what a unimolecular ionization is, what makes this reaction S_N1, and what S_N1 stands for (substitution nucleophilic unimolecular).

Now that we had introduced the mechanism for an S_N1 reaction we then needed to decide how to introduce S_N2 mechanisms. For this we selected the example of ethanol reacting with hydrobromic acid to form ethyl bromide and water. This example showed the characteristics of an S_N2 (substitution nucleophilic bimolecular) reaction.

Since these two examples standing alone did not provide all the information we wished the students to know, we included some additional information in the manual. The information included here explained that the reaction with the tertiary alcohol was the fastest because it passed through the most stable intermediate, a tertiary carbocation. Information explaining why the reaction of the secondary and primary alcohols proceeded at different rates, and which pathway each reaction would follow was also included here.

After this difficult material had been presented, we moved on to material that wouldn't be quite as cumbersome, but was still interesting. We decided to devote the remainder of the course to discussing different functional groups. We the functional groups into two sections; the first being a broad overview of some functional groups and the second section being more focused on carboxylic acids and esters.

Since there are so many organic functional groups we had to select which ones were most important for our purposes. The first group we chose to discuss was alkenes. This seemed to be a logical progression from alkanes. A discussion of alkenes also lends itself to a brief discussion of stereochemistry and elimination reactions. Alkenes are formed through elimination reactions, leaving them with a double bond between two of the carbons in the molecule. Since alkenes have this double bond there is no free rotation around it, this lack of free rotation leads to the formation of stereoisomers and more nomenclature rules. We decided that these rules were not important enough to discuss in detail in our course, therefore we mentioned what they were and showed the students the difference between the two stereoisomers using models.

The next group we selected to discuss was ethers. We chose ethers because they have a simple structure and most students have heard of "ether" not knowing that is actually diethyl ether. Many people don't realize that ether is a class of compounds, not just one compound. In this section we also chose to include a brief explanation of the nomenclature of ethers.

At this point we moved onto the main topic of discussion for this section: carbonyl compounds. First we listed the types of carbonyl compounds that we would be studying: ketones, aldehydes, carboxylic acids, and esters. Then we moved on to explain a little bit about the carbonyl carbon, the carbon double bonded to the oxygen in a molecule. First we mentioned that the bond is polarized partially, this is due to inductive effects and resonance effects. We decided that this was the appropriate place to insert information about resonance forms, but only a small amount. We included more information about resonance in the *Supplemental Materials* section of the manual.

Aldehydes were then discussed briefly. We inserted several examples here as well (formaldehyde and cinnamaldehyde). Next we chose to introduce ketones describing how they are different from aldehydes. Ketones have an "R" group on either side of the carbonyl carbon, where an aldehyde has an "R" group on one side and a hydrogen on the other, or a hydrogen on either side in the case of formaldehyde. Examples of ketones were also chosen to be included (ethyl methyl ketone and raspberry ketone).

We decided that it was then appropriate to introduce a more complicated reaction. The reaction we chose to include was the iodoform test for methyl ketones. This reaction involves the mixture of a methyl ketone, sodium hydroxide, and iodine to eventually form iodoform. Eventhough the reaction mechanism has many steps and we felt that the students would understand the reaction better if they were to see the mechanism written out, rather than to just show reactants and products.

Our final section selected was the synthesis of esters via the Fischer Esterification Synthesis. Before discussing this synthesis we needed to select the background material. First we outlined the structure and properties of carboxylic acids. Then we selected two examples that the students would be familiar with, methanoic acid and citric acid, because both of these acids may be found in nature.

Esters were our next topic to cover. Esters are fun to discuss (in our opinion) because they often have pleasant odors, may be found in nature, and may be found in artificial additives. They are commonly found in desserts and beverages to "pep" up the odor or flavor. We decided that it would interest the students if a chart of ten esters and the flavor or fragrance that they produced were produced.

Finally we came to the actual presentation of the Fischer Esterification Synthesis. We first explained that via this route esters are synthesized using a carboxylic acid, an alcohol, and a strong acid catalyst. Two sample reactions were then selected to be used as examples. Since this reaction is an equilibrium reaction it also allowed us to discuss equilibrium briefly as well. We opted not to include the mechanism in the manual, and decided to write it on the board in the classroom instead. This way the students would have to practice writing mechanisms by copying it down.

6.2. Labs

After selecting the appropriate material for the course we were then faced with the challenge of picking out laboratories that corresponded to it. We also wanted to choose labs that would teach students about new laboratory techniques, could be completed in the allotted class time, and would be cost effective.

Our first decision was to have the laboratories go along at the same pace as the material. Therefore our first "lab" was on the topic of naming organic compounds. We had many ideas about how to do this. Our ideas varied from the students making molecular models with marshmallows and gumdrops to playing a game. Our final decision was to play a game. To play the game the class was divided into two teams.

Each team went up to the board. A transparency with the structure of an organic compound was projected and as a team they had to name it and write the name on the board (or they were given the name and had to draw the structure). The game was designed this way so all students would be able to participate, but no one would be put on the spot in front of the class (See Appendix D).

After the naming section was completed it was time to decide on the "real labs." The first lab we selected was *Fractional Distillation* (See Appendix C). This lab was chosen because it introduces students to the distillation apparatus and is simple enough that it would allow students time to become familiar with the basic equipment that they have never used before (for example: wearing gloves and using pipets). The chemicals are not very dangerous, therefore students could become more familiar with equipment without being afraid of the chemicals.

Our next lab was designed specifically to fit in with our lecture. *Alcohol Identification* is a lab that is simple in regards to procedure and equipment (See Appendix C). However, students are taught how to work with concentrated acids in this lab. Concentrated hydrochloric acid is added to different unknown alcohols, and students had to draw conclusions based on their observations. This lab was selected to allow the students to make scientific decisions based on their observations, or in other words: we wanted the students to "think like scientists." This lab is very conceptual. The procedure is not challenging; the conclusions are the difficult part.

Iodoform Test for Methyl Ketones was the next lab we selected (See Appendix C). This lab was selected because we felt that the mechanism was interesting, it fit in with the discussion of functional groups, and it formed a final product very different from the starting materials. Acetone starts out as a clear liquid and the potassium iodide solution was a dark purple, but when all the reactants were combined the yellow solid product (iodoform) is formed. This lab was also chosen in order to familiarize students with the suction filtration and the melting point apparatuses.

The next lab we selected was *Synthesis of n-Propyl Acetate* (See Appendix C). Choosing this lab was difficult. We knew that we wanted to do a lab involving the Fischer Esterification Synthesis, because the procedure involves many valuable organic laboratory techniques: working with concentrated sulfuric acid, reflux, use of a separatory funnel, and distillation, but we weren't sure which ester we should synthesize. Originally we had wanted to synthesize isoamyl acetate because it smells like bananas and the materials needed, isoamyl alcohol and concentrated sulfuric acid, were already in the CDS lab. However, isoamyl acetate is the alarm pheromone of honeybees, and it occurred to us that doing this in a lab with open windows, on a tropical island, in the middle of spring was probably not such a good idea. So we wanted to find something we could make with the available materials that would still be something with a familiar odor. We tried to make n-octyl acetate first (smells like oranges). We discovered (after melting a plastic connector or two) that it distills at too high a temperature (210°C) for our purposes. Finally we settled on synthesizing n-propyl acetate (pear-like odor).

The last lab we selected was *Synthesis of Acetylsalicylic Acid* (See Appendix C). This lab did not correspond directly with the material, but was chosen because it involves a product that the students would be familiar with, acetylsalicylic acid, which has been used in pain relievers, and it incorporates many valuable laboratory techniques. The laboratory technique that this lab was selected to stress was that of recrystallization.

All of these labs were tested at WPI to be assured that they would work under some conditions. They were then tested on St. Croix to be assured that they would also be successful under the very different conditions there. All labs were successful in both locations.

7. Summary of Teaching

7.1. Final Preparation

Upon arriving on St. Croix, after receiving and unpacking our supplies, one of the first things that we did was retest all of the labs. The retesting of the labs was done to make sure all of the labs would work in the high humidity and high temperatures of the island. It also allowed us to become familiar with the equipment in the CDS lab that we had not used before, which differed slightly from what we used at WPI. All the labs worked out as planned and we received the anticipated results. This retesting allowed us to make sure that we had taken all precautions for the safety of the students. During this time we made sure we knew where all the safety equipment was in the lab in case of an emergency.

7.2. Sequence of Events

Prior to the beginning of the class we set up a syllabus to follow for the lectures and labs. This may be found in the manual (See Appendix C). For the first few classes we were on schedule with what we had put in the syllabus, but then unplanned absences and other events forced us to shuffle some of the material around and remove some material. Below is a brief summary of the actual events of the class. Our full journal may be found in Appendix A and Mr. Summerhayes' Daily Journal may be found in Appendix B.

7.2.1. Summary of Daily Journal

1st Day: March 26, 2001

Mr. Summerhayes started out the class with a quick introduction and a review of the safety features of the lab. Then we introduced ourselves and explained the purpose of the class. The manuals and lab notebooks were handed out, and at this time it came to our attention that there were ten students instead of eight. The survey *High School Experimental Chemistry* (See Appendix J) was distributed for the students to fill out to get a general idea of the students' previous knowledge of organic chemistry (See Appendix K). The material for Lecture 1: *Introduction to Organic Chemistry* was presented. The homework assigned was to read over pages 5-8 & 20-22 in the manual (See Appendix C).

2nd Day: March 28, 2001

In response to the answers given by the students on their surveys, a brief history of organic chemistry was given to clear up the misconceptions. Then the material from the previous class was reviewed. Students were then given several practice worksheets on naming to work on in partners (See Appendix F). The homework was to review for the game to be played in the next class.

3rd Day: March 30, 2001

This class began by informing the students about the lab equipment that they would be using and safety in the lab. There was a discussion of what the students needed to include in the mole table for the first lab and what it should look like. Following this the naming game was played. The transparencies from which the game was played may be found in Appendix D. Students were assigned reading on pages 28-31.

4th Day: April 3, 2001

The first lab, *Fractional Distillation,* took place today (See Appendix C). A brief introduction was given describing how the lab was to be done and the equipment involved in the lab. Students took longer than expected and the lab ran over the allotted time period. All students stayed to complete it. Reading on pages 9-12 was assigned.

5th Day: April 5, 2001

Today started out by asking if there were any questions on the lab performed in the previous class, there were none. The lecture on *Introduction to Reaction Mechanisms* was then presented (See Appendix C). The homework assigned was to re-read pages 9-12 and come up with two questions, which would be collected the next class.

6th Day: April 9, 2001

Half of the class was absent today. As Starla collected and read over the questions a few of the students had written, Jeff explained the procedure for the *Alcohol*

Identification lab (See Appendix C) and passed out the *Alcohol Identification Corrections* worksheet (See Appendix E). After Starla replied to the questions the students had written, she presented the second part of the mechanisms lecture. Homework assigned was to read the lab and prepare a mole table for it.

7th Day: April 11, 2001

The students began their second lab today, *Alcohol Identification* (See Appendix C). Before beginning the lab procedure was reviewed. Then it was time to check the students' mole tables before they began the lab. It turned out that the majority of the students had not filled in their mole tables, thus the lab was delayed while the students completed them.

8th Day: April 17, 2001

Today a few students wanted to continue working on the *Alcohol Identification* lab. So the class was divided in two groups: Jeff took the students who wanted to continue working on the lab and Starla took the other students to review naming and isomerism. Students were given the assignment *More Work With Alcohols* as homework (See Appendix G).

9th Day: April 20, 2001

The alcohol homework assignment was due today. Several of the students did not do the assignment, but the majority did complete the worksheet. The students exchanged worksheets and the answers were reviewed and corrected as a class. After the homework had been collected the lecture on *Functional Groups* was presented. Homework was to read the next lab and prepare the mole table (See Appendix C).

10th Day: April 23, 2001

Today we were prepared to have the students work on the third lab, *Iodoform Test for Methyl Ketones* (See Appendix C). But to our surprise only 5 of the students showed up. Since 5 lab stations were already set up it was decided that each student would do the experiment by them selves. We handed out *How To Pass This Class*, a list of requirements the students needed to fulfill to pass the class, and it was discussed (See Appendix E).

11th Day: April 25, 2001

Today the lecture *Esters and Fischer Esterification* was presented (See Appendix C). The homework was to study for the *Quiz*.

12th Day: April 27, 2001

Today the students were given the *Quiz* on naming, mechanisms, reactions, and all the material in the first two lectures (See Appendix H). Three of the students were absent. The students were given a worksheet on classifying organic compounds to complete as homework. Students were also told to read the lab and prepare their mole tables for the next class.

13th Day: May 8, 2001

School cancelled because of heavy rains and flooding. The day was spent at home planning the remainder of the classes out.

14th Day: May 10, 2001

This class began with a demonstration of the proper way to use a separatory funnel. The students then worked on the first part of the *Synthesis of n-Propyl Acetate* lab (See Appendix C). The students were assigned homework dealing with esters.

15th Day: May 14, 2001

Today the students worked on the second part of the *Synthesis of n-Propyl Acetate* lab. We informed the students when all material for the class was due and what the plan was for the remaining classes. The final exam format was also discussed. *Review for Final* was given out for the students to complete as homework (See Appendix G).

16th Day: May 16, 2001

First: the three students who had been absent for the *Quiz* were sent to the library to take it. Students were informed that they had to receive a 50 or greater on the final to pass the class. The students were also told that the last day to hand in their lab notebooks would be on May 29th.

17th Day: May 22, 2001

Today the final exam was given to the students. There was one student absent.

18th Day: May 24, 2001

The students were given a number of surveys to fill out today.

Final Wrap-Up: May 30, 2001

Although Jeff left St. Croix this morning, there was still a pizza party for the students. Awards were given to the students who had done well, achieving high averages and turning in excellent notebooks. The student absent for the final took it on this day. Students who had not yet turned in assignments or notebooks turned them in as well.

7.2.2. Attendance of Students

One of the main reasons for all the changes with the scheduling was to adjust for the unforeseen absences that occurred. For the first four classes there appeared to be no problem at: all the students showed up with one exception of someone being sick. But the fourth class one student informed us that he would be absent the next three classes because of a soccer tournament. The next class, five of the students were absent due to a quiz bowl event. Then the sixth class a student informed us that he would be missing the next four classes because he was going to look at colleges. These absences were unfortunate but at least we had some notice that they were not going to be in class. This was not always the case though; one lab day we were surprised when class started and there were only five students instead of the ten we expected. We continued as planned and did the lab with the students that showed up, but it became a big challenge trying to schedule a make-up time for everyone that had missed the lab. It was a project in itself trying to keep track of who missed what and when they could make it up. After the first few classes there were only a couple of classes where all of the students were present.

7.2.3. Grading System

Being students ourselves we wanted to take special care in selecting a grading system for this class. We didn't want to put any unnecessary pressure on our students. Therefore our original plan was to use an effort-based system.

On the first day of class we told the students that if they participated and attempted to do their assignments then they would pass the class. At this point we were assuming that we would be using a letter grading system. In our minds we wanted them to put forth an honest effort, and for it we were planning on giving them A's.

After the first few weeks of class it became very obvious that students were not doing their work ahead of time. In many cases students were not even attempting to do the assignments at all. They would come to class without a mark on the paper and say "I didn't understand." The readings that were assigned were ignored by 90% of the class on most occasions, making lecture much harder to go through. This lack of effort made it clear that our "ideal" effort-based system was not going to work, because we couldn't fail 70% of the class.

One of the requisites of the class, printed very clearly in the manual, was that lab notebooks were due *every* Friday before 3:00. After several weeks a few students quit turning in their notebooks. This struck us with the realization that we may have to fail several students. Around this time the possibility of turning this class to Pass/Fail was discussed with Mr. Summerhayes, and confirmed by the dean.

It was clear that the course grading system needed to be more organized and strictly enforced. This was a disappointment to us, but we knew we had to set some grading standards. By having a set grading system, Pass/Fail, we were able to make a set of standards for the students to follow. We printed out a list of four requirements, *How To Pass This Class*, that the students had to meet, and distributed it to the class the following day (See Appendix E).

Once the students realized that the class was only Pass/Fail those that were doing poorly put in a little more effort, and a few of the students doing well put in less effort. One student stated in a survey "I would have studied a little harder if this class were graded rather than pass/fail." As the course proceeded effort was definitely at a low.

One of the requisites for the class was to *take* all exams and quizzes. However, as the final neared, we were sure that if all the students had to do was take the test, then there would be no effort put forth at all. Therefore we set a cut off for the final exam. Students had to receive a 50% or above to pass the course, as well as meet all the other requirements. Doing this assured us that all the students would study to some degree. We were pleased when all the students did score above 50%, even those that had put no effort forth up until that point.

As the final grades were written up, it was somewhat disheartening to have to give the same grade to students who put in maximum effort to pass and those who had put in the bare minimum to pass. Two students failed this course, one because he did almost nothing the entire duration of the course or in his words, "I put as much effort forward as I do when I get dressed in the morning, and if you have seen what I wear you would get the idea," and the other because he simply did not turn in his lab book the last time. Individual students' grades and report card comments are included in the Appendix M. Also, sample student work may be found in Appendix I.

7.2.4. Evaluations

The survey that we distributed to the students on the first and last day of class, *High School Experimental Organic Chemistry,* was intended to gauge several things (See Appendix K). First of all, we wanted to find out what kind of background the students had and what their perceptions of organic chemistry were. Our hope was that if in the beginning of the class they didn't know what organic chemistry was, then at the end of the class they should at least have a better idea. We also designed this survey to give us an idea as to whether the students had been given a broader view of chemistry in general. In this survey we added a question to determine whether or not students knew what the practical applications of organic chemistry are. A question about personal interest was included to measure whether the interest of students had grown throughout the course.

The overall course evaluations (*Course Evaluation, Written Response Questions, Teaching Evaluation: Starla,* and *Teaching Evaluation: Jeff*) were designed with many objectives in mind (See Appendix K). Before discussing the subject matter we will briefly describe the general format of the four surveys. The design of the *Course Evaluation* was very similar to the WPI course evaluation (i.e. agreeing or disagreeing with a statement). In writing the statements we tried to make them as clear as possible. Throughout the survey the subjects of the statements were varied so that the students would not get tired of one type of question. After the rating section we added a section where the students were to place the subject matter from easiest to hardest (fill in the blank). Our next survey was *Written Response Questions.* This survey consisted of nine questions where the students would be allowed to express their ideas and concerns more clearly. Next, *Teaching Evaluation: Starla* and *Teaching Evaluation: Jeff* combined the rating system and written response formats.

The questions for overall course evaluations were selected for many different reasons. Several questions were selected in order to get an idea of how challenging the class was for each individual student. We also wanted to get an idea of whether they thought the presentation of the material in the manual and in class was clear and understandable. Another area that we explored in these questions was whether or not the labs enhanced the course (were they appropriately placed? did they relate to the material?). Many of the questions were intended to probe the students' personal attitudes towards the class, and how much effort they put into it. Some questions were also included to see if the students found the classroom atmosphere was appropriate. Questions on the *Teaching Evaluations* were intended to establish what effect we, as the instructors, had any effect on the success or failure of the project.

The summaries of the results from these evaluations may be found in Appendix K and L.

8. Discussion

8.1. Preplanned Objectives

8.1.1. General Overview of Fundamentals of Organic Chemistry

Our first objective going into this project was to give the students a general overview of organic chemistry. We can examine the success of this goal by looking at the manual, to see if it covers the fundamental topics of organic chemistry. To obtain a more professional opinion on the matter we consulted several organic chemistry professors at WPI. One professor commented that he believed that the manual was well organized and felt that the "Question-Response" format was a good approach. They felt that the appropriate material was covered. One professor commented on word choices, but there were no major objects to the manual's organization or content.

8.1.2. Prepare Students for College Chemistry

Our second objective was to try to prepare students for college level chemistry courses. We tried to accomplish this task by designing the course similar to the way a college level course is taught but keeping in mind that the students only had a background of high school chemistry. One of the main differences between a chemistry lab in high school and a chemistry lab course in college is the use of a lab notebook. One student stated, "I enjoyed learning new material and working with new lab set-ups. They gave me a better understanding of college level lab procedures. Also, I have a concept of what is required in a lab book." We not only taught the students the proper way to set up the notebook, but also about how to record their procedures and observations *as* they performed their labs. This will not only help them in future chemistry classes but will also be valuable in any scientific field of study. No matter how rarely the students turned in their notebooks, when they did, their observations were very thorough and properly recorded. As the course progressed their notebooks improved. Another student's comments seem are related to this, "The lab entries seemed tedious in the beginning, but gradually grew more systematic and easier to complete."

8.1.3. Stimulate Interest in Organic Chemistry

Our third objective was to stimulate the students' interest in organic chemistry. We tried to accomplish this by making the presentation of the material as appealing to the students as possible. However, just as Roger Summerhayes's daily journal states "all a teacher can do is lead the horses to water and try to make the water attractive to drink. The teacher then must faithfully measure out how much (or how little) the horse did drink." Based on the student responses we would say that very few of them were interested in pursing organic chemistry after completing this course. In response to a question about how much the students felt they had learned one student shared this with us: "I have learned that under no circumstances will I be taking any science courses, especially chemistry, ESPECIALLY ORGANIC in college. I have also learned that organic chemistry is no fun."

8.1.4. Awareness of Organic Chemistry

Our fourth goal was to develop the students' awareness of the nature of organic chemistry. We can use the First Day/Last Day Survey, *High School Experimental Organic Chemistry*, to prove the success of this goal (See Appendix K). Many students began the course thinking that organic chemistry was the study of living systems. At the end of the course many understood that organic chemistry is the study of compounds containing carbon and that is has many practical uses in the world around them, as in synthesis of pharmaceuticals, food additives, and in oil refinement. Nearly every student listed appropriate uses of organic chemistry by the last day of class.

8.1.5. Familiarize Students with Specialized Lab Techniques

Our fifth objective was to introduce students to new lab techniques and equipment. The class was designed so each of the labs would show the students a fundamental technique used in an organic laboratory. According to the surveys the students filled out, they strongly agreed that they had learned new lab techniques. One student commented, "I felt like I have learned a lot more lab techniques (which is more interesting than learning straight from the books!)" The students also felt that they had learned how to use the equipment associated with organic laboratory. Another student commented "I liked the information and also the privilege to use the lab equipment. It looks like what you think of when you see a mad scientist in his lab. Also the purple gloves were a plus." Their lab notebooks, especially the post-lab questions may be used to indicate how much the students had learned. During lab students would ask questions involving theory rather than procedure, which showed that they understood the principles behind the lab. Walking around the classroom during lab periods we could hear the students discussing and explaining different parts of the lab to each other. The students seemed to grasp and retain the knowledge that they learned in lab. The final exam was a test of this, it contained a section on lab setup and general questions about laboratory principles. All the students did particularly well on this section of the exam.

8.1.6. Give Broader Overview of Chemistry and Science

The sixth objective was to give the students a broader view of chemistry and science in general. We believe that this was successful. One of the questions on the First Day/Last Day Survey was *"Do you know of any other branches of chemistry? Can you* *name a few?"* Eight out of the ten students were able to name more branches at the end of the course than at the beginning. Two claimed to have known none at the beginning and none at the end. Comments from two other students demonstrate our success: "I feel that I have taken my previous knowledge of chemistry and applied it to a new branch." "I have taken chemistry courses prior to this course, but the chemistry class I took was not thorough. This made me feel stupid in class, but this class gave me a better understanding of chemistry." Throughout the course there were times that the instructors, and Mr. Summerhayes, would mention other branches of chemistry and their relationships to organic chemistry (for example: rates of reactions are related to kinetics and thermodynamics).

8.1.7. Cost Effective

Our final objective was to keep the project cost effective. In order to minimize our expenses we explored many options. The first thing we did in order to accomplish this was to try and alter our experiments to use the chemicals that were already at CDS. We explored alternatives to using expensive equipment (or equipment that would be expensive to ship). One way that we planned to do this was to *very carefully* use Bunsen Burners in certain experiments rather than hotplates. Certain equipment and chemicals were donated by different sponsors (WPI, CDS, and Hovensa). We also practiced thrifty shopping when purchasing other supplies for the course once on STX.

9. What Really Happened

Based on the results of the surveys we have drawn some conclusions. We feel that it is important in some cases to relate how well a student may have done in the class to the answers that they gave. Although the students believed that the surveys were given anonymously some students did not answer questions in agreement with their performance in the classroom.

9.1. Communication

The first thing we need to establish in discussing the effectiveness of this project is whether or not the students understood what they were getting into from the beginning. Our surveys revealed that the students believed that they were well informed as to the purpose of the class, and also they were well informed about what material would be covered on their quiz and exam. "They gave me the information in the notebooks, games were played in class, and worksheets helped prepare for the exam and the quiz." Seven of the ten students stated that they felt that their instructors had prepared them properly for the exam. Many of the students stated that the material was properly covered in class. Therefore, there was no element of surprise in dealing with the subject matter covered and it was communicated clearly.

9.2. Class Time

Since it is clear that the students knew what was expected, the next issue to address is the use of class time. Nearly all the students agreed that the material was presented in a sensible order, and that class time was used efficiently. One may also wonder whether or not the classroom atmosphere was appropriate, since two college students were teaching ten high school students, relatively close in age. One question in our survey showed that all the students either didn't show any concern for this or felt that the atmosphere was appropriate. We examined one more part of the classroom atmosphere asking students whether they felt too intimidated to ask questions, the surveys showed that they did not.

9.3. Material

As for the difficulty of the material there were mixed feelings among the students. Most students either did not seem to have an opinion on the matter or did not think the material was too hard. However, two students did feel that the material was too hard: one of these students was the one who did no work until the very last minute and his mother forced him to do that small amount, or in his words "The only effort I put forth was at the end because my mother made me."

9.4. Manual

The students' only resource outside of the classroom was the custom made manual. Although the instructors and professors at WPI felt that this was an easy to follow booklet for students to consult, perhaps the students did not feel this way. Only six of the ten students claim to have actually spent the time to read the manual, and of those six students two of them did not think that it was presented in a clear and easy to understand fashion. But out of all the students, six students felt that the manual was easy to understand. Eighty percent of the students felt that if they had questions then they could consult the manual and find an answer. From this we draw the conclusion that the manual was generally helpful to the students and that it would not have been possible to write a manual which appealed to all of the students.

9.5. Homework/Quiz/Exam

One of the ways we tried to prepare students for exams was to give them homework. All material on the quiz and test was covered in the homework assignments. This is a question that we did not *need* to ask the students, since we wrote both the homework and the tests. We did ask the students anyway, to find out how much effort and attention they gave their homework. Sixty percent students admitted to having put an honest effort into their homework assignments. The general feeling we got from the surveys was that the homework did aid in their learning of the material and that it also helped prepare them for the quiz and final.

9.6. Lab Correlation

Since we have now discussed all these issues we now get to one of the main purposes of the project: Did the hands on approach to organic chemistry help stimulate their interest and aid their understanding of the material? One hundred percent of the students saw the correlation between the material presented in class and the labs. One student said "...you could apply what you learned from the book to actually doing something." This is one of the problems that we had wanted to overcome since our research had indicated that the most common problem with organic laboratories is that the students had trouble seeing the correlation between the material in class and in the labs. Did the correlation help the students understand the material in depth? We knew that the labs alone could not make the connection clear. We had to develop a way to relate the labs to the lecture material. This was done with the post lab questions. Aside from what the students believed, the questions did actually make them think more about the material that they had learned in class. The average opinion of the students stated that they didn't have any particular feelings about the helpfulness of the labs. However, four of the students found the labs helpful and one student found them extremely beneficial. Most students did agree that the labs challenged them to think about the material. "I didn't understand the material until I asked more questions in order to answer the questions in the lab notebook." The results that we found from the written response questions were similar. Seven of the students found that doing the labs and answering questions allowed them to have a more in-depth working knowledge of the material. One student stated "The labs helped me understand the material that had been previously taught. It helped me 'see' what everything did and made much more sense."

9.7. Other Lab Issues

If the labs did not help one might wonder where the fault lies. It could lie in the instructor. The problem could be one of uninteresting labs that relied on old and boring equipment. Perhaps the students did know how to use the equipment. Maybe students didn't like working with lab partners. From the surveys we found that none of these were a factor. All students were exposed to new equipment and laboratory procedures, and this interested them more in the labs. In response to what they liked best about the lab portion of the class a student replied, "I have been exposed to new equipment." It is also worth mentioning that the students were all very excited that they got to wear purple gloves. All students believed that their instructors showed them how to use the equipment properly. As for the issue of lab partners the class was greatly divided. Some felt that lab partners helped, others felt they hindered, and many had no preference. One student stated in her written response questions "Some of the labs could have been done by rotating partners instead of keeping one partner for the entire quarter." We toyed with the idea of allowing students choose their own partners before we began teaching the course, but we followed the advise of Summerhayes and allowed him to select the best suited pairs of partners. These issues do not seem to be the ones that greatly affected the results of our project.

9.8. Time

We had several major obstacles to overcome for this project. The first and most important one was time. Lack of time was what caused our project to not be as successful as we had hoped. We began the project with a very limited amount of time. Eighteen forty-five minute class periods were not enough time. Given that limiting factor we also had to account for days lost when not all the students would show up to class, or when no one was prepared for a lab and it therefore had to be prolonged an extra day, or the day that the school was flooding and classes were canceled. The forty-five minute class period caused problems as well. Most organic labs cannot be done in such a limited amount of time.

As the instructors, we knew that our limited time was a problem and tried to keep to our schedule, but we also did not want to sacrifice the quality of our teaching. We tried to press on at a reasonable pace when confronted with different obstacles. Even this pace was not as slow as we would have liked. We were eager to have the students do the labs and we were tempted to shorten lectures and eliminate lab notebooks in order to give the students more time to concentrate on the actual lab, but we quickly realized that there would be no real academic gain from this situation. As the end of the quarter neared we could see that there was clearly not going to be enough time to fulfill all the plans in our syllabus. We thought about what we had left. There were five days of class left, and we needed six in order to complete the two labs. In the end we decided to eliminate the final lab and take the leftover days to give a final exam and fill out course evaluations.

The students were also frustrated by the lack of time. Although the students all felt that there was adequate time for each lab, we felt that they were cheated out of some important lab experience by not having to set up their own equipment (or clean it for that matter!). On the survey half the students stated that there had not been enough time to learn the material. Many students commented on the fact that a lot of material was taught in a short amount of time. The students' frustration with the lack of depth was apparent. They would ask for more explanation on certain topics, and there was no way to answer their questions without taking another 45 minutes of class time, if not more, to give them all they wanted. Students suggested that having the class everyday would have been beneficial and would have helped to hold their interest more than a class that was only every other day. One student stated, "...offering this class everyday would have stimulated more interest."

9.9. Timing

Another obstacle was the fact that we taught this class the last period of the day in the last quarter of the school year. The fourth quarter of the school year at Country Day School is dotted with holidays and other commitments (See CDS calendar in Appendix N). Time was taken off for the Easter holiday. There was a week off for Mini-Gusto (a kind of career/activity week). One student was gone for a week at a soccer tournament on another island. Another student was taken out of school for two weeks by his parents to look at colleges in the states. Several students were consumed by the school musical. Plus there were still many other little problems that sprung up during the course of our project. These caused our classes to be inconsistent, and we also lost class days because of these things. Twice during the quarter only five of the students were in class. Class was carried on as usual on these occasions, but teaching only half the class caused confusion and those that missed the lecture or lab would complain or fall behind.

9.10. Academic Credit

One of the other frustrating issues that we had to deal with was the amount of credit that this course was worth. It was worth less than a quarter of a credit, which is less than their gym classes are worth. Only the most dedicated students would be willing to put forth effort in such a situation. We have two student quotes that show their feelings quite clearly: “I only studied because I knew I could pass without much effort. There were other classes that were more important to me.” “…because of the lack of interesting material coupled with the small amount of credit awarded for passing this course I put in little to no effort.”

9.11. It’s Not All Bad

We are aware that many of the comments sited have been negative and don’t view our project as successful. But there were students who did enjoy the class, and left with a postitive attitude about it, and the instructors. One student commented, “In general I enjoyed the class and the instructors did a magnificent job, it was me who didn’t put forward the effort.” Another student made this comment on the *Teaching Evaluation: Starla*, “…she showed us that she understood and in turn taught us as if we were WPI students ourselves.” Another student stated that they “found her [teaching] very effective.”

On the *Teaching Evaluation: Jeff* one student stated “Jeff knew what all the lab set-ups were about and explained [to] us how to use them very effectively.” Another student said, “Jeff’s mode of instruction was flawless.” And Jeff’s personal favorite student comment was “Jeff is god, and should be head of all lab procedures. He NEVER gave homework.”

These comments show that there was definitely a positive attitude from the students about the course and the instructors. The students also left this course with a positive feeling about WPI and its project program, or as one student commented on their survey, "WPI Rocks… I think that the teachers were well prepared and very professional."

10. Our IQP: Take Two

As we went through this project it continually occurred to us how we would do things differently if we had the chance to do it again. Therefore we have suggestions for anyone that may wish to do this project again in the future.

The first issue to address is the material. We believe that we have designed a very solid program in regards to the material and labs selected. DO NOT try to write your own manual… this is an IQP in itself. We offer this manual to students who wish to attempt the project again. However, in the event that anyone does wish to use this manual again, we request that we are credited as the authors of the manual.

The selection of site is really up to the students pursuing the project. St. Croix Country Day School is now completely equipped to run this project again. All the materials are already there, with the exception of water aspirator traps and heating mantles, which we shipped down. St. Croix may not be the choice spot for other students to run this project. It is far away and accommodations would be difficult to find. It could be done, but there are many logistical issues to be addressed.

In selecting the sight there are a few issues that the instructors may wish to consider. We selected St. Croix Country Day School because it was the school which Starla had attended. The administration and faculty were very interested in and supportive of the project. Starla was very familiar with the school, which was positive and negative. Right now, we're going to discuss the negatives. Because of the size of

CDS (approximately 100 high school students & 500 total students in K-12) many of the students were familiar with Starla already. Therefore it was difficult to capture the respect of these students. However the presence of an authority figure that they already knew (Mr. Summerhayes) was an essential and indispensable part of this program. Based on this we suggest that this project be done in a location where there is a great amount of administrative support, but where the students are not extremely familiar with you as a fellow student.

The timing of the project could have many possibilities. We will discuss our favorite set-up. This would be a summer program running two to three weeks, about five or six hours a day. In the morning have an hour or two dedicated to lecture and written activities. The afternoons could include the laboratories. This would allow time for the students to learn how to set up, break down, and clean their own equipment. Students wouldn't be rushed through everything. If time had allowed we had also intended to include the following either as labs or as demonstrations: *Silver Mirror Test* and *Preparation of Soap*(See Appendix O). Also we believe that more hands on work should be done with molecular models. A lab or activity involving the building and naming of models should be done as well.

Lastly, if performed during the school year this course should be offered for some significant amount of academic credit. We found that students put little effort forth in a course that they are not getting a lot of credit for. Also, the grading system should be rigid. Pass/Fail is not a good idea. Our students needed more motivation, and therefore probably more graded assignments as well.

11. Reflections: Jeff

Going into the first class we had the greatest expectations of the students in the class. These students had volunteered to take this class and did well in their other academic courses, meaning that they had wanted and were interested in taking this class. After the first class it was hard to judge the reactions and feelings of the students because this was new to everyone. The students were rather quiet which is expected on the first day.

As the course progressed, however, it was disappointing to see the students come to class without any of their homework done. We did not overburden the students with work, so it should have been easy for them to complete the assignments. But this was not the case most of the time. In part we are to blame for not being stricter with the assignments. This brings me to a lesson that I think that I will carry away from this project. The lesson is, if you want the students to remember or to do an assignment write it on the board. Even though the majority of the students in the class maybe auditory learners and only a few visual, if you write an assignment on the board there is a better chance that the students will do the assignment. I think that students have it implanted in their minds that if it is important enough for the instructor to write it on the board than it must be important for the student to learn and the rest of the material not written on the board must not be as important.

I think that some of the problems in the class stemmed from the fact that the students still viewed Mr. Summerhayes as the primary teacher. From my past experience observing student teachers teaching classes the students usually do not give the respect and attention that they should. I think that they feel that that the student teacher is not as qualified as the regular teach to teach. Instead of looking at who is instructing the class at the time the students look to who usually instructs them which happens to be the primary teacher.

I was disappointed to see the students not even put forth any effort towards the class work at times. It was also frustrating to come in to class prepared to do a lab and find that the students had not done their part in preparing for the lab.

Despite this disappointment, it was a good feeling to know that the students did get something out of the class. Even though they didn't do their homework assignments, the discussions that they would have in lab about the material proved that they had absorbed the material. Even though the students did not put forth a worthy effort outside of class in class the student were very focused. I think that overall we did accomplish what we set out to do. The students did learn introductory organic chemistry.

The end result is that I would still consider becoming a teacher after retiring from industry. I think it is hard to judge exactly what it is truly like teaching without having students of my own from the first day of the school year until the last day of the school year.

12. Reflections: Starla

When I was little I used to make homework assignments and tests for my dolls. I would sit them down in rows like in a classroom. I would teach them how to add and subtract and spell, and as time went on their lessons grew more difficult. They were the best students; they did their homework, and paid attention (except of course when my brother's GI Joe's would burst in and my dolls had to go into hand to hand combat). The point is… I have wanted to be a teacher for a long long time.

Throughout my years as a student I have always been a peer tutor of sorts. I enjoy helping students to understand. To see someone smile when they finally "get it" has always made me feel wonderful. The three greatest influences in my life have all been teachers. When I was a senior in high school I still wasn't sure what to study in college, which at the time seemed like a big problem. But as I went to chemistry class every day I found something that I truly thought was wonderful. I decided then that studying chemistry was what I wanted to do. People discouraged me from pursuing a career in teaching because everyone says, "there isn't any money in teaching."

Once I came to college and told people what I was studying most showed repulsion. So many people claimed that they hated chemistry because "I had a terrible teacher." This made me think back to my time in high school and what a great teacher I had. I thought that if everyone had such a great teacher then perhaps they would be more passionate about what they are learning. And I felt strongly that I could be a good teacher, and I figured the country could use one more good teacher.

As I studied chemistry here at WPI I decided that organic chemistry was what I loved best. I thought that if I could just find a good way to explain it then others would love it too. So I set about my task. My IQP was the perfect opportunity to test this out. I decided that going back to Country Day School for a term and teaching a course there would be the best way to do this. I searched out a partner, and I convinced him that this would be the easiest IQP ever, and I believed it was going to be.

After almost a year and a half of planning we were ready to go. But before I talk about that I would like to just take a few moments to explain what kind of operation this really was. I started out with TONS of material to sift through. The subject matter for the original course was about five times greater than the final selection. The manual went through many revisions. Also, I went through a great deal of trouble trying to get this project off the ground. A few professors told me that it didn't sound like a solid plan and it wouldn't work. In a meeting with my sufficiency advisor I told him of my difficulties trying to get my IQP started, and that I was considering dropping the whole idea and just doing a preplanned project. He didn't agree and urged me to continue on, so I went on with the plan. Obviously in the end all the details worked out because you are reading this in the final report.

By the time we arrived on St. Croix, we had received so much support for this project (from WPI, CDS and Hovensa) that we assumed that everything was going to work out. Why would so many people and organizations offer their support to something that didn't seem like a good idea? We set up the classroom for ourselves during the spring break at CDS, anxiously awaiting our first day of class.

Day 1 arrived and class began. The introductions went fine and the students seemed pleased with their brand new manuals and lab notebooks. But as I stood in front of the class to deliver my very first real lecture, I couldn't stand having them glare at me with obvious irritation. It wasn't that I was nervous having people watch me, I have been on stage a great deal in my life, but it was that I could tell that they hadn't wanted to learn anything on their first day of class. I felt like every minute was an hour. The room felt dead silent, even as I talked, I felt like the words were being sucked into some void. As the class progressed that day the students asked a few questions. I breathed a sigh of relief when the bell rang and they shot out of the class. We assigned reading for homework, but weren't too strict about it.

The next class we did naming exercises, which would have gone more quickly and smoothly if they had done their homework. I knew almost none of them did. It was my first smack of reality. As Mr. Summerhayes and I circulated the room answering questions about naming compounds, I noticed that their inclination was to call for his help over mine, which is understandable considering the circumstances, but it was discouraging none the less.

The next class gave me hope for the future of the course. The students played the naming game and seemed to enjoy and understand what was going on. I had a positive feeling about the rest of the course. However, as the classes went on, and students came to class unprepared my hopes went back down.

I had wanted to allow them the freedom of taking a class without strict homework assignments or a rigid grading system. But it became apparent that we could not do this. I also wanted to help every student who struggled in the class, I wanted to reach out and force them to accept my help. But in order to keep myself from being overwhelmed and going crazy I made it my policy to offer my unlimited help to those that asked for it. Basically, all they had to do was ask. And you know how the story goes, they didn't ask.

I felt a great deal of emotional strain when I came to the realization that I couldn't force the students to do the work I assigned and that I was going to have to fail a few students. At night (which I spent working at a local restaurant) I was frustrated from a day of dealing with the "attitude" I received from some of the students. One student in particular gave me a nasty glare almost every class for the first five weeks or so. In short, the class created a lot of stress in my life.

In addition to all of this I was also upset by the fact that the students developed a friendlier attitude towards my partner. I felt cheated out of the students' affections since I had put so much of my heart into this course. This course was not just a project for me, it was a trial run. I wanted to test to see if I could be a good teacher. But regardless of whether or not I was capable of actually teaching the material, I don't know if I could handle all the other requirements of being a teacher, the ones you will never read about in any teaching book.

How could these students, who I cared so much about and only wanted to show them a little bit about something that I love, not put any effort forth and perceive *me* as the "bad guy"? It was too frustrating. What is a teacher supposed to do when a student who is only trying to be funny, and isn't being offensive, is just taking up too much of your class-time? I didn't like having to tell students to sit down and be quiet, I wanted them to behave on their own, so I wouldn't have to be the bad guy. What are you supposed to do when you see that one student giving you the "evil eye" every day?

There were so many issues that disheartened me during the course of this IQP and poor Mr. Summerhayes had to bear the brunt of it, as he listened to his former student (me) babble about her concerns of being a poor teacher. His notes outline the situation best. He was a wonderful mentor to have for this project; his advice was very insightful, and calming in those more hysteric times.

I wish I had some solid conclusions about what I have learned, and advice for anyone that wants to be a teacher, but I don't. I am still not sure if I was a good teacher or a bad teacher in the eyes of others. I remember reading a few brutally honest comments from students on their evaluations, one in particular. In response to the question: *What did you dislike about this class?* He wrote, "The material, the way it was taught, and the unreasonable amount of work required to pass a class worth .13 credits. I found the material boring and loathsome. The only way it would have been tolerable would have been if the instructor was fantastic and she was not. Personally, I like Starla a lot and we get along pretty well but I don't think that she is a very good teacher." Not all the good comments in the world would change the way those few made me feel. From my experience I want to say that you can't have too much heart if you want to be a teacher, but I know that just isn't true.

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APPENDIX TABLE OF CONTENTS

Appendix A

Daily Journal

1^{st} Day March 26, 2001

The class began with an introduction from Summerhayes. He reviewed the safety features of the room with the students. After this was completed he turned the floor over to us. We introduced ourselves and explained our background. Starla briefly explained the purpose of the class and that it is an experimental study. Jeff and Starla explained what their individual role would be in teaching the class. Then we handed out the manuals and lab notebooks. By this time we had discovered that there were ten students in the class rather than eight, as we had originally thought there would be. Immediately after this we handed out the surveys, which gave us a general idea of the classes background knowledge of organic chemistry.

Starla then presented the material in Lecture 1: *Introduction to Organic Chemistry*. There were very few questions, aside from questions involving the interpreting of structural formulas. For example: *In skeletal structures how do you show that there is something other than hydrogen or carbon?* There were also questions involving organic vocabulary, what does the "ane" mean at the end of methane. The students appeared uncomfortable and were mostly quiet. The material in the lecture was covered and there were still fifteen minutes, so the students asked to continue on and begin covering naming. We asked students to read over pgs. 20-24 in the manual before the next class, but they were not *required* to do the problems within those pages. By which we mean that they were not specifically assigned as homework.

After class we had to figure out how to resolve the problem of more students than we had manuals and notebooks. We had brought ten report covers for the manuals with then intention of making one for each of the eight students, one for Summerhayes and one for Jeff. So we simply used the extra printed manuals for the two students. However there were only eight lab notebooks. Therefore we went to K-mart and sifted through the notebooks there. We found only two suitable ones that did not have Pokemon on the cover. Luckily we had brought enough lab materials with us because we wanted extra to be prepared in case anything was broken.

Upon reviewing the surveys that the students had filled out we discovered that students had many of the classical misconceptions about organic chemistry. They thought that it was the study of compounds from "organic" sources (plants and animals). But most of them had actually no idea what organic chemistry really was. And many students did not know what different fields of chemistry there are.

2^{nd} Day March 28, 2001

The class seemed more comfortable this time. Starla began class by clarifying what organic chemistry really is, and described a little bit of its history. Then we handed out sheets to work on naming, the sheets that were distributed were "Practice Sheet: Isomerism" "Practice Sheet: Naming" and "Practice Sheet: Naming #2." Before the students went to work on the sheets we reviewed the material covered at the end of the previous class. The students then went to work with their partners on the worksheet "Naming." After a few minutes it became painfully clear that not a single student had read the assignment. While working on the sheets, students used their manuals to aid them in answering the questions. As the students worked we wandered around the room to answer their questions (Mr. Summerhayes did this as well). Most students did not complete the first naming worksheet, however, two of them completed it and moved on to "Naming #2."

3rd Day March 30, 2001

This class was video-taped. Jeff began the class by discussing some of the details of the lab work. These were the points he reviewed:

Lab Stuff: Safety and Equipment

- Each group will be assigned a lab kit, every single piece of glassware is expensive… so please be careful, the flask heaters are also costly
- When handling chemicals, always wear gloves
- All small volumes of liquid are to be transferred by pipet.
- When heating or boiling *any* organic liquid… USE BOILING STONES.
- DO NOT BOIL DOWN TO NOTHING!
- Be safety conscious.
- Before commencing with any lab have your apparatus and mole table checked.

We then discussed what they would need in the mole table for the first lab. After this we played the naming game. The students were very active and all of them participated with some enthusiasm. As we went through and students did not understand answers we stopped to explain them. Once the game was over we awarded everyone with Pokemon pens, and each member of the winning team received bubbles.

4th Day April 3, 2001

Prior to class we went in and set up the five distillation apparatuses. Class began with Jeff showing them the distillation apparatus. He named all the different parts of it and explained their basic functions. Jeff then demonstrated how to use a pipet properly. The students then went to their lab stations and began the lab. Each group was assigned a lab kit, these assignments were:

Kit #	Names
1	James & Jenna
2	Joey & Julie
3	Joseph & Joe
4	Jimmy & Jessica
5	John & Jody

As the lab progressed we wandered around the room helping students and showing them one on one how to use the equipment properly. The lab took longer than expected and some students remained as long as twenty minutes after the lab. A few students even stayed afterward to help us clean up.

During the course of the lab we noticed that the students were not familiar with or skilled in handling the equipment. It took them much longer than we had anticipated to measure out the solution, thus the lab ran over the allotted time.

5th Day April 5, 2001

We started out the classes today by asking if there were any questions on the lab that they had performed in the previous class. There were a few questions on the way that the notebook is organized.

After this Starla began her lecture on mechanisms. We knew before giving this lecture that it was going to be the hardest topic of the course. And to our expectations there were many questions and the students seem to be in a confused state for most of the lecture. The students asked many questions trying to understand what was going on. Some questions could not be answered without going in the topic in more detail, which would have lead to further confusion. Thus some steps in the processes the students were told just to accept the actions that happened. This resulted in the anticipated reaction of the students that they were frustrated.

Their homework assignment for the next class was to re-read the lecture notes that dealt with the material presented today and to come up with 2 questions on anything that is not clear or that they don't understand. It was made a point that these questions would be collected at that time some of the students indicated that they would not be present for the next class. We then came up with two solutions for those students that would not be there on Monday. They could either email the questions to us by Monday or write the questions in their lab notebooks, which would be collected on Friday.

6th Day April 9, 2001

Today started out with Jeff explaining the procedure for the next lab (Alcohol Identification) while Starla collected the questions that the students were asked to write. Half of the class was absent today do to a school event. Of the 5 students that were present 3 of them did have the questions written out, the others quickly wrote down their questions. So while Jeff went over the procedure, Starla read over the questions that they had written. Starla then tried to clear up any confusion that the students had indicated in their questions. After this the next part of the lecture was started.

Today's lecture dealt with the second part to the mechanisms. This lecture lead up to the use of mechanism to identify different types of alcohols, which they would use in their next lab. There was not as many questions today as there had been in the previous class. We think that this is most likely that either it was because their was such a small group of students or that the students may have still had feelings of being discouraged by the difficulty of the material.

7th Day April 11, 2001

Today we started out by first having Jeff go over the lab procedure one last time before the students performed it for themselves. We then went around the room to check their lab to make sure that their mole tables were correctly filled out. It quickly became apparent that most of the students had not completed the mole table. But as the policy is that they must have the mole table completed and checked before beginning the lab. This caused the lab to be delayed about ten minutes while the students completed their tables. The students had no trouble identifying which of the alcohols was the tertiary alcohol. A problem arose however when they had to distinguish between the primary and secondary alcohol. Upon heating two different results were obtained by the same group when the test was repeated.

8th Day April 17, 2001

There were still a few students who wanted to continue working on the Alcohol Identification lab. These mostly wanted to see if they could achieve better results. Thus the class was divided those that wanted to continue work on the lab, whom went with Jeff, and those that had finished the lab, whom went with Starla. Starla reviewed naming with the students. This was done by going over the worksheets that had been assigned to the students and answering questions. Starla also worked with the students through a worksheet to practice isomerism.

9th Day April 20, 2001

Today the homework on More Work With Alcohols was due. After about two seconds, it was clear that several of the students did not do the assignment. The majority of the students did try to do the assignment though. Anyway, the homework was corrected by having the students pass it to the student next to them, then each student was asked to give the correct answer to the problem.

After the homework was corrected and collected, Starla began her lecture on functional groups and reaction mechanisms.

10th Day April 23, 2001

Today we were surprise when class started and there were only 5 students present. We decided that since we had five stations setup for the 5 lab groups already that we would just have each student work by themselves instead of in partners.

The lab went well today with the few students. Without partners the students seemed to be more focused on the lab work than in the passed, probably do to the fact that all the pressure was now on individuals to get results instead of a group. Anyway it was clear everyone understood what they were doing. Everyone came up with good results and also finished on time.

11^{th} Day April 25, 2001

Today the lecture on carbonyl compounds was presented.

12^{th} Day April 27, 2001

Today a quiz on naming, mechanisms, reactions, and all material up to the second to last class. The material on reaction mechanism for esterification was not included. Three of the students were absent. The majority of the students finished the quiz in 30 minutes. After the handing in the homework the students were given a worksheet to do for homework "Classifying Organic Compounds". Some of the students finished the worksheet in the remaining time.

13^{th} Day May 8, 2001

School cancelled because of heavy rains and flooding. The day was spent at homing planning the remainder of the classes out.

14^{th} Day May 10, 2001

Today the students work on the n-propyl lab. For this part of the lab the students had to use a Separatory funnel. Before the lab Starla demonstrated the proper way to use the funnel. The lab went very well and the all achieved good results.
The students were also given a homework assignment dealing with esters, it was the following:

Write down the carboxylic acid and alcohol that would be needed in order to form each of the esters on pg17.

Write the mechanism for the esterification of n-propyl acetate.

15^{th} Day May 14, 2001

Today the students worked on the second part of n-propyl lab. Informed the students when all the material was due and what the plan was for the remaining classes. The final exam format was also discussed. A review sheet for the final exam was given out for the students to complete as homework.

16^{th} Day May 16, 2001

The three students who were absent on the day of the quiz were sent to the library to take the quiz. The students were informed that they must receive a 50 or greater in order to pass the class. Students were notified that they must have their notebooks completed and turned in by May 29^{th}.

17th Day May 22, 2001

Today we gave the students the final exam. All the students were present to take the test except for one student. Looking over the exams as they were passed in the students seem to have done okay on the exam.

18th Day May 24, 2001

Today we gave the students several evaluations to fill out to express their opinions of what they thought of the class. There was one evaluation on the course itself and the material. This evaluation consisted of a rating system from 1 to 5, ranging from strongly disagreeing with the statement to strongly agreeing with the statement. The second evaluation was in the form of written responses dealing with mainly the interaction of the class and lab work. The third and fourth evaluation were to see what the students thought of the instructors. These evaluations were a mixture of the rating system and written response.

From the time and the quietness in which the students filled out these evaluations, it seems that they took the evaluations seriously. However, we will soon find out.

Appendix B

Summerhayes' Journal

Dated Notes for Experimental Organic Chemistry   Spring 2001

26 March

Starla was predictably nervous the first day and the 10 students were predictably quiet. Starla rushed her lecture a bit, because students were unresponsive. I suggested she extend her "wait time" between question and answer in the future.

28 March

Starla was more comfortable today and the students were much more responsive. She had students practice naming organic compounds while she and I walked around the class answering questions.

Suggestions: Make assignments more assertive – grade them like chemistry? Discuss schedule for the rest of the quarter. Be more sensitive to clock and provide a concise wrap-up at the end.

30 March

Students split up into 2 teams and played a naming game against each other. Lasted all period, and all students got involved.

Starla needs to be more firm in giving assignments and reading – not just suggesting that they do these things. She realized that at the end of class today. I videotaped this class.

3 April

Fractional Distillation Lab
Pre-lab instruction was good, both by Starla & Jeff. More *specific instructions* and a *statement of purpose* should have been written into the lab instructions. Lab ran late, but all students willingly stayed at least 15 min. past the bell.

Starla is now writing specific homework assignments on the board. I talked to Cecile about making the course Pass/Fail to simplify grading and will discuss further with Starla.

5 April

Starla lectured on reaction mechanisms today – the most difficult topic to grasp. Students asked questions, but were also anxious because of the difficulty. One student caught a mistake that Starla made, and she immediately apologized & corrected the error. The situation was a credit to the student (showing he was really paying attention) and to Starla (responding appropriately and moving on.

After class we discussed using Pass/Fail for grading and Starla agreed. I confirmed with Cecile later.

9 April

Reaction mechanisms lecture. Dense material dealing with carbo-cations and the like. Students were quieter than usual. Baffled? Comprehending?

11 April — Alkyl Halide production lab. Students worked well once they started doing the lab, but many did not have their mole tables prepared, and so, got started late. Starla needed to give more specific instructions as to the preparation of the mole table.

When Starla made announcements to the class, she did not always have everyone's attention. She needs to get all students to stop what they're doing, look at her, and listen to instructions.

17 April — Starla broke the class up into 2 groups today. Six who needed to re-do (or do for the first time) the alkyl halide lab worked on that with Jeff, while Starla went over naming exercises and isomerism with the four remaining students. The small groups worked particularly well, and everyone was cooperative.

20 April — Starla lectured on functional groups and reaction mechanisms today. Students were "wound up" today. Early on, Starla was helping one student with a question, but the rest of the class was undirected and rowdy. She needs to give the rest a task while she is helping one student.

She needs to make a decision about how much she wants the students to retain and/or be able to reproduce on a test or homework. She hurries through the lecture because it's difficult, but is unclear how much they really need to know. She asks "Understand?" but doesn't wait long enough for an answer.

If they don't have to really understand the material in depth, why ask the question? If they do have to understand and reproduce the material, "wait time" for answers has to be much longer.

Errors continue to crop up in the notes she has printed up for the kids. Accuracy of information needs to be checked more thoroughly in advance.

23 April — Only 5 students, because of sickness and other obligations. Students performed the synthesis of iodoform lab. Things ran particularly smoothly with such a small group. Plenty of time for individual attention.

25 April — Starla presented the reaction mechanism for esterification in class today. Students were overwhelmed by the details and complexity of the process. Quesitons of: "Do we have to know this?" and "WHY do we have to know this?" cropped up frequently. It may have been better to skip (or simplify) this process and go strait to doing the lab.

27 April	Test given on naming, mechanisms, etc.
8 May	School cancelled because of heavy rains and flooding.
10 May	Formation of Ester Lab. Most students had not completed their mole tables, so they were delayed in starting the lab. All went well, but 2 of 10 were absent. Starla and Jeff stayed another hour after the students had left, to allow sufficient time for lquids to reflux completely.
14 May	Starla reprimanded the students as 6 has neglected to turn in their lab notebooks last Friday, as is required every Friday, Starla is wrestling with the possible necessity of failing one or two students because of their neglecting to meet certain minimum requirements for the course. I told her that these were issues all first-year teachers need to come to terms with. Starla is hurt that the students don't work as hard at and love the material as much as she does. I told her that all a teacher is lead the horses to water, and try to make the water attractive to drink. The teacher then must faithfully measure out how much (or how little) the horse did drink. The lab portion went well today. Starla demonstrated the use of the separatory funnel, and the students performed well, enjoying the technique. I was particularly pleased that none of them spilled any of the 18M sulfuric acid!
16 May	Starla was very decisive today. 3 students were sent to the library to make up a quiz they'd missed. The others worked on a couple of different labs – either going on to the next step or making up a missed experiment. The Final Exam is next week and Starla clarified her expectations for preparing for the final. She also spelled out what was necessary for a Pass or Fail in this course. After class, Starla was regretful that she hadn't done things differently in the course. I reassured her that the best-laid lesson plans and cirricula only work after they have been tested and polished. Starla has barely had any time to test her material. Most important, she's noticed what's worked and what hasn't. She wishes she could start over again right now, incorporating her recent experience.
22 May	Final Exam administered to class. (One student absent without excuse)

24 May

Course Evaluation administered to class. Evaluation forms were thoughtful, complete, and specific both to this course and these particular instructors.

Appendix C

Student Manual

Experimental Organic Chemistry
Student Manual

Table of Contents

Introduction To Experimental Organic Chemistry

Who are we and why are we here?

As juniors at Worcester Polytechnic Institute (WPI) it is required that we complete an interactive project. We have selected to do ours in education. Starla Richter is a chemistry major and will be doing most of the lectures in this class. Jeffery Brown, a mechanical engineering major, will be responsible for instructing the lab-work.

What will this class be like?

Our biggest concern in this class is that you learn the material. We would like for the class to be as interactive as possible. Instead of trying to use a confusing text book that would cover more material than we are interested in, we have put together this manual for you to use. However, if you do wish to get further clarification on any material learned in class, all you need to do is ask.

Since this class is experimental, many evaluations are necessary. The best way for us to evaluate you is to have homework assignments and other graded materials. Occasionally we will give you forms to evaluate our classroom performance as well.

The five laboratories planned for this course should take up much of the class time. These labs should give you a more in-depth understanding of the material presented. Keeping a lab notebook is an important part of any profession where experiments are performed, therefore we will be stressing how to keep an accurate lab notebook.

If we have questions outside of class how can you be reached?

We will both be very available for questions outside of class, but it would be best if you set up a meeting ahead of time. Our email addresses are starla@wpi.edu and jeffery@wpi.edu (email is a VERY reliable way to contact us). If you wish to call us we can be reached at 773-8631. Feel free to contact us if you have any questions or concerns.

Class Schedule

Class	Material To Be Covered
1	What the purpose of the course is Introduction to Organic Chemistry Naming Alkanes
2	Naming Alkanes and Cycloalkanes Isomerism
3	Naming Game Introduction to Laboratory Procedures
4	Fractional Distillation
5	Discussion of Alcohols and Alkyl Halides Substitution Reactions and Mechanisms
6	Alcohol Identification Laboratory
7	Discussion of Alkenes, Ethers, and Carbonyl Compounds in general, Aldehydes, Ketones, Silver Mirror, Iodoform
8	Iodoform Test
9	Carboxylic Acids and Esters Fisher Esterification
10	Synthesis of n-Propyl Acetate Day 1
11	Synthesis of n-Propyl Actate Day 2
12	Synthesis of n-Propyl Acetate Day 3
13	Synthesis of Acetylsalicylic Acid Day 1
14	Synthesis of Acetylsalicylic Acid Day 2
	Synthesis of Acetylsalicylic Acid

15	Day 3
16	Finishing Up Labs
17	Evaluations

Lecture Notes

Introduction to Organic Chemistry

In this section we will discuss the basic principals of organic chemistry, and establish some ways to communicate, including writing and naming structures.

What is organic chemistry???

Chemistry is such a diverse field of study that it is necessary to break it up into many different areas. In order to study the thermodynamics (heat) and kinetics (rate) of reactions we use the concepts in physical chemistry. Biochemistry is the reaction of biological compounds. Inorganic chemistry focuses on the reactions of compounds that are not carbon based. Organic chemistry is the study of carbon-based compounds.

Are all carbon-containing compounds organic?

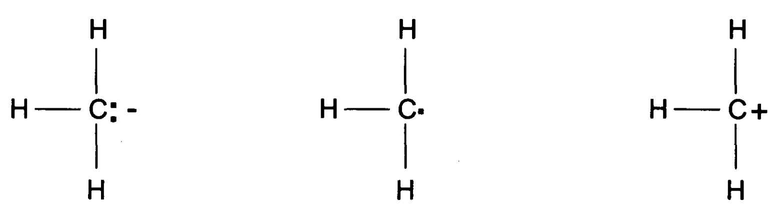
All organic compounds contain carbon, however not all carbon containing compounds are organic, there are a few that are not. Sodium Bicarbonate is an example of this.

What are the characteristics of carbon?

Carbon is the element atomic number 6, and atomic mass 12. Carbon has 4 valence electrons and therefore has the ability to form four covalent bonds, this lends itself to tetrahedral geometry. Carbon has the ability to form single, double or triple covalent bonds with itself. It has the ability to form very small and very large rings and chains with itself.

Is it possible to have a carbon that only has three bonds?

Yes, it is possible, but these species are only short-lived, high reactive **intermediates** in reactions. They only exist for a short period of time in the middle of the reaction as the reactants are changing to products. The possible **trivalent carbon species** are the **carbanion**, the **free radical**, and the **carbocation**.



	a carbanion	a free radical	a carbocation
Formal Charge On Carbon:	-1	0	+1

What other elements are found in organic compounds?

Most organic compounds may also contain these elements: Hydrogen, Oxygen, Chlorine, Bromine, Iodine (the halogens), Nitrogen, Sulfur and Phosphorus. For our purposes we will focus on those containing hydrogen, oxygen, and halogens.

What types of formulas are used in organic chemistry?

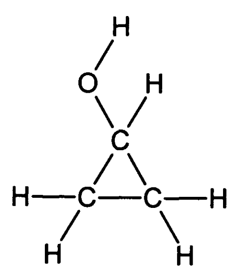
Formulas are very important. There are two types of formulas; molecular formulas and **structural formulas**. While they may be useful in other areas of chemistry, a molecular formula will not be able to give you all the information you need about an organic compound. In organic chemistry we generally use structural formulas.

Is the arrangement of atoms important?

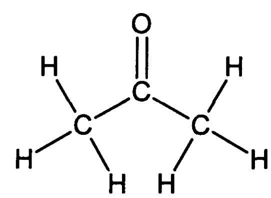
The arrangement of atoms is of great importance in organic chemistry. Compounds that have the same molecular formula may not have the same structural formula, therefore causing them to be drastically different.

How could arrangement influence the identity of a compound?

For Example we have two compounds with the formula C_3H_6O, however their different structures cause them to be two separate compounds.



Cyclopropanol



Dimethyl Ketone (Acetone)

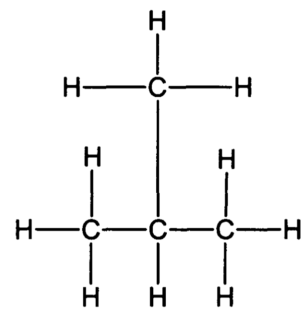
But why are these two compounds different?

Organic compounds are most often identified by their **functional groups**. In organic chemistry we will encounter many different functional groups. However we will keep our attention focused on a select few (alkanes, alkenes, alcohols, alkyl halides, aldehydes, ketones, carboxylic acids, and esters). *Refer to Functional Group Chart*

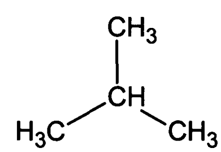
Is there only one type of structural formula?

One of the key elements of understanding organic chemistry is being able to "see" the structures. If you cannot understand this then you will not be able to communicate in the language of organic chemistry. We have several different ways to represent structural formulas on paper; these are **full structures, condensed structures** and **skeletal structures**.

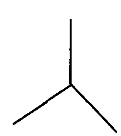
In **full structures** all bonds are drawn:



In **condensed structures** we do not draw carbon – hydrogen bonds



In a **skeletal structure** only elements that are not carbon or hydrogen are labeled. Carbon atoms are located on the ends and bends of the lines. The appropriate number of hydrogens must be supplied mentally.



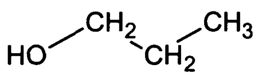
Many students find skeletal structures difficult to understand. Once you have master the ability to understand and use skeletal structures you will find them much easier and faster to draw.

What exactly are isomers?

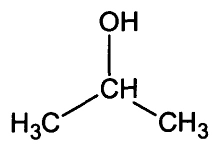
Isomers are compounds that have the same number and types of atoms, but in different arrangements. There are two main types of isomers **constitutional isomers** and stereoisomers. We will only be discussing constitutional isomers in this class.

Are there different types of constitutional isomers?

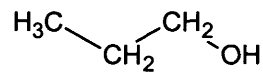
There are two types of constitutional isomers. The first are **structural isomers**. Structural isomers are isomers that have the same numbers and types of atoms with completely different arrangements of atoms, they may even have different functional groups. An example of this is the acetone and cyclopropanol instance that was mentioned earlier. The second type of constitutional isomerism are **positional isomers**. Positional isomers are compounds that have the same functional group, but placed at different "positions" on the carbon skeleton.



A



B



C

Looking at these three different compounds we can see that **A** & **C** are the same compound, it is just flipped over. This compound is called 1-propanol (a.k.a. n-propyl alcohol). Compound **B** is not the same as the other two however, this compound is called 2-propanol (more commonly known as isopropyl alcohol). The compounds are different with different boiling points.

Now that we know how to draw them, how do we name organic compounds?

There are rules to naming organic compounds. This is another thing we need to learn to be able to communicate in the language of organic chemistry. The most important part is learning the names of the basic strait chained hydrocarbons. These are part of a class of compounds called **alkanes**. Alkanes contain all singly bonded carbons and hydrogens, therefore they are saturated. The simplest of these are the following:

Number of Carbons	**Name**	**Structure**
1	Methane	CH_4
2	Ethane	CH_3CH_3
3	Propane	$CH_3CH_2CH_3$
4	Butane	$CH_3CH_2CH_2CH_3$
5	Pentane	$CH_3CH_2CH_2CH_2CH_3$
6	Hexane	$CH_3(CH_2)_4CH_3$
7	Heptane	$CH_3(CH_2)_5CH_3$
8	Octane	$CH_3(CH_2)_6CH_3$
9	Nonane	$CH_3(CH_2)_7CH_3$
10	Decane	$CH_3(CH_2)_8CH_3$

The important part is to know the relationship between the number of carbons and its assigned name. For complete instructions in naming please see the Sheets *Naming Alkanes* and *Naming Cycloalkanes*.

Introduction to Substitution Reactions & Mechanisms

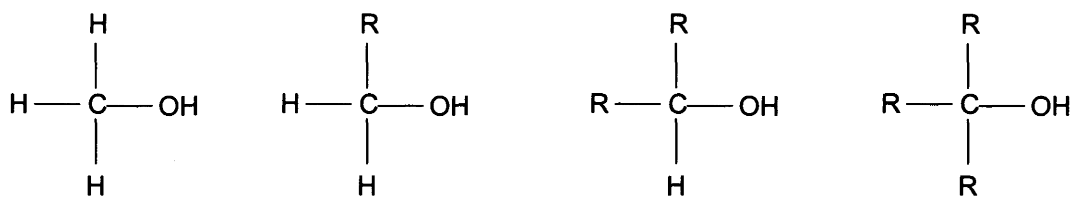
This section includes material on the workings of substitution reactions and their mechanisms. This section will enforce the principals of resonance theory and introduce you to alcohols and alkyl halides.

What do I need to learn in order to understand this section?

What we will learn prior to the discussion of reactions will be the structure of **alcohols** and **alykl halides**, the definition of **electrophile** and **nucleophile** (and what makes them different from acids and bases), the relative stability of **carbocations**, and how to write and understand a mechanism.

What is an alcohol?

Alcohols are a functional group that are defined by the attachment of an –OH group to a carbon. There are four different categories of alcohols.



Methyl ***Primary (1°)*** ***Secondary (2°)*** ***Tertiary (3°)***

Sidenote: "R" may be any aliphatic group, but not aromatic
Aliphatic – any open-chained compound, or cyclic with properties of an open chain
Aromatic – cyclic like benzene, or some other ring with properties of benzene

In an alcohol the carbon is partially positive and the oxygen is partially negative due to **inductive effects**. An **inductive effect** is the transfer of charge through a **sigma** (σ) **bond**. For our purposes we will think of sigma bonds as the single bonds between atoms. (A double bond consists of a sigma bond and a pi (π) bond.)

What is an alkyl halide?

Alkyl halides are generally written in the form R-X where the R is an alkyl group and X is a halogen (F, Cl, Br, I). Alkyl halides may also be referred to as being methyl, 1°, 2°, or 3°. There is also bond polarization in alkyl halides, the carbon is partially positive and the halogen is partially negative.

What are electrophiles and nucleophiles? What is their relationship to acids and bases?

The first thing we need to address is the definition of **Lewis acids** and bases and **Bronsted acids** and bases. A Bronsted acid is defined as a proton donor, and a Bronsted base is a proton acceptor. Lewis bases donate electron pairs, and Lewis acids are electron pair acceptors.

Electrophiles are the reactant in an organic reaction that is electron deficient.
Nucleophiles are the reactant in an organic reaction that is electron rich.

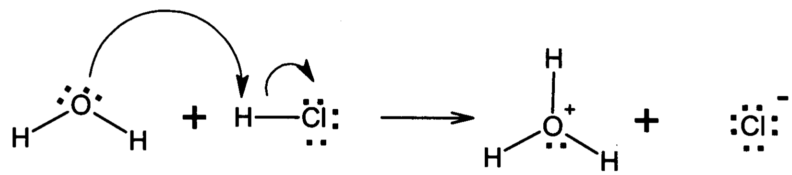
Keep these definitions in mind as we continue on to our next topic.

What is a mechanism?

A mechanism is the detailed structural and energy changes that take place as reactants go to products.

How do I draw a mechanism for one and two step reactions?

One Step

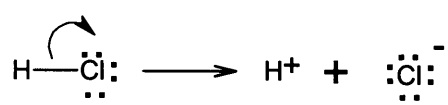


This particular reaction is a **substitution reaction** because one thing comes in and one thing leaves.

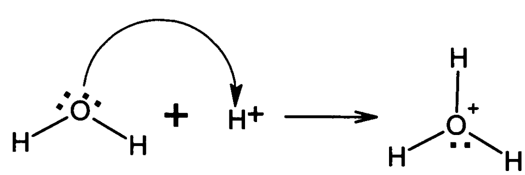
The H–O bond formed as the H–Cl bond was broken. In every reaction there will be a **rate-determining step**. People sometimes refer to this as the "slow-step." Since our reaction only has one step, it is the rate determining step. This step involves two "things" coming together, therefor it is **bimolecular**. Our reaction is a **bimolecular substitution.**

Two Step

Step 1:



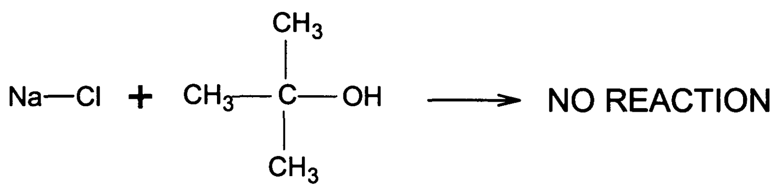
Step 2:

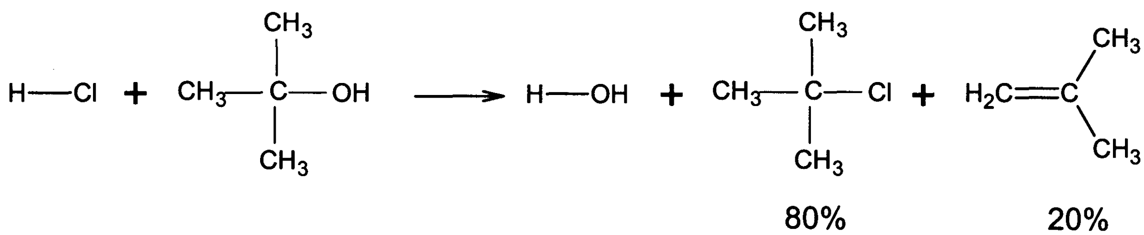


Step one is the slow, rate-determining step, this particular step is known as a **unimolecular ionization**. The second step is very fast. The rate determining step of this reaction is unimolecular therefor this is a **unimolecular substitution.**

How do I apply this information to alcohols and alkyl halides?

Suppose we have an alcohol, t-butyl alcohol (2-methylpropanol) for instance, and we would like to convert it to the corresponding alkyl chloride, t-butyl chloride (2-chloro-2-methylpropane) how would we do this? There are two methods that may immediately come to mind. What if we mixed NaCl with our alcohol? Or we could try HCl.

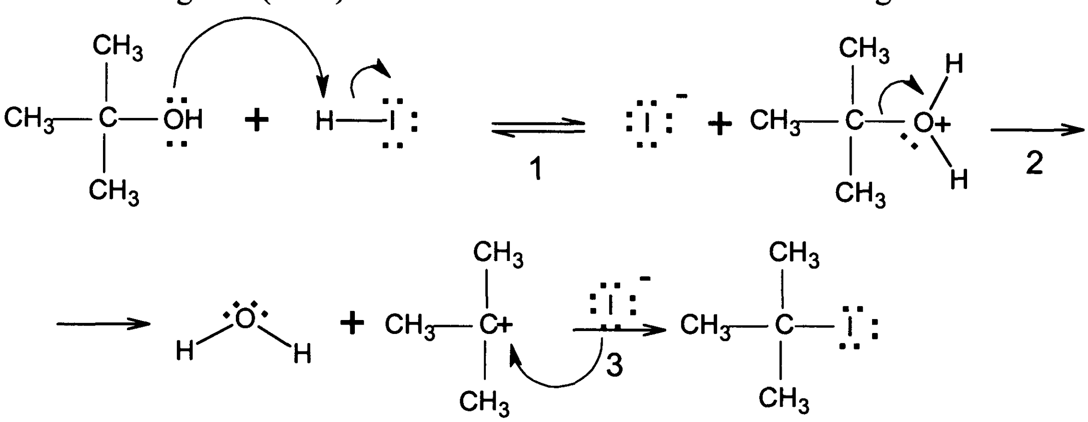




The first reaction will not proceed because the NaCl is not strong enough to remove the OH. An acid is necessary for this, we will see why when we look at the mechanism. But first we will discuss the structure reactivity correlations.

For H-X: H-I > H-Br > H-Cl > H-F
Reactivity
For R-OH: 3°R-OH > 2°R-OH > 1°R-OH > CH_3OH

When reacting a 3° (or 2°) alcohol with H-X it follows the following mechanism.



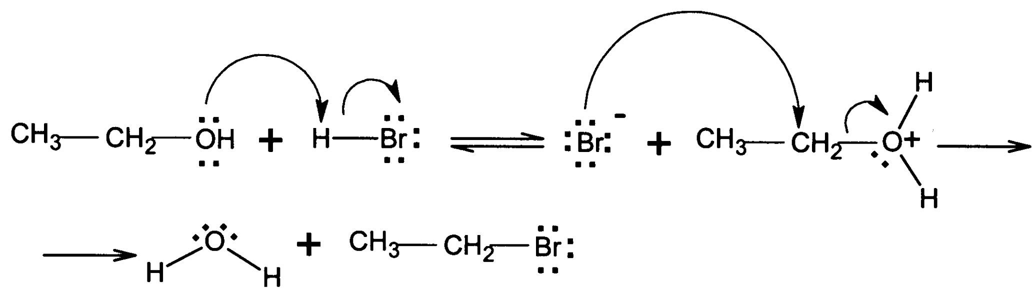
Notes on mechanism:

Step 1 is a acid-base proton transfer, this is a very fast step
Step 2 is a unimolecular ionization, this is a slow step, the rate-determining step
Step 3 has the I^- *capturing the carbocation, this is a very fast step*

Because this nucleophilic substitution reaction has an unimolecular rate-determining step it is known a S_N1 (Substitution Nucleophilic Unimolecular).

What about primary and methyl alcohols, what sort of mechanism do they follow?

Primary and Methyl alcohols follow what is known as an S_N2 mechanism. Here is an example:



Notice in this mechanism there is the protonation of the alcohol, then this is followed by the Br^- coming in and pushing off the water, this second step is the rate determining step and it involves two species coming together, therefore this mechanism is known as S_N2 (Substitution Nucleophilic Bimolecular).

Why do the different types of alcohols follow these different mechanisms?

On the previous page it stated that 3° alcohols were the most reactive. The reason behind this is they form the most stable intermediate. 3° alcohols may form 3° carbocations, the most stable type of carbocation. Therefore the S_N1 mechanism will proceed readily in very mild conditions.

For a 2° alcohol the conditions need to be a little harsher (may need to be heated slightly). It is most likely that the alcohol will proceed via the S_N1 mechanism, it is also possible for it to proceed via S_N2 in certain cases (we will not be discussing these). The 2° carbocation that is formed in the S_N1 pathway is a fairly stable intermediate, therefor this reaction may proceed with only a little bit of "pepping up."

In the case of a 1° alcohol, the S_N1 pathway will NEVER occur. It always follows the S_N2 path, because 1° carbocations are not stable enough to be formed. In order for the S_N2 path to occur the conditions must be even harsher than in the case of the 2° alcohol (more heat).

Functional Groups

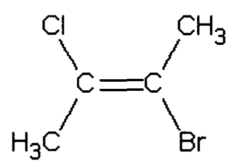
In this section we will be discussing the characteristics of the functional groups: Alkenes, Ethers, Aldehydes, and Ketones. We will discuss their reactivity, and we will also learn what a carbonyl group is.

What are the characteristics of an alkene?

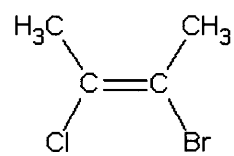
Alkenes are hydrocarbons that contain at least one double bond. Alkenes may be formed through elimination reactions. This is a reaction where two things are removed from adjacent carbons so a double bond may form in-between.

Are there any special nomenclature rules for alkenes?

Since alkenes have a double bond they cannot rotate freely about the bond causing structures that would seem similar to actually be different.



E-2-bromo-3-chloro-2-butene

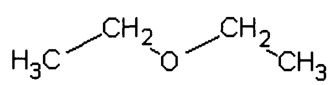


Z-2-bromo-3-chloro-2-butene

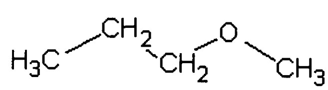
For our purposes you need not know how to characterize which is which, you need only know that there are special naming rules for alkenes and other compounds that do not allow free rotation.

What is an ether?

The defining characteristic of an ether is an oxygen bonded to two carbon groups. Ethers are generally unreactive and are frequently used as solvents in reactions.



Diethyl ether

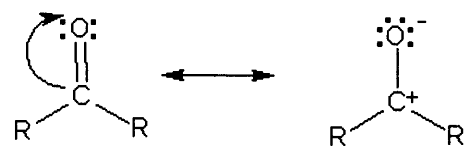


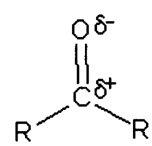
Methyl propyl ether

In order to name an ether you simply name the substiuents on either side of the oxygen and place ether at the end. If the two groups are the same, then you add the prefix di- in front of the name.

What is a carbonyl compound?

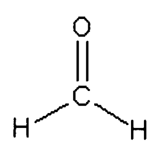
The carbonyl carbon in a compound is the carbon double-bonded to an oxygen. There are many types of carbonyl compounds (please refer to your functional group chart for their structures), including ketones, aldehydes, carboxylic acids, and esters. The double bond to oxygen leads to an inductive effect, leading the carbon to be partially positive and the oxygen partially negative.



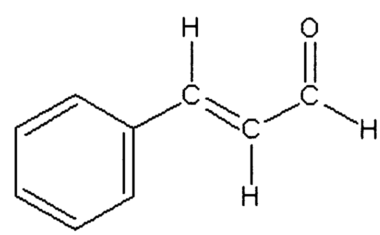


Do aldehydes have any special characteristic?

The hydrogen atom bonded to the carbonyl carbon is very acidic (very reactive). Aldehydes and ketones are often responsible for odors and flavors.



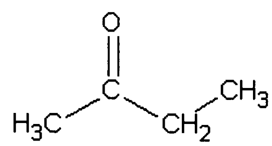
Formaldehyde



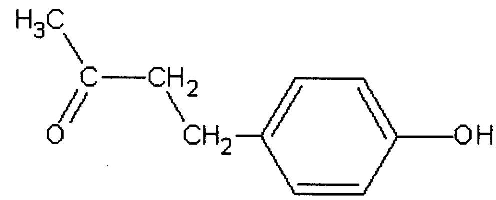
Cinnamaldehyde

How do ketones differ from aldehydes?

Aldehydes and ketones may appear similar in structure but instead of a hydrogen and an alkyl group on either side of the carbonyl carbon, there is an alkyl group on either side of the carbonyl carbon.

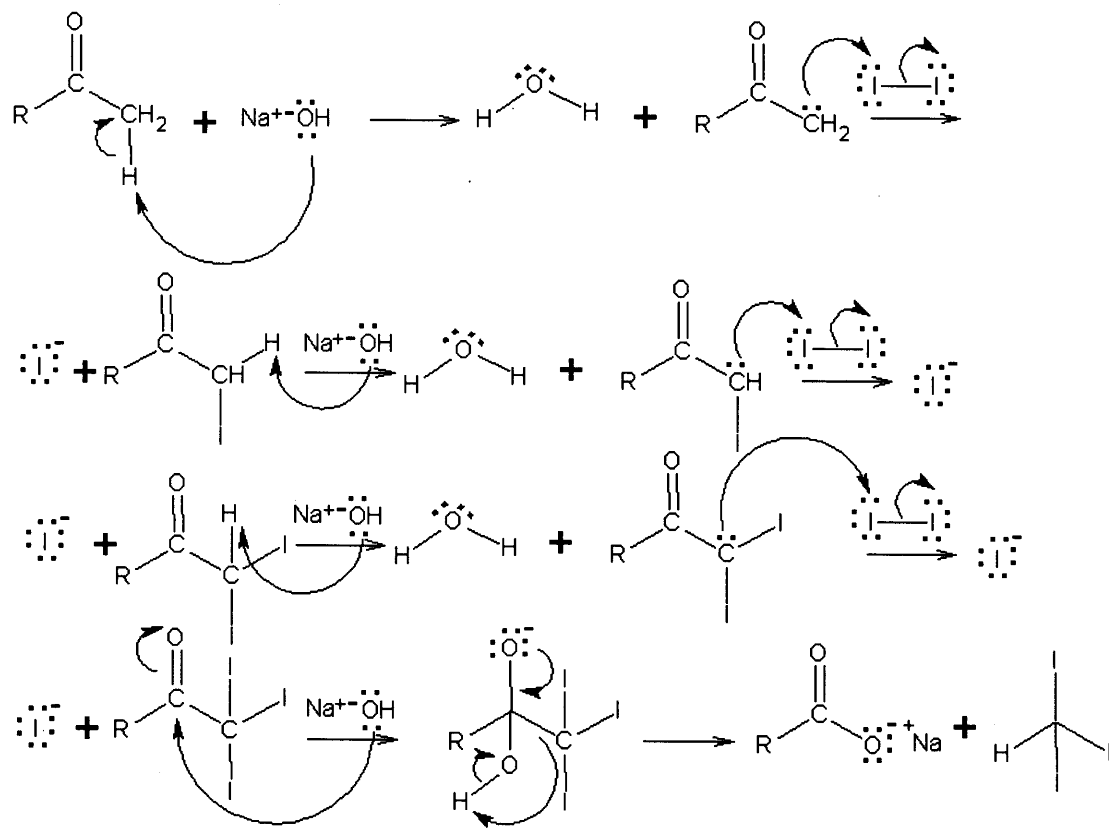


Ethyl methyl ketone



Raspberry ketone

In order to tell the difference between aldehydes & ketones you may wish to a classification test. One test is the iodoform test for methyl ketones. This test will only work with methyl ketones. This reaction requires basic (as opposed to acidic) conditions… let's examine the mechanism.

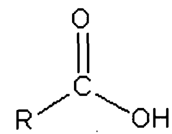


More on Carbonyl Compounds

In this section we will be discussing the Fischer Esterification synthesis. In order to do this we will first discuss carboxylic acids and esters.

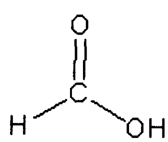
What is a carboxylic acid?

Carboxylic acids are characterized by the –OH group attached to the carbonyl carbon.

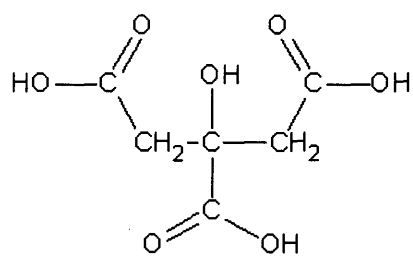


a carboxylic acid

Carboxylic acids are much weaker than inorganic acids (such as hydrochloric, sulfuric, and nitric). Many carboxylic acids occur naturally in plants and animals, such as the two below:



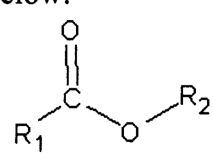
Methanoic Acid
(found in ants)



Citric Acid
(found in citrus fruits)

What is an ester?

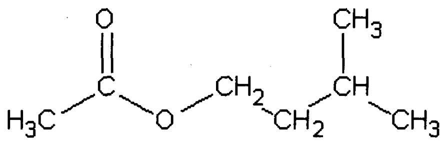
The structure of an ester is pictured below:



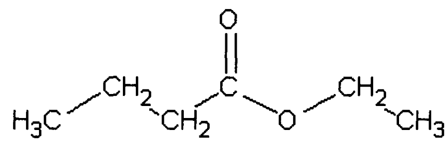
an ester

Esters are commonly found in plants and they are responsible for some distinctive odors and flavors. Synthesizing esters can be a very simple process, so they are often used as food additives. Some esters are found in the chart on the following page. These esters are commonly used to "pep" up the odor or flavor of desserts and beverages. Many of these types of additives do not have a natural basis ("juicy fruit"). These are not used in perfumes however because once they contact sweat they undergo hydrolysis and become carboxylic acids.

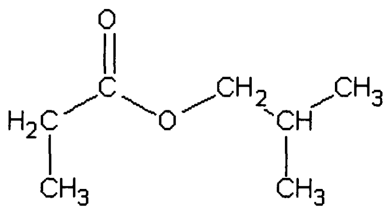
Ester Flavors and Fragrances



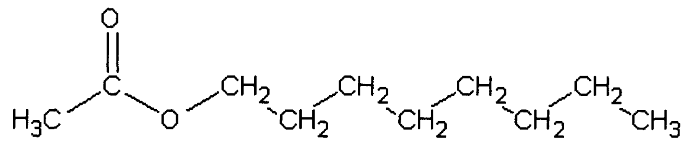
Isoamyl acetate (Bananas)



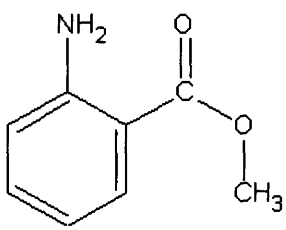
Ethyl butyrate (Pineapple)



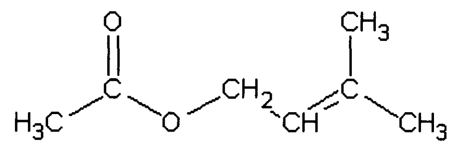
Isobutyl propionate (Rum)



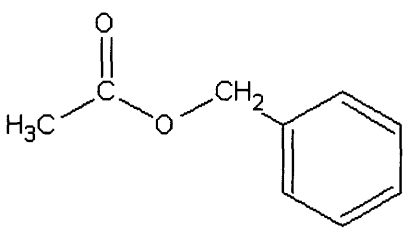
Octyl acetate (Oranges)



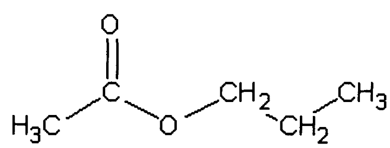
Methyl anthranilate (Grape)



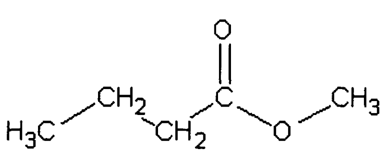
Isopentenyl acetate ("Juicy Fruit")



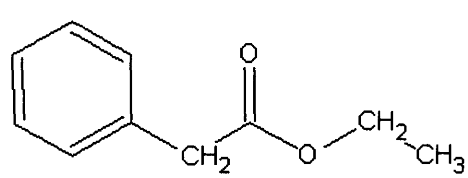
Benzyl acetate (Peach)



n-Propyl acetate (Pear)



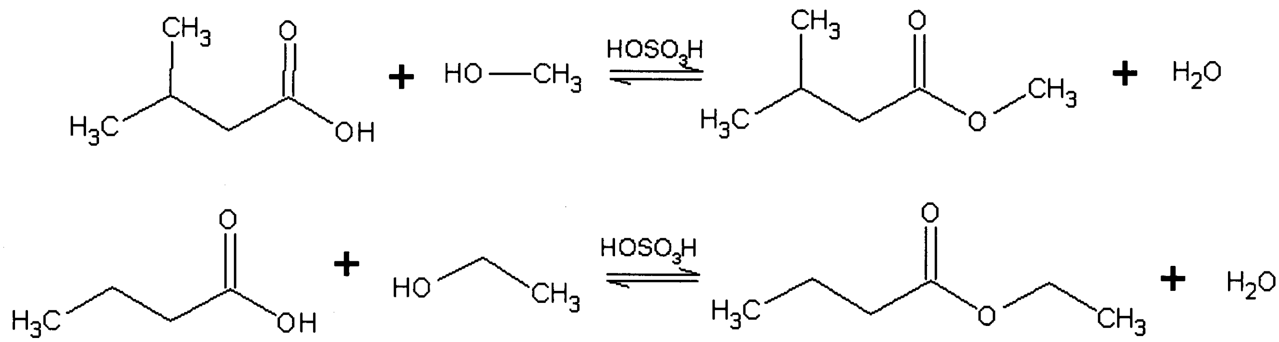
Methyl butyrate (Apple)



Ethyl phenylacetate (Honey)

How are esters synthesized?

There are many ways to synthesize esters, but we will now learn a fairly simple reaction to make esters. We will learn the **Fischer Esterification Synthesis**. In the Fischer Esterification a carboxylic acid, an alcohol, and a strong acid catalyst react to form an ester and water.



You may notice that these are equilibrium reactions. The yield of this reaction depends of the equilibrium constant (K_{eq}). To drive the reaction to the right (to products), use an excess of one of the reactants. To drive the reaction the other way add a lot of water.

Supplemental Materials

Naming Alkanes

1. **Identify the parent chain.** This will be the longest continuous chain. Be careful, the longest continuous chain can turn corners.

Example:

$CH_3CH_2CHCH_2CH_2CHCH_3$

$\quad\quad\quad |\quad\quad\quad\quad |$

$\quad\quad CH_2CH_3 \quad CH_2CH_2CH_3$

Once you have identified the parent chain, name it according to the number of carbons it contains. In the above example the name of the parent chain would be nonane.

2. **Identify and Name Substituents.** Identify all the groups connected to the parent chain. Note: when naming **alkyl** substituents the –ane ending becomes –yl. (Example: Butane becomes butyl)

Example:

$CH_3CH_2CHCH_2CH_2CHCH_3$

$\quad\quad\quad |\quad\quad\quad\quad |$

$\quad\quad CH_2CH_3 \quad CH_2CH_2CH_3$

In this example our two substituents are ethyl and methyl groups.

3. **Number the substituents.** Now you must number the carbons in the chain in order to give your substituents the lowest possible numbers.

Example:

$\overset{1}{CH_3}\overset{2}{CH_2}\overset{3}{CH}\overset{4}{CH_2}\overset{5}{CH_2}\overset{6}{CH}CH_3$

$\quad\quad\quad |\quad\quad\quad\quad |$

$\quad\quad CH_2CH_3 \quad \underset{7}{CH_2}\underset{8}{CH_2}\underset{9}{CH_3}$

The above is the correct way, below is **incorrect**!

$\overset{9}{CH_3}\overset{8}{CH_2}\overset{7}{CH}\overset{6}{CH_2}\overset{5}{CH_2}\overset{4}{CH}CH_3$

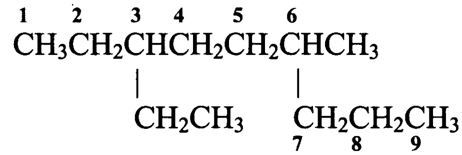
$\quad\quad\quad |\quad\quad\quad\quad |$

$\quad\quad CH_2CH_3 \quad \underset{3}{CH_2}\underset{2}{CH_2}\underset{1}{CH_3}$

Therefore our substituents will be labeled 3-ethyl and 6-methyl.

4. **Name your compound.** Now we put all the pieces together. Substituents are put in alphabetical order, *not* by their number.

Example:



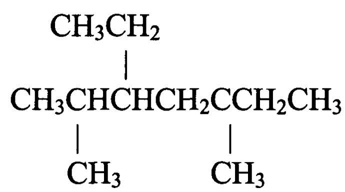
We have 3-ethyl-6-methyldecane.

These are the basic rules. There are more rules, which we will explain as they are encountered.

A few more things:

1. If a compound has two or more of the same substituent on it then the multiplier prefixes di-, tri-, tetra-, etc. must be used in order to identify the compound.

   Example:

   This compound would be named: 3-ethyl-2,5-dimethylheptane

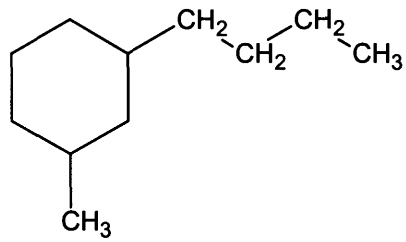
2. Notice that separating words and numbers we find dashes, and separating numbers we find commas, these are conventions of the naming system, be sure to use them.

3. You should also notice that the substituents are alphabetized by the root hydrocarbon, not by the multiplier prefix.

Naming Cycloalkanes

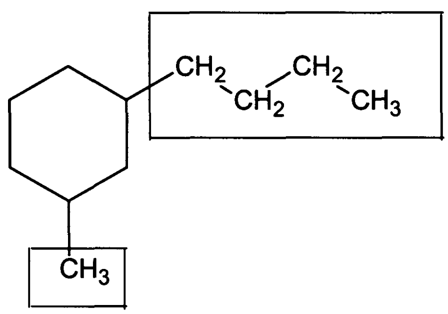
1. **Identify the parent chain or ring.** If the chain has more carbons then it is the parent, but if the ring has more then the ring is the parent. In the case that there are equal numbers the compound should be named using the ring as the parent chain.

   Ex.



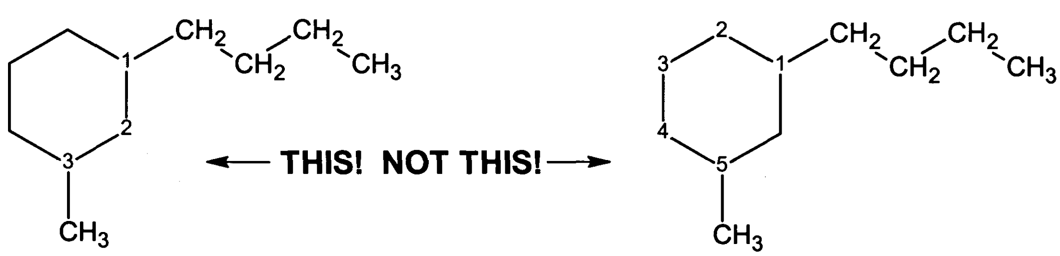
Cyclohexane is the parent.

2. **Identify the substituents.**



Substituents are butyl and methyl

3. **Number** substituents so they can have the lowest possible numbers. When two or more atoms are in the position to potentially receive the same number, they are numbered by alphabetic priority.



4. **Name** your compound.

   1-butyl-3-methylcyclohexane

Isomerism

Now that you know what isomers are and how to name, here is an exercise in both. It may be clear to see that once a hydrocarbon has more than 4 carbons, it may be subject to isomerism. To demonstrate this, draw structures of butane and 2-methylpropane. You can see that they have identical molecular formulas, but they have different structures.

1.) See how many different isomers of C_5H_{12} and C_6H_{14} you can draw, and name.

In the common naming system there are some names of substituents that are widely used. The ones we will be using involve isomers of substituted groups. Here they are:

Name	Structure
n-propyl	$-CH_2CH_2CH_3$
isopropyl	| CH_3CHCH_3
n-buytl	$-CH_2CH_2CH_2CH_3$
isobutyl	| $CH_3CHCH_2CH_3$
tert-butyl	| CH_3CCH_3 | CH_3

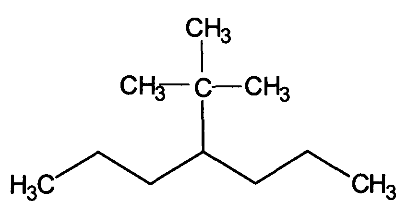
The lines indicate the position where the group would be attached to the main chain.

Notes on naming:

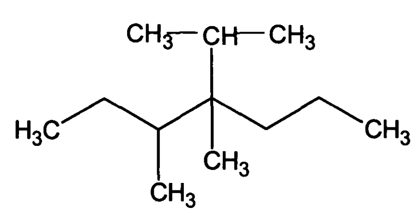
1. When alphabetizing, to name your compound, remember that the iso- groups are alphabetized under I, while the other groups are alphabetized using the name of the hydrocarbon (example: n-propyl).
2. The n- simply is a classic notation meaning "normal." It is used to indicate a strait-chained substituent.

2.) Name the following compounds using the common system names you have just learned:

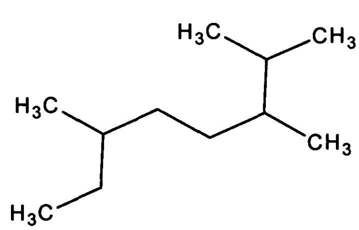
a.)



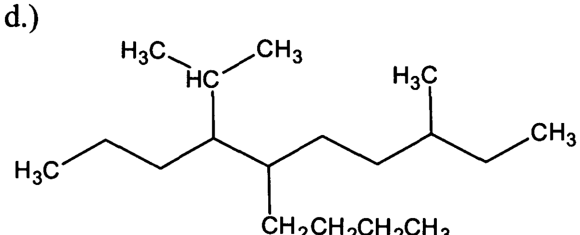
b.)



c.)



d.)



Resonance

Why do we need resonance forms?

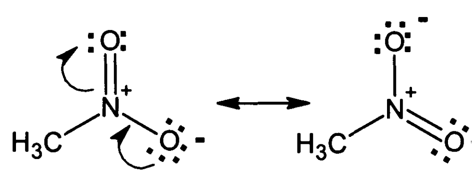
When structures are drawn people often visualize them as having the electrons in fixed positions, just as they are drawn. However, this is not true. Electrons are not usually localized (remain in one position). They tend to spread across the molecule to all possible positions. This is called **delocalization**. A **resonance form** will show other possibilities for the positions of the electrons.

Which resonance form is the correct one?

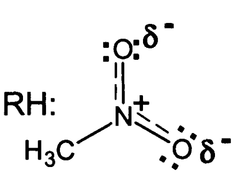
None of the resonance forms are "correct." In reality none of the forms have any physical significance, only the **resonance hybrid** is a reasonable representation of the actual structure of a molecule. The resonance hybrid is a combination of all of the resonance structures and is more stable than any of them.

How do I draw a resonance structure?

Resonance structures are drawn by moving *electrons only*! Atoms do not move! Here is an example:



RH:



Notice the resonance structures show that one of the oxygens bears the negative charge (the charge is localized), however the resonance hybrid shows that the negative charge is spread over the two oxygens (delocalized). (The δ signifies a partial charge.) There are dashed lines to signify that the bond is only partially there. Also, you should notice that the arrow between the two structures is a double-headed arrow… this type of arrow is always used to signify resonance.

Laboratory Materials

Lab Notebook

Why keep a notebook?

An important part of doing lab work is knowing how to keep a lab notebook. All your results should be carefully recorded in your notebook. The first page or two of your notebook should be reserved for a table of contents. Please number the pages in your notebook for easy reference. In order to keep more careful track of what is important information we will write up labs on the right-hand side of the notebook and use the left side for scratch work.

What should I have in my notebook?

Each page should be dated in the upper right-hand corner of the page; each new set of information should be dated as well. Each new experiment should be titled. This should be followed by the equation of the main reaction. After this there should be a mole table, including the important chemicals of the reaction (we will tell you which these are). Next you should state the purpose or objective of the experiment, this only needs to be a short one-sentence statement. Following this is the procedure, the main part of your lab notebook. You should write down all the steps that you followed, including the weights and measurements that YOU used. DO NOT copy the procedure given to you. More details will be given in class about the exact format.

At the end of the lab you should give your percent yield and compare the literature values to your experimental values.

You should answer your lab questions on a separate page IN your notebook.

When is my notebook due?

Notebooks are DUE every Friday; they may be placed in the box in the lab by 3:00 on Friday afternoon. Notebooks will be available to be picked up by 8:00 on Monday morning.

Sample of Notebook Format

Synthesis of Octyl Acetate

9/20/00 (2)

$$CH_3(CH_2)_6CH_2\text{-}OH + CH_3COOH \xrightarrow{H_2SO_4} CH_3\text{-}\overset{O}{\overset{\|}{C}}\text{-}O\text{-}CH_2(CH_2)_6CH_3 + H_2O$$

Compound Name	Boiling/Melting Point (°C)	Molecular Weight (g/mol)	Density (g/mL)	Mass (g)	Volume (mL)	Moles	Toxicity
Acetic Acid	117.9 bp	60.0	1.05	4.8	4.6	0.08	Corrosive Irritant
Octyl Alcohol	195 bp	130.2	0.83	4.3	5.2	0.033	Irritant Flammable
n-Octyl Acetate	205 bp	172.3	0.867	5.7	6.6	0.033	Flammable
Sulfuric Acid	280	98.1	1.84	1.8	1.0	.0098	Corrosive
Water	100 bp	18.0	1.0	0.59	0.59	.033	

Objective: To synthesize octyl acetate in a relatively high yield using the Fisher Esterification Synthesis.

Procedure: 4.6 mL of acetic acid was added to a round bottom flask along with 5.2 mL of n-octyl alcohol. To this clear colorless solution 1.0 mL of sulfuric acid was added with swirling. This clear colorless solution was then refluxed for 60 minutes. During the first few minutes of heating the solution turned to a yellow, then, orange, then red, then very dark ~~to~~ color. The refluxing liquid was clear and colorless. When reflux was complete the liquid was a very dark color (brown?). Saturated solutions of sodium bicarbonate and sodium chloride were prepared. The solution was then added (after it had been allowed to cool to room temperature) to a beaker containing 20 mL of aqueous saturated sodium bicarbonate. There was a great deal of bubbling occured and bubbled over at one point (oops!). This was done in the hood since it smelled bad! The solution was then placed in a 125 mL separatory funnel and washed several times with aqueous saturated sodium bicarbonate and several times with ~~aqueous~~ a saturated solution of NaCl in water. The result was an orange clear liquid. There was a layer of residue but we were told to ignore it. When the organic layer was isolated it was dryed overnight in the fridge over anhydrous calcium chloride.
The orange clear liquid was then distilled into an ice-cooled centrifuge tube over a range of 157-158 °C. Product was a clear colorless liquid (1.57 g – 1.80 mL). 28% yield

Fractional Distillation

Notebook Preparation:

No mole table is required for this lab. All that is required is that you have the literature values for the boiling points of *acetone* and *toluene*.

Procedure:

Distillation:

Place 10mL of the *acetone/toluene* mixture in a 25mL round bottom flask along with several boiling stones. Have your set-up approved before you commence heating. Using the distillation apparatus heat the liquid. Use a sample vial as your receiving flask. When your first fraction begins distilling record the temperature every five drops. When the first fraction has been collected change vials. Use the same recording procedure for the second fraction. After the distillation is complete, determine the volume of each fraction that was collected.

Analysis:

Place 1ml of your 1st fraction in a 10 ml graduated cylinder. Fill the remaining 9ml of the cylinder with the salt-water solution. A separation will occur. The portion on the top will be the *toluene* left in that fraction. Take a reading from the graduated cylinder and calculate the percent purity of your sample. Do this for your 2nd fraction as well.

Fraction Distillation: Questions

1. Is distillation a useful identification technique? What vital characteristic of a compound may be identified using distillation?

2. Explain what happens inside the distillation apparatus. (Just the basic idea.)

3. Why is the placement of the thermometer important inside the distillation apparatus? What would happen if the thermometer bulb were well above the mouth of the condenser?

Alcohol Identification

Notebook Preparation:

Prepare a mole table for the following chemicals: *isoamyl alcohol, isopropyl alcohol, t-butyl alcohol, isoamyl chloride, isopropyl chloride, t-butyl chloride,* and *water.*

Procedure:

In three small test tubes place approximately 1 ml of either 1A, 1B, & 1C or 2A, 2B, & 2C in each. To each of the test tubes add approximately 1 ml of concentrated hydrochloric acid. Observe the test tubes, if there is no immediate visible reaction then the test tubes may need to be heated. Be sure to use boiling stones when heating. Identify (1 or 2) A, B, & C based on your observations.

Alcohol Identification: Questions

1. Based on what you know of mechanism explain how you know that the tertiary alcohol was the first to react with the HCl.

2. Draw out the mechanism for a reaction of isopropyl alcohol and HCl. How quickly, and under what conditions is it likely that this reaction will occur.

3. Place the following alcohol in the order in which they would react with HCl: t-butyl alcohol, isopropyl alcohol, n-octyl alcohol, and methanol.

Iodoform Test for Methyl Ketones

Notebook Preparation:

Prepare a mole table for the following chemicals: *sodium hydroxide, iodine, and acetone.* (Note: for amounts in the mole table put: *excess* for acetone, *excess* for NaOH and *limiting* for iodine)

Procedure:

Into a large test tube add approximately 0.5mL of acetone, 1mL of sodium hydroxide. Next add 3mL of *potassium iodide solution*, this should be added dropwise. Stir the solution, after the precipitate has appeared filter the solution through a Büchner funnel. Dry the crystals in the oven. Determine the melting point.

Iodoform Test for Methyl Ketones: Questions

1. Draw out the mechanism for this reaction. (Should include acetone, NaOH, and I_2.)

2. Some nailpolish removers claim to be acetone free. Design an experiment to prove or disprove this claim.

3. Can you think of any reasons why it would be a better idea for us to make iodoform rather than chloroform?

Synthesis of n-Propyl Acetate

Notebook Preparation:

Prepare a mole table for the following chemicals: *n-propyl alcohol, glacial acetic acid, n-propyl acetate,* and *water.*

Procedure:

Place 2.0g of *n-propyl alcohol* and 4.8g of *glacial acetic acid* into a 25mL round bottom flask. Carefully add 1mL of *concentrated sulfuric acid* to the flask, with swirling. Add several boiling stones to the mixture and set up for reflux.

Bring mixture to a boil by heating with a flask heater and allow the mixture to reflux gently for 60 minutes.

Allow the mixture to cool to room temperature. Then cautiously, with stirring pour the reaction mixture into a beaker containing 20mL of *saturated aqueous sodium bicarbonate.* After no further liberation of carbon dioxide pour the mixture into a seperatory funnel. Separate the aqueous from the organic layer and wash the latter with two 1mL portions of *saturated sodium bicarbonate.* Upon each addition of *aqueous sodium bicarbonate*, first swirl the unstoppered flask gently until carbon dioxide is no longer evolved, then stopper and gently shake the funnel once or twice before venting. Repeat these steps until no vapors are evolved when the seperatory funnel is vented. Discard the aqueous extracts and wash the organic layer with one 1 mL portions of *water saturated with NaCl.* Discard the aqueous layer and transfer the crude ester to a test tube and dry it over *anhydrous calcium chloride.*

Carefully transfer the dried ester into a round bottom flask, add several boiling stones, and distill the ester into an ice-cooled receiving vial. Collect the product over no more than a four degree boiling range. Transfer the product into a properly tared vial. Determine the weight and yield of the n-propyl acetate product.

Synthesis of n-Propyl Acetate: Questions

1. Briefly describe what reflux is. What do you think it accomplishes?
2. Why was sodium bicarbonate added during the synthesis?
3. How can you be sure of which layer is the organic layer and which is the aqueous layer?
4. What possible impurities may exist in your product?
5. Were there any steps in this procedure that you did not understand their purpose? If so, please specify.

Synthesis of Acetylsalicylic Acid

Notebook Preparation:

Prepare a mole table for the following chemicals: *salicylic acid, acetic anhydride, sulfuric acid* (excess), *acetic acid, and acetylsalicylic acid.*

Procedure:

Place 0.007mol of *salicylic acid* in a 125mL Erlenmeyer flask. To this add 0.026mol of *acetic anhydride*, along with 3 drops of *concentrated sulfuric acid.* Swirl the flask gently until the salicylic acid dissolves. Heat the flask gently on a hot water bath for at least ten minutes. Allow the flask to cool to room temperature, during which time the acetylsalicylic acid should begin to crystallize (if not then scratch the walls). After crystals form add 50mL of water and cool the mixture in an icebath. Do not add water until crystallization is complete. Collect the product by suction filtration using a Büchner Funnel. Rinse the crystals using several portions of *cold water*. Suction until crystals are mostly dry. Remove them and allow to air-dry (if crystals are too wet you may wish to place then in the oven). Calculate the yield of the dry crude.

<u>Purification</u>:

Transfer your crude solid to a 100mL beaker and add 25mL of saturated *aqueous sodium bicarbonate* solution. Stir until all signs of reaction have stopped. Filter the solution through a Büchner funnel. Wash the beaker and funnel with 5 to 10mL of water. You will be given a diluted *hydrochloric acid* solution. Carefully pour the filtrate, a small amount at a time, into the diluted acid solution while stirring. The aspirin should precipitate. If it does not then check to make sure that the solution is acidic, using litmus paper. Solution must be acidic. Cool the mixture in an icebath, filter the solid by suction, wash well with *cold water*. Air-dry the product (again, if crystals are too wet you may use the oven) and calculate the percent yield.

<u>Recrystallization</u>:

Dissolve the product in a minimum amount of *hot ethyl acetate* (no more than 2-3mL) in a 50mL Erlenmeyer, while gently and continuously heating the mixture on a hot water bath. While the mixture cools to room temperature the product should crystallize. Filter, and calculate yield, determine melting point.

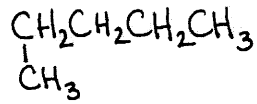
Synthesis of Acetylsalicylic Acid: Questions

1. Using what you already know of mechanisms, form a reasonable mechanism for the transformation of reactants to products.
2. Can you think of any possible impurities that may be in your product?
3. Identify all function groups present in the reactants and products.

Compound Name	Molecular Weight (g/mol)	Boiling Point (°C)	Melting Point (°C)	Density (g/ml)	Toxicity
Acetic acid	60	117.9	16.6	1.05	Corrosive
Acetic Anhydride	102	139.9	-73.1	1.08	Corrosive Flammable
Acetone	58	56.2	-94.3	.79	Flammable
Acetylsalicylic Acid	180	140	135	1.35	Irritant
Chloroethane	65	12.3	-136.4	.92	Flammable Liquid
Ethanol	46	78.3	-114	.79	Flammable
Ethyl Acetate	88	77.1	-83.6	.89	Flammable
Hydrochloric Acid	36	-	-	-	Highly Corrosive
Iodine	254	184.3	114	4.39	Corrosive Toxic
Iodoform	394	218	120	-	Toxic
Isopropyl Alcohol	60	82.4	-88.5	.79	Flammable
Isopropyl Chloride	79	35.7	-117	.86	Flammable Irritant
n-propyl acetate	102	102	-96	.89	Flammable Irritant
n-propyl Alcohol	60	97.2	-126	.80	Flammable Irritant
Potassium Iodide	166	-	681	-	Irritant
Salicylic Acid	138	-	159	144	Irritant
Sodium Hydroxide	40	-	-	-	Highly Corrosive
Sulfuric Acid	98	-	-	-	Highly Corrisive
Tert-Butyl Alcohol	74	82.2	25.5	.79	Flammable
Tert-Butyl Chloride	93	51	-26	.84	Flammable
Toluene	92	110.6	-93	.87	Irritant Flammable

Appendix D
Transparencies: Naming Game

Transparency From Naming Game

(1)


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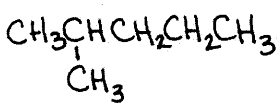

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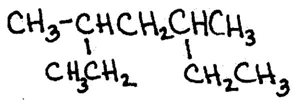
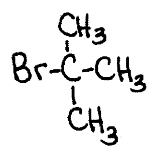


(4) $Cl-CH_2CH_2CH_3$

(5)


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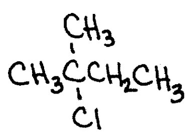

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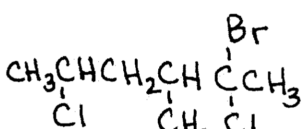

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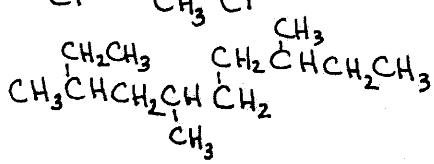

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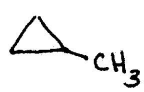
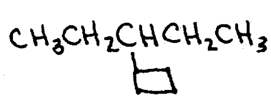
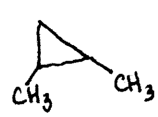


(10) $Cl-CH_2CH_2-Cl$

(11)


(12)
*2 pts.


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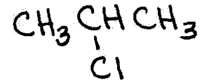

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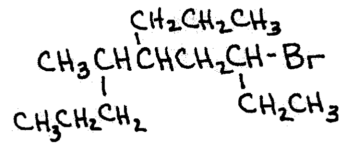
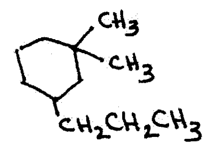


(15)
* 5pts.


(16) 1,1-dichloropropane

(17) 3-ethyl-4,4-diiodoheptane

(18) Tribromomethane

(19) 1,1,2-tribromoethane

(20) 3-bromo-4-chlorohexane

(21) 2,4-dimethylpentane

(22) 1,3-dimethylcyclopentane

(23) propylcyclohexane

(24)


(25)


(26)


(27)

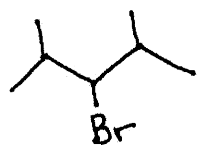

(28)

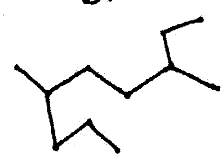
(29)

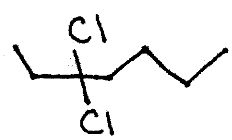

(30)

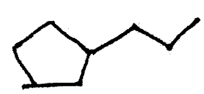

Transparency From Naming Game

31 

32 

33 

34 

35 

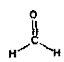
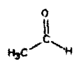
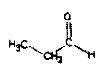
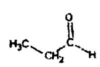
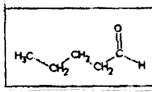
Appendix E

Handouts (Informational)

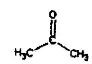
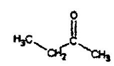
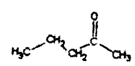
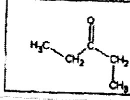
4/19/01

Naming Patterns of Other Functional Groups

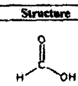
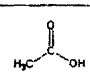
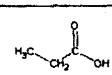
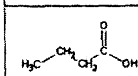
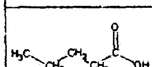
Aldehydes

Structure	Common Name	IUPAC Name
	Formaldehyde	Methanal
	Acetaldehyde	Ethanal
	Propionaldehyde	Propanal
	Butyraldehyde	Butanal
	Valeraldehyde	Pentanal

Ketones

Structure	Common Name	IUPAC Name
	Dimethyl ketone	Propanone
	Ethyl methyl ketone	Butanone
	Methyl propyl ketone	2-pentanone
	Diethyl ketone	3-pentanone

Carboxylic Acids

Structure	Common Name	IUPAC Name
	Formic acid	Methanoic acid
	Acetic acid	Ethanoic acid
	Propionic acid	Propanoic acid
	Butyric acid	Butanoic acid
	Valeric acid	Pentanoic acid

How to Pass This Class

These are the things you must do in order to pass the class…All of these rules will take effect starting today!

1. You MUST turn in your notebook every Friday! It doesn't matter if you have changed anything since the last time, just turn in your notebook.

2. There are not many written homework assignments in this class; therefore you are expected to do all that are assigned. If more than one homework is missed you will not pass.

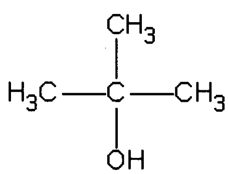
3. All the labs that we finish in this class must be signed.

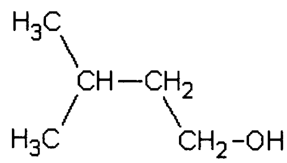
4. You must take all quizzes or tests (if any) that are given.

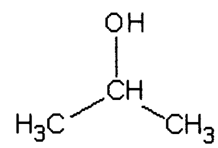
4/10/01

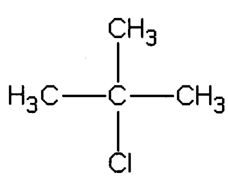
Alcohol Identification Corrections

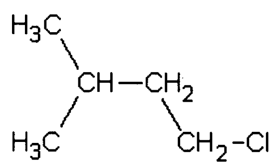
These corrections are what you should actual have in your mole table. Please have the following chemicals in your table: t-butyl alcohol, isopropyl alcohol, isoamyl alcohol, t-butyl chloride, isopropyl chloride, and isoamyl chloride. These are different than what your manual says. There are three reactions for this lab… please a draw all of them (not the mechanisms… just the reaction!) If there are any questions, there is information about how to contact us.

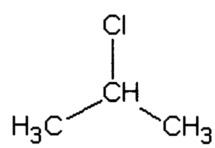












These are the structures of the compounds you will be working with. (Amyl is a common name for pentyl.)

Compound Name	IUPAC Name	Molecular Weight (g/mol)	Boiling Point (°C)	Density (g/ml)	Toxicity
isoamyl alcohol	3-methyl-1-butanol	88.15	130	0.809	Irritant Flammable
isoamyl chloride	1-chloro-3-methylbutane	106.59	99	0.87	Irritant Flammable
t-butyl alcohol	2-methyl-2-propanol	74	82.2	0.79	Irritant Flammable
t-butyl chloride	2-chloro-2-methylpropane	92.57	51	0.842	Irritant Flammable
Isopropyl alcohol	2-propanol	60.1	82.4	0.785	Irritant Flammable
Isopropyl chloride	2-chloropropane	78.5	35.7	0.862	Irritant Flammable

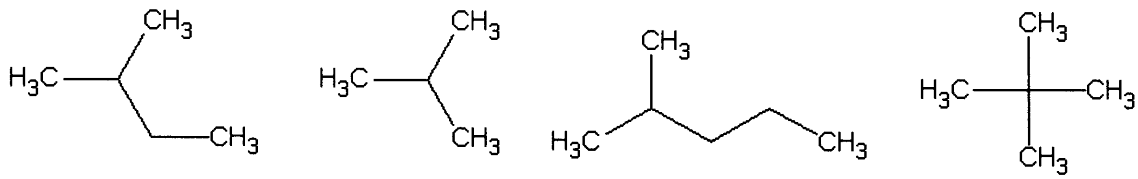
Appendix F Handouts
(Assignments not collected Homework)

Practice Sheet: Isomerism

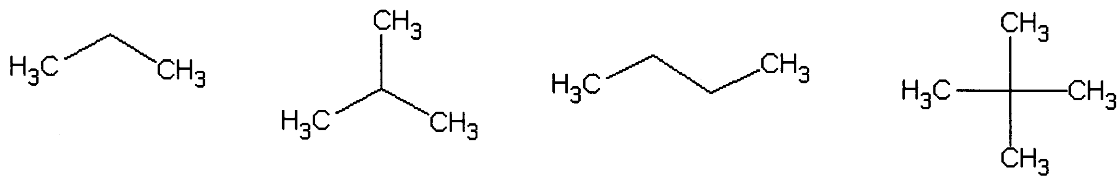
3/28/01

For questions 1-4 circle the two structures that are isomers.

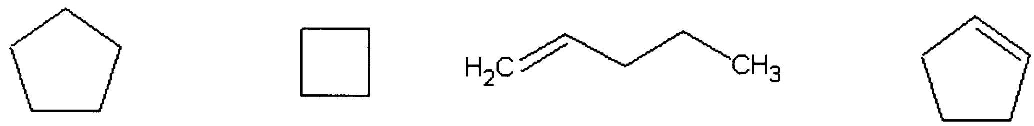
1.)



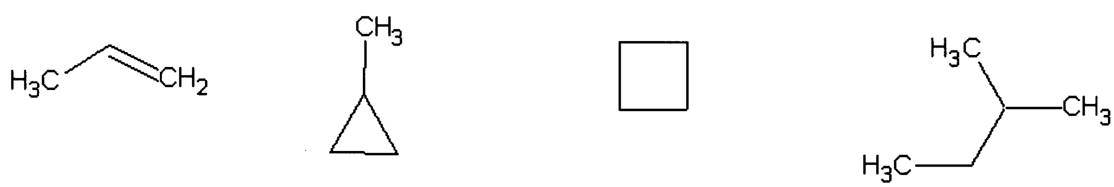
2.)



3.)



4.)



5.) Draw the three isomers of pentane. (Use either condensed or skeletal structures)

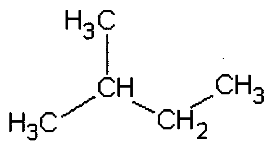
6.) Draw the five isomers of hexane. (Use either condensed or skeletal structures)

3/28/01

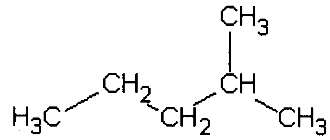
Practice Sheet: Naming

Name the following structures using the IUPAC naming system.

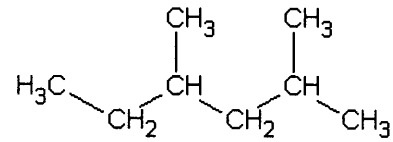
1.)



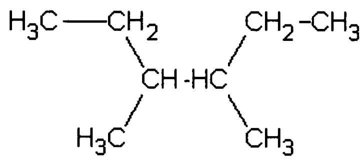
2.)



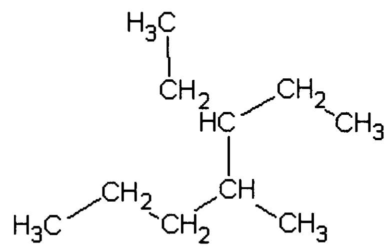
3.)



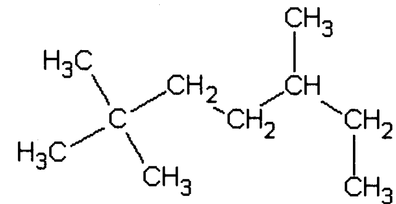
4.)



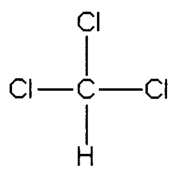
5.)



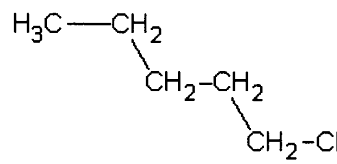
6.)



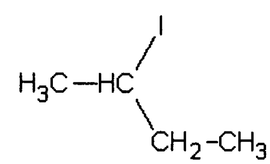
7.)



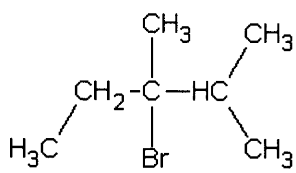
8.)



9.)



10.)



Draw the structures for the following names.

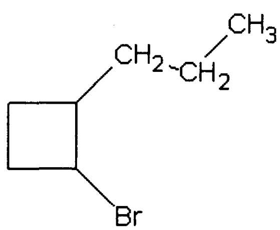
11.) Ethane
12.) 3-Methylpentane
13.) 1,1-Dibromopropane
14.) 1,2-Dibromopropane
15.) 3,4-Dimethylnonane
16.) 3-Ethyl-4,4-dimethylheptane

3/28/01

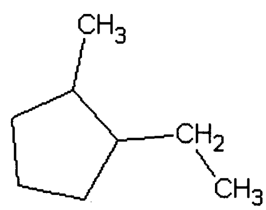
Practice Sheet: Naming #2

Name the following structures using the IUPAC naming system.

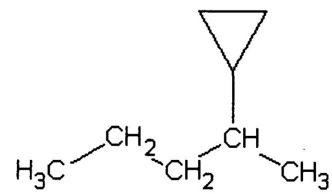
1.)



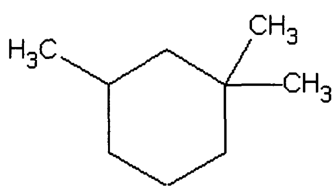
2.)



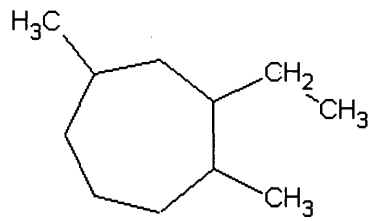
3.)



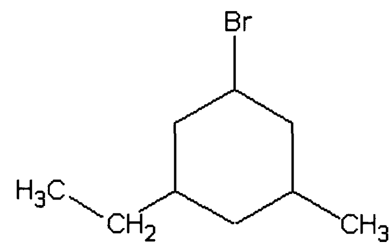
4.)



5.)



6.)



Draw the structures for the following names.

7.) 1,1-Dimethylcyclooctane
8.) 3-Cyclobutylhexane
9.) 1,2-Dichlorocyclopentane
10.) 1,3-Dibromo-5-methylcyclohexane

Appendix G

Homework (Collected)

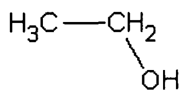
Name:______________________________

4/17/01

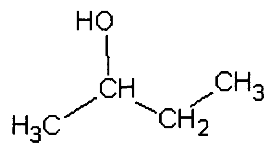
More Work With Alcohols

Label the following as primary, secondary, or tertiary.

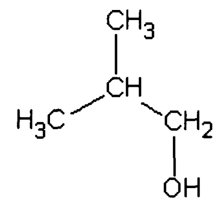
1.



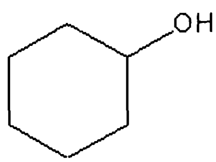
2.



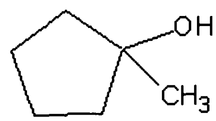
3.



4.

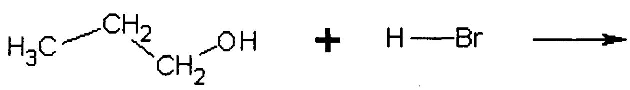


5.

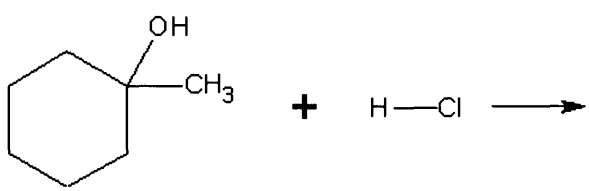


Predict the product of each reaction.

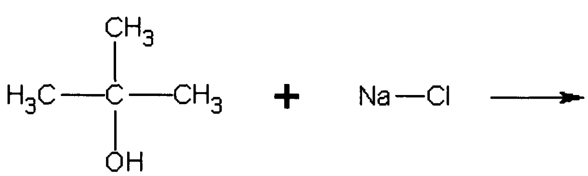
6.



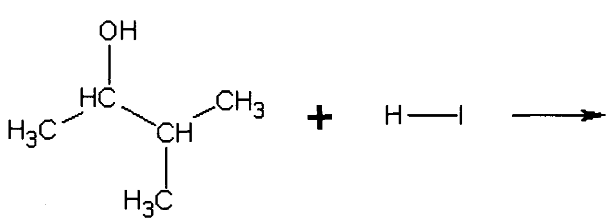
7.



8.

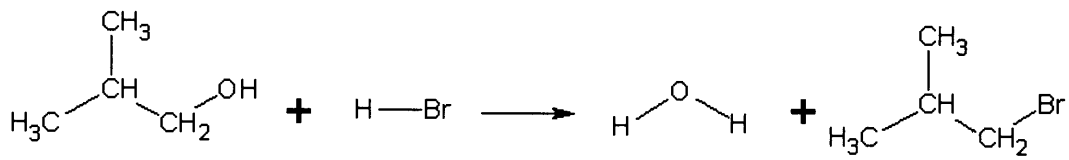


9.

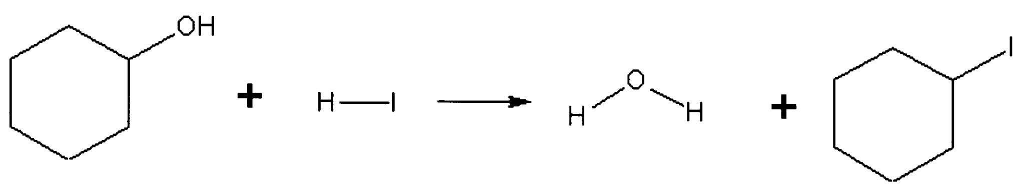


Write out the mechanism for the following reactions.

10.



11.



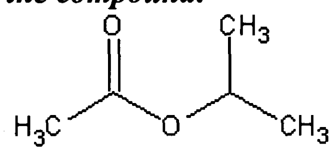
Esters Homework

This homework was written on the board, students were asked to copy the assignment down.

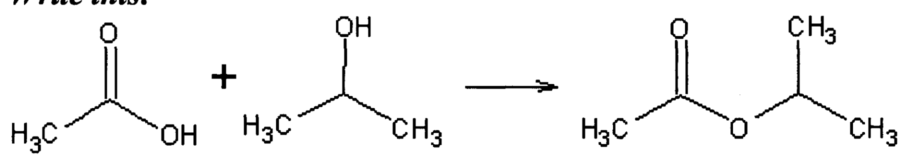
1.) Write down the carboxylic acid and the alcohol that would be needed in order to form each of the esters on pg17 in the manual. Please use this form:

Example:

For the compound:



Write this:



2.) Write the mechanism for the Fischer Esterification of n-propyl acetate.

Name___________________________

5/14/2001

Review for Final

Select the correct word to fill in the blank. There are more words than you need

alcohol	melting point	aldehyde
alkanes	ether	nucleophile
suction filtration	cabocation	3
unimolecular	reflux	ketones
bimolecular	density	fractional distillation
methyl ketones	carboxylic acid	fast
acidic	carbanion	slow
basic	isomers	4
carbonyl	electrophile	alkenes
alkyl halide	acid	boiling point
5	base	isotopes

1. _________________ contain all singly bonded carbon and hydrogen atoms, therefore they are saturated compounds.

2. The ________________ carbon in a ketone is the one that is double bonded to the oxygen.

3. Carbon can have ______ bonds around it.

4. _______________ are electron rich, but ________________ are electron deficient.

5. A positively charged carbon species is called a _________________.

6. S_N1 reactions have a rate-determining step that is __________________.

7. _______________ are defined as organic compounds containing only an –OH group on the main carbon chain.

8. In an aldehyde the hydrogen atom bonded to the carbonyl carbon is very _______________.

9. A _________________ is a negatively charged carbon species.

10. When separating two liquids of significantly different boiling points, a techniques that one may wish to use is ____________________________.

11. S_N2 reactions have a rate-determining step that is ____________________.

12. ____________________ are a class of organic compounds that contain at least one double bond between carbon atoms.
13. A compound that has a halogen attached to the carbon chain may be referred to as a(n) _________________________.

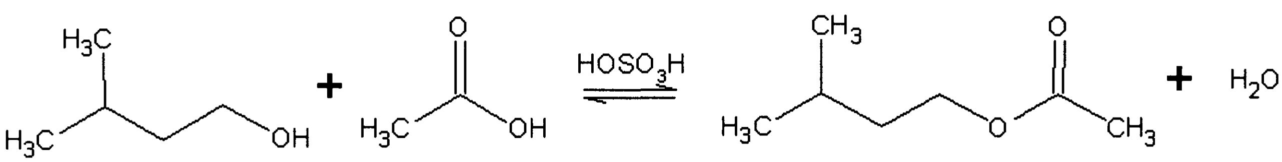
14. The temperature at which a liquid distills is known as its ______________________.

15. In order to form an ester you must react a(n) ______________________ and a(n) ____________________ in the presence of an acid catalyst.

16. ________________________ are compounds that have the same number and types of atoms, but in different arrangements.

17. The iodoform test is used to identify ________________________.

Fill in the missing information in the mole table below. The reaction is the esterfication of isoamyl acetate.



Compound Name	Boiling Point (°C)	Molecular Weight (g/mol)	Density (g/mL)	Mass (g)	Volume (mL)	Moles
Acetic Acid	117.9		1.05		4.6	0.080
Isoamyl Alcohol	130	88.1	0.809	2.9		0.033
Isoamyl Acetate	142	130.2		3.8	4.9	
Water	100	18.0				

Appendix H

Exams

Name:______________________________

April 27, 2001

Quiz 1

For questions 1-8 please write the name of the compound in the space provided. (3 points each)

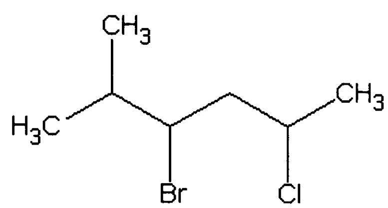
1. CH_4 ______________________________

2. CH_3CH_3 ______________________________

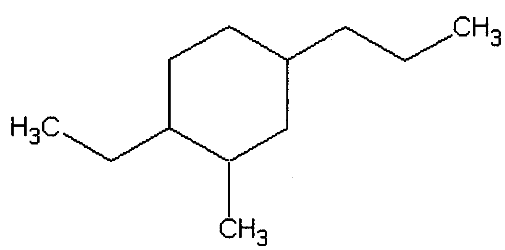
3. $CH_3CH_2CH_3$ ______________________________

4. $CH_3CH_2CH_2CH_3$ ______________________________

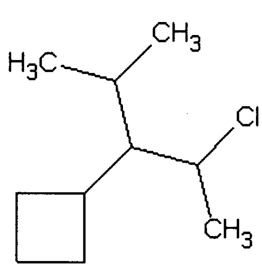
5. ______________________________



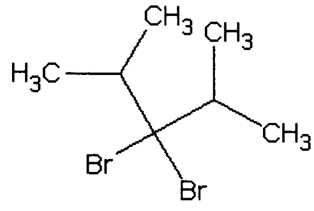
6. ______________________________



7. ______________________________

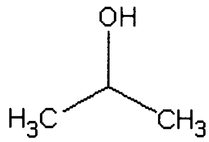


8. ______________________________



For Questions 9-13 please identify each alcohol as primary secondary, or tertiary. (2 points each)

9.



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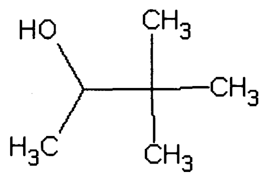

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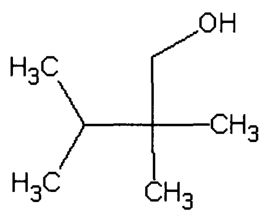

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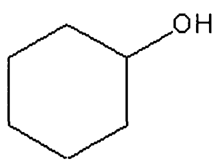
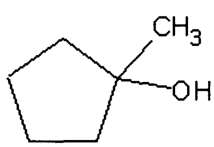
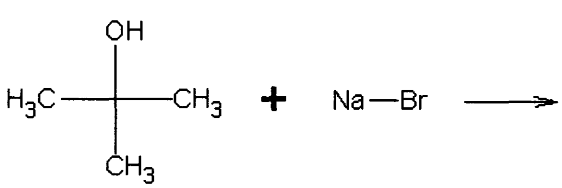


13.



For Questions 14-19 predict the product of the reaction. (5 points each)

14.



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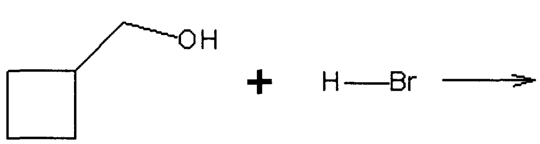

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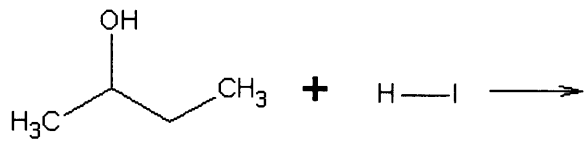

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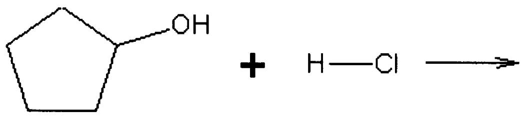

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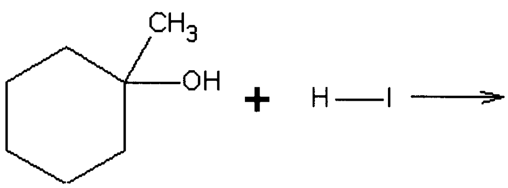

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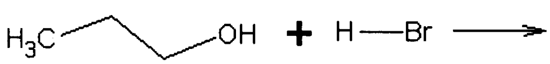


For Questions 20-24 please indicate whether the specified reaction (from #15-#19) follows the S_N1 or S_N2 mechanism. (5 points each)

20. Which mechanism will reaction **#15** follow? ________________

21. Which mechanism will reaction **#16** follow? ________________

22. Which mechanism will reaction **#17** follow? ________________

23. Which mechanism will reaction **#18** follow? ________________

24. Which mechanism will reaction **#19** follow? ________________

For Question #25 please choose one of the above reactions that follows the S_N2 pathway and write the mechanism (use the back of this sheet). Then please explain why it follows this pathway rather than S_N1. (11 points)

Bonus: (5 pts.)

Explain what the terms S_N1 and S_N2 stand for.

Name:_________________________

May 22, 2001

Final Exam

(Remember you must get at least a 50% on this to pass the class.)

Name the following compounds using the IUPAC naming system.

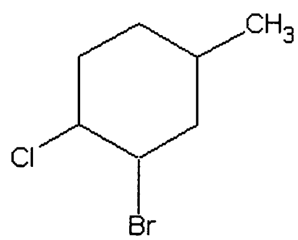
1. CH_4 ____________________

2. $CH_3CH_2CH_2CH_3$ ____________________

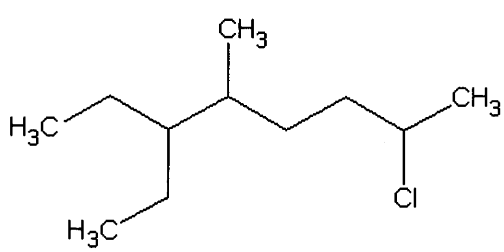
3. CH_3CH_3 ____________________

4. $CH_3CH_2CH_3$ ____________________

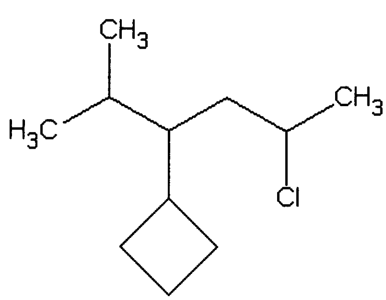
5. ____________________



6. ____________________

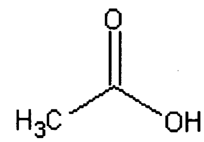


7. ____________________

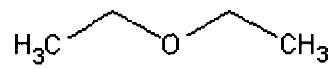


Identify the functional groups in the following compounds, as either ether, alcohol, aldehyde, carboxylic acid, ketone, or ester.

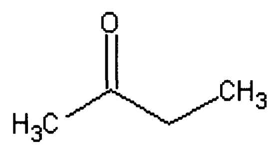
7. ______________________



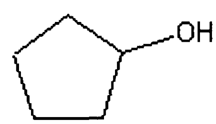
8. ______________________



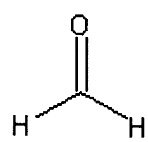
9. ______________________



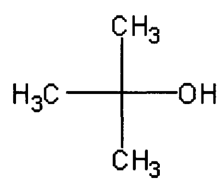
10. ______________________



11. ______________________

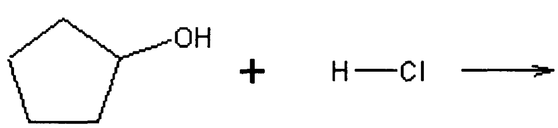


12. ______________________

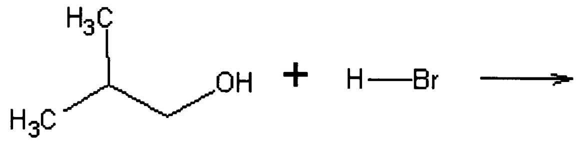


Write the major organic product(s) of each of the following reactions.

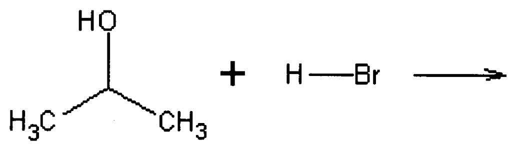
14.



15.



16.



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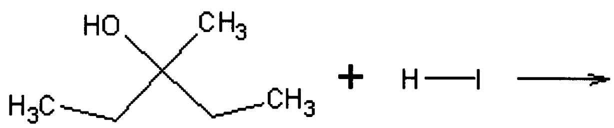
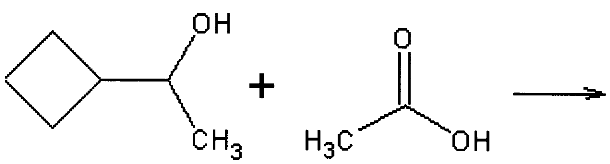
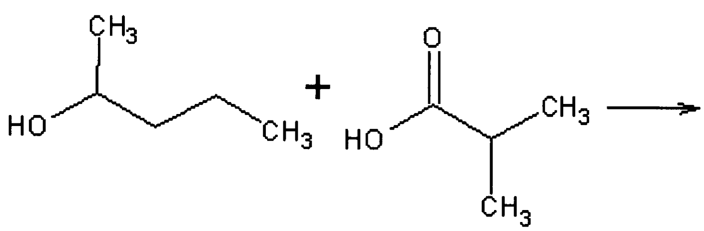


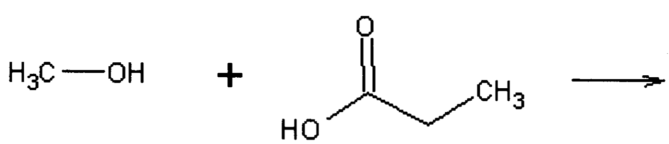
18.



19.



20.



21. *Write out the mechanism of the reaction in problem #16.*

Fill in word that best completes each statement. There are more words than you will need.

boiling point	fast	unimolecular
acid	slow	bimolecular
cabocation	ketone	distillation
electrophile	suction filtration	base
reflux	isomer	carbanion
mechanism	nucleophile	iodoform

22. Set up #1 is used for ________________________.

23. Set up #2 is used for ________________________.

24. Set up #3 is used for ________________________.

25. ___________________ are electron deficient, but _______________________ are electron rich.

26. S_N1 mechanisms have a rate-determining step that is _____________________.

27. The rate determining step in a reaction is the _________________ step.

28. The ___________________ test is used to identify methyl ketones.

29. A positively charged carbon species is known as a ____________________.

30. SN2 mechanisms have a rate-determining step that is _____________________

Indicate the Mistakes Made on this Notebook Entry

7

Title: Synthesis of Isoamyl Acetate

(Mole Table on Seperate Sheet)

Purpose: To Synthesize Isoamyl Acetate in high yield.

Procedure & Observations:

A mixture of isoamyl alcohol, glocial acetic acid, and concentrated sulfuric acid was prepared in a 25 mL round bottom flask. The mixture was heated with a bunsen burner and allowed to reflux for 60 minutes. While the solution was heating it changed color.

The mixture was cooled and then poured into a beaker containing 20 mL of saturated sodium bicarbonate quickly, the mixture bubbled over and spilled. This mixture was then poured into a separatory funnel. The organic layer and aqueous layer were washed and separated.

The organic layer was dried over anhydrous calcium chloride. This liquid was then distilled over the range [redacted] 129 - 131 °C. The product was collected in a yield of 40%.

Appendix I

Sample Student Work

Good Sample Student Homework

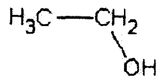
Name: [redacted]

4/17/01

More Work With Alcohols

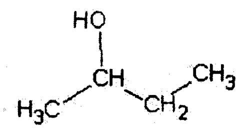
Label the following as primary, secondary, or tertiary.

1.



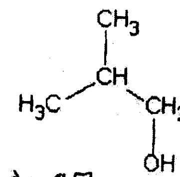
primary

2.



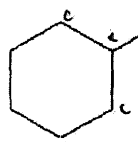
secondary

3.



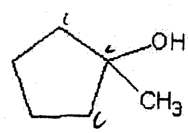
primary

4.



secondary

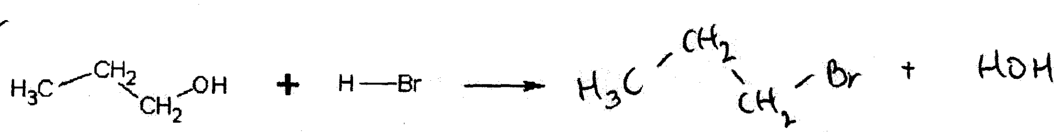
5.



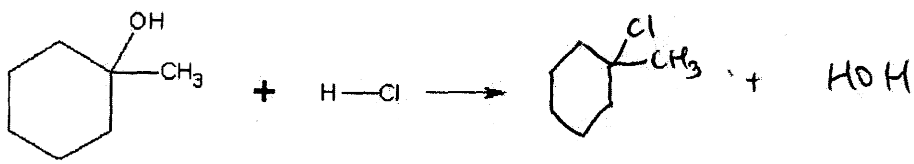
tertiary

Predict the product of each reaction.

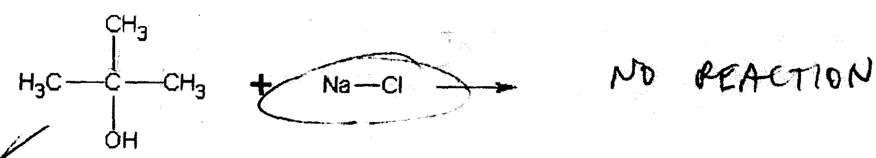
6.



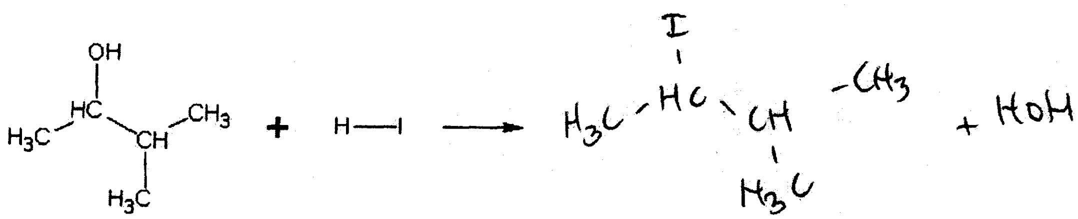
7.



8.



9.

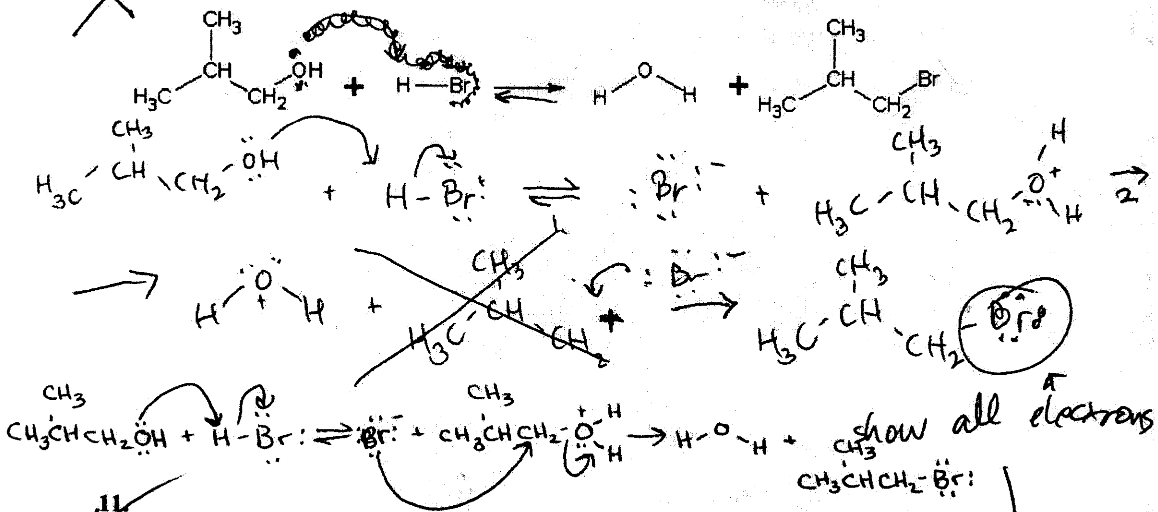


Good Student Homework Continued

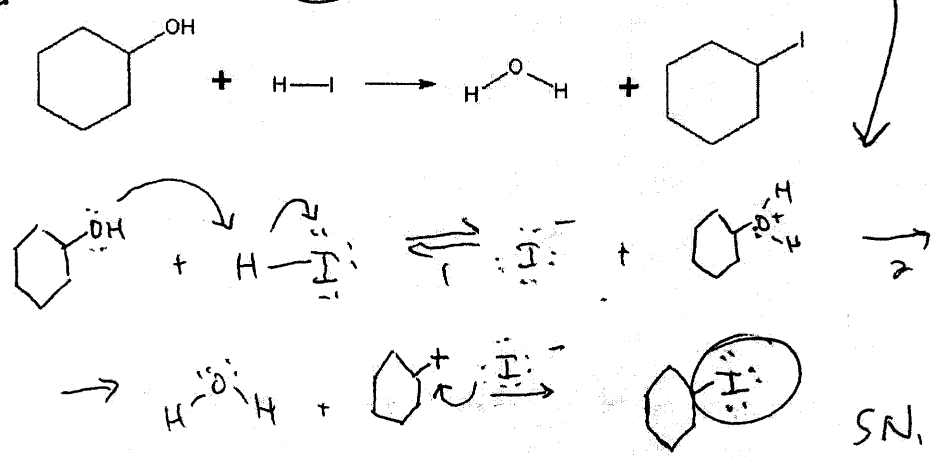
SN2

Write out the mechanism for the following reactions.

10.



11.



Poor Sample Student Homework

Name [redacted]

5/14/2001

Review for Final

Select the correct word to fill in the blank. There are more words than you need

alcohol	melting point	aldehyde
alkanes	ether	~~nucleophile~~
suction filtration	~~cabocation~~	3
unimolecular	reflux	ketones
bimolecular	density	fractional distillation
methyl ketones	carboxylic acid	fast
acidic	carbanion	~~slow~~
basic	isomers	~~4~~
carbonyl	~~electrophile~~	alkenes
alkyl halide	acid	boiling point
5	base	isotopes

1. ___ether___ X contain all singly bonded carbon and hydrogen atoms, therefore they are saturated compounds.
2. The ___carboxylic acid___ X carbon in a ketone is the one that is double bonded to the oxygen.
3. Carbon can have ___4___ bonds around it.
4. ___nucleophile___ are electron rich, but ___electrophile___ are electron deficient.
5. A positively charged carbon species is called a ___carbocation___.
6. S_N1 reactions have a rate-determining step that is ___slow___ X.
7. ___alkene___ X are defined as organic compounds containing only an –OH group on the main carbon chain.
8. In an aldehyde the hydrogen atom bonded to the carbonyl carbon is very ___acidic___.
9. A ___carbanion___ is a negatively charged carbon species.
10. When separating two liquids of significantly different boiling points, a techniques that one may wish to use is ___fractional distillation___.
11. S_N2 reactions have a rate-determining step that is ___fast___ X.
12. ___alkyl halide___ X are a class of organic compounds that contain at least one double bond between carbon atoms.

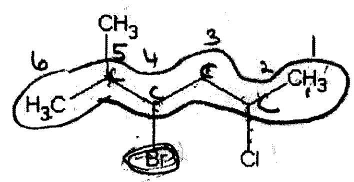
Excellent Sample Student Quiz

.9 95% **Name:** [redacted]

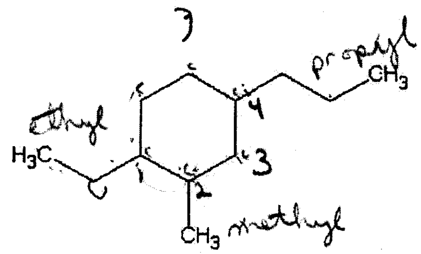
Quiz 1

For questions 1-8 please write the name of the compound in the space provided. (3 points each)

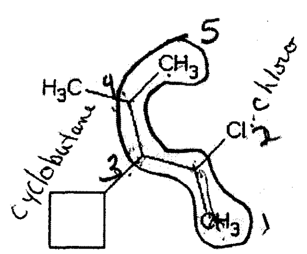
1. CH_4 methane ✓
2. CH_3CH_3 ethane ✓
3. $CH_3CH_2CH_3$ propane ✓
4. $CH_3CH_2CH_2CH_3$ butane ✓
5. 2-chloro-4-bromo-5-methylhexane -2
   3-bromo-5-chloro-2-methylhexane



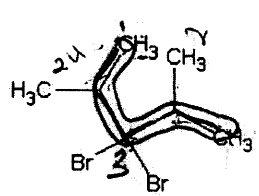
6. 1-ethyl-2-methyl-4-propylcyclohexane



7. 2-chloro-3-cyclobutyl-4-methylpentane ✓



8. 2-methyl-3,3-dibromopentane -1½
   3,3-dibromo-2,4-dimethylpentane



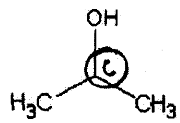
1

-3

Excellent Sample Student Quiz Continued

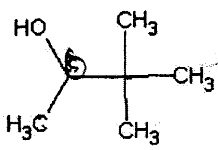
For Questions 9-13 please identify each alcohol as primary secondary, or tertiary. (2 points each)

9.



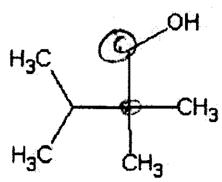
2° (secondary)

10.



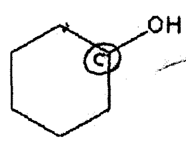
2° (secondary)

11.



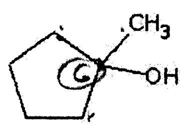
1° (primary)

12.



2° (secondary)

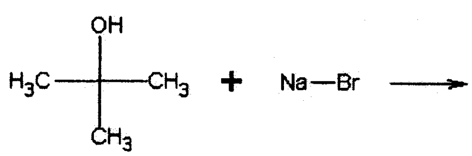
13.



3° (tertiary)

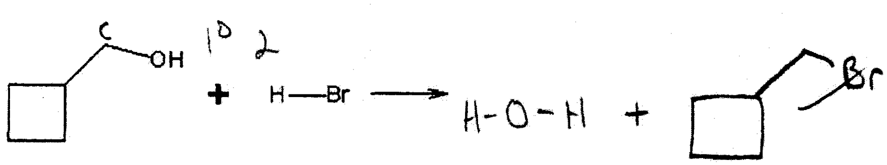
For Questions 14-19 predict the product of the reaction. (5 points each)

14.



no reaction ✓

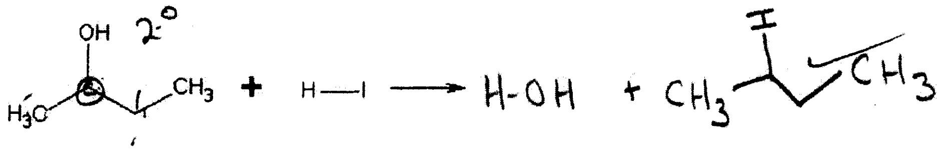
15.



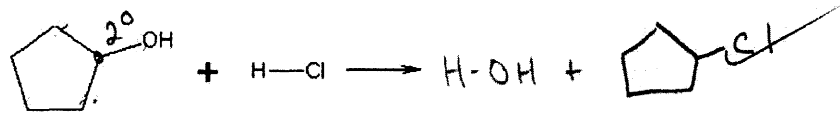
-0

Excellent Sample Student Quiz Continued

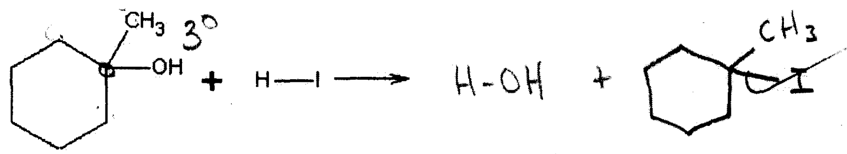
16.



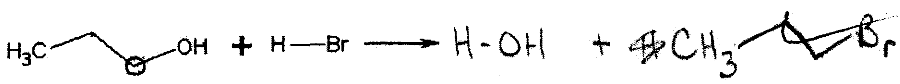
17.



18.



19.



For Questions 20-24 please indicate whether the specified reaction (from #15-#19) follows the S_N1 or S_N2 mechanism. (5 points each)

20. Which mechanism will reaction **#15** follow? S_N2 ✓
21. Which mechanism will reaction **#16** follow? S_N1 ✓
22. Which mechanism will reaction **#17** follow? S_N1 ✓
23. Which mechanism will reaction **#18** follow? S_N1 ✓
24. Which mechanism will reaction **#19** follow? S_N2 ✓

For Question #25 please choose one of the above reactions that follows the S_N2 pathway and write the mechanism (use the back of this sheet). Then please explain why it follows this pathway rather than S_N1. (11 points)

-3

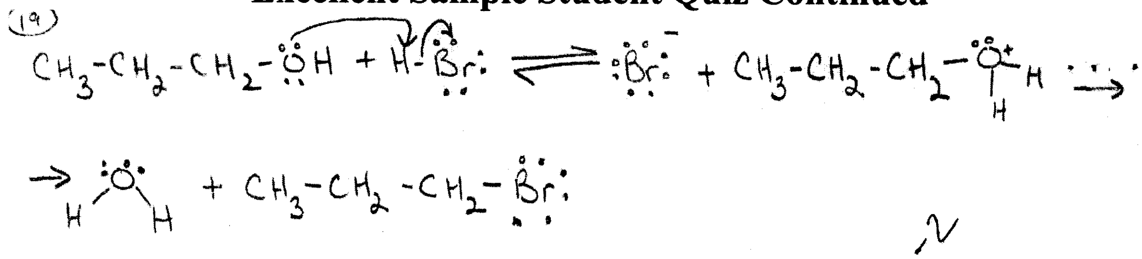
Bonus: (5 pts.)
Explain what the terms S_N1 and S_N2 stand for.

The 1 means unimolecular
The 2 means bimolecular

-3.2

Excellent Sample Student Quiz Continued

(19)



This reaction follows the S_N2 mechanism because the original alcohol is only a primary alcohol. It does not follow the S_N1 mechanism because when the water leaves the compound, the part that is left is too unstable to remain on its own. The halogen, in this case, bromine, immediately attaches to it, yielding the final product

This means that it will not form a stable carbocation, so the Bromine ion must ~~push the water off of the ion must~~ push the water off of the ion, rather than the carbocation pushing the H_2O off on its own. The intermediate ion is too weak.

Good Sample Student Exam

86.5%
+ 5
91.5%

Name: [redacted]

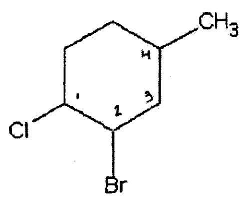
May 22, 2001

Final Exam

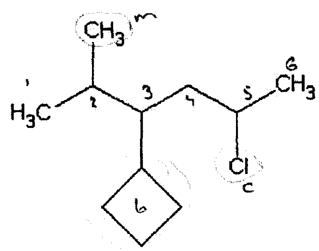
(Remember you must get at least a 50% on this to pass the class.)

Name the following compounds using the IUPAC naming system.

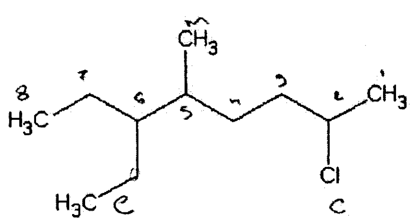
1. CH_4 — methane ✓
2. $CH_3CH_2CH_2CH_3$ — butane ✓
3. CH_3CH_3 — ethane ✓
4. $CH_3CH_2CH_3$ — propane ✓
5. 2-bromo-1-chloro-4-methylcyclohexane ✓



6. 3-cyclobutyl-5-chloro-2-methylhexane -1/2



7. 2-chloro-6-ethyl-5-methyloctane ✓

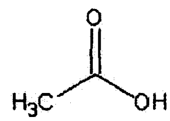


-1/2

Good Sample Student Exam Continued

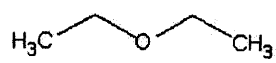
Identify the functional groups in the following compounds, as either ether, alcohol, aldehyde, carboxylic acid, ketone, or ester.

8.



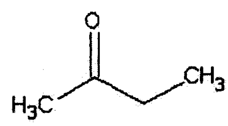
carboxylic acid ✓

9.



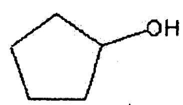
ether ✓

10.



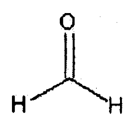
ketone ✓

11.



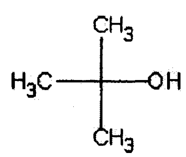
alcohol ✓

12.



aldehyde ✓

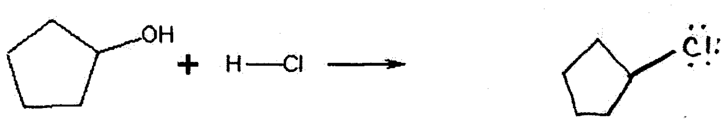
13.



alcohol ✓

Write the major organic product(s) of each of the following reactions.

14.



✓

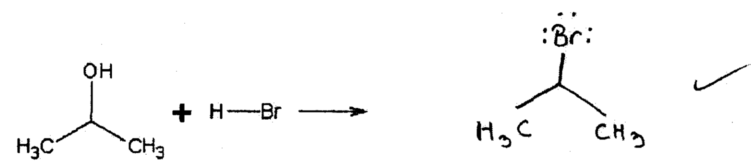
2

-0

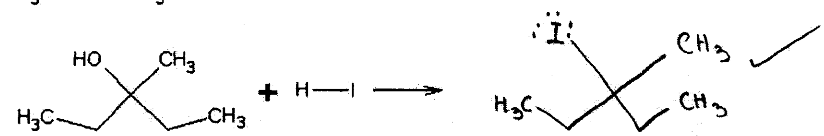
Good Sample Student Exam Continued

15.

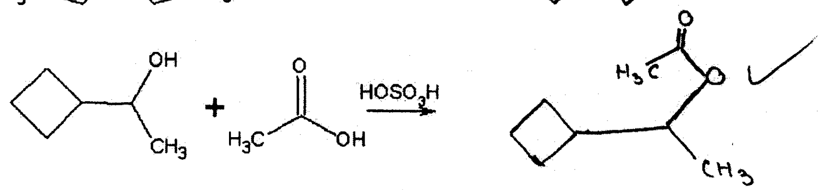
16.



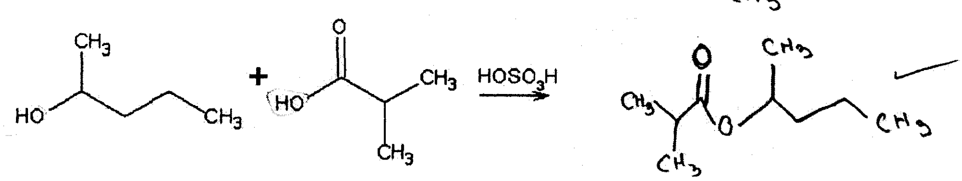
17.



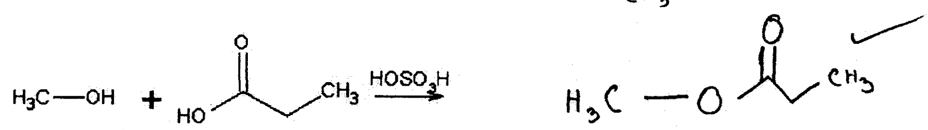
18.



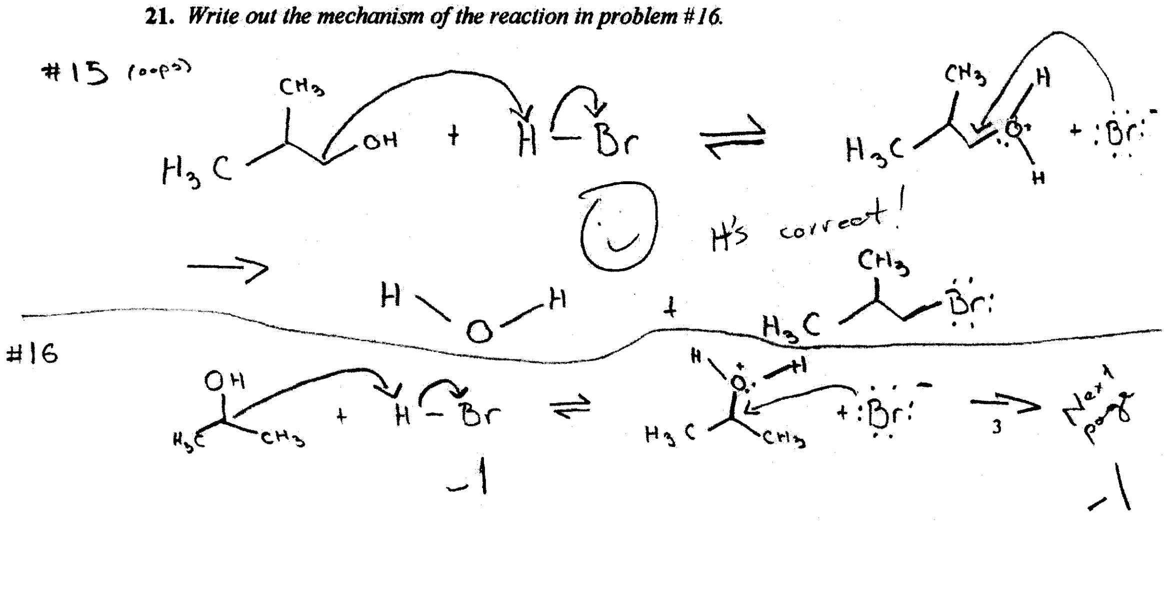
19.



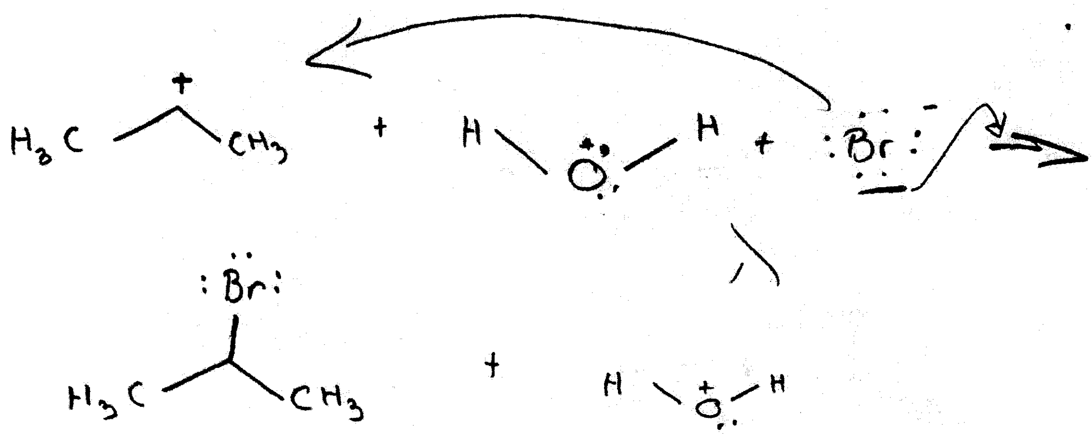
20.



21. ***Write out the mechanism of the reaction in problem #16.***



Good Sample Student Exam Continued



Good Sample Student Exam Continued

Fill in word that best completes each statement. There are more words than you will need.

boiling point	fast	unimolecular iodoform
acid	slow	bimolecular
cabocation	ketone	distillation
electrophile	suction filtration	base
reflux	isomer	carbanion
mechanism	nucleophile	alcohol

22. Set up #1 is used for suction filtration ✓.

23. Set up #2 is used for distillation ✓.

24. Set up #3 is used for reflux.

25. Electrophiles ✓ are electron deficient, but nucleophiles ✓ are electron rich.

26. S_N1 mechanisms have a rate-determining step that is unimolecular ✓.

27. The rate determining step in a reaction is the slow ✓ step.

28. The iodoform ✓ test is used to identify methyl ketones.

29. A positively charged carbon species is known as a carbanion -2.

30. SN2 mechanisms have a rate-determining step that is bimolecular ✓.

4

-2

Good Sample Student Exam Continued

Instructions:
Comment on mistakes

Needs date here

Title: Synthesis of Isoamyl Acetate
Needs chemical equations here.
(Mole Table on Seperate Sheet)

Purpose: To Synthesize Isoamyl Acetate in high yield.

Procedure + Observations:

A mixture of isoamyl alcohol, glacial acetic acid, and concentrated sulfuric acid was prepared in a 25mL round bottom flask. The mixture was heated with a bunsen burner and allowed to reflux for 60 minutes. While the solution was heating it changed color.

Should comment on changes during mixing.

The mixture was cooled and then poured into a beaker containing 20mL of saturated sodium bicarbonate quickly, the mixture bubbled over and spilled. This mixture was then poured into a separatory funnel. The organic layer and aqueous layer were washed and separated.

Should indicate number of repetitions

The organic layer was dried over anhydrous calcium chloride. This liquid was then distilled over the range [redacted] 129-131°C. The product was collected in a yield of 40%.

Should indicate number of repetitions.

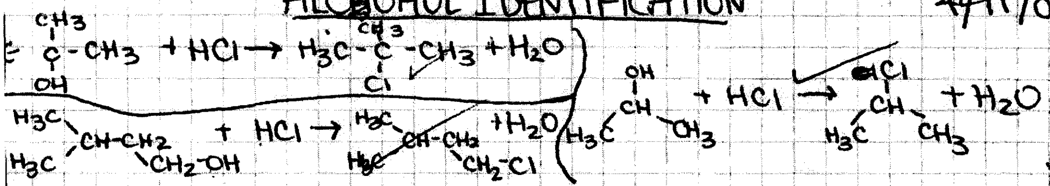
Needs answers to questions here.

-10

Excellent Sample Student Lab Notebook

ALCOHOL IDENTIFICATION

4/11/01 (6)



Compound Name	Molecular Weight (g/mol)	Boiling Point (°C)	Density (g/mol) (mass g)	Toxicity	Volume	mols
isoamyl alcohol	88.15	130	0.809	Irritant Flammable	1mL	0.0091
isoamyl chloride	106.59	99	0.87	Irritant Flammable	1mL	.0082
t-butyl alcohol	74	82.2	0.79	Irritant Flammable	1mL	.011
t-butyl chloride	92.57	51	0.842	Irritant Flammable	1mL	.00910
Isopropyl alcohol	60.1	82.4	0.786	Irritant Flammable	1mL	.013
Isopropyl chloride	78.5	35.7	0.862	Irritant Flammable	1mL	.0110
water	18	100	1.0	none	1mL	.056

~~Purpose: To determine which of the 3 unknown alcohols is isoamyl alcohol, t-butyl alcohol & isopropyl alcohol.~~

Objective: To determine which of the 3 unknown alcohols is isoamyl alcohol, which is t-butyl alcohol, & which is isopropyl alcohol.

Procedure: 3 test tubes were labled 1B, 2B, & 3B. 1mL of the appropriate unknown alcohol was placed in each of the 3 test tubes. This was done by measuring the 1mL of unknown in a graduated cylinder from a pipet. The liquid was then poured into it's appropriate test tube.* All three were clear colorless liquids that smelled strongly of being alcohols. Next 1mL of HCl was placed into each of the test tubes. The HCl was taken from its container to the test tube with a special measuring pipet attatched to a syringe. Alcohol 1B reacted immediately to the added HCl. A cloudy substance was formed & settled to the bottom, leaving

4/11/01 (7)

a clear, colorless liquid (presumably H_2O) at the top. About 2/3 of the liquid in the test tube was the newly formed white cloudy substance. Because of the immediate reaction time of alcohol 1B, it can be concluded that this was the 3° alcohol, t-butyl alcohol (2-methyl-2-propanol). The unknown alcohol 3B also reacted to form a white cloudy solution & a clear, colorless liquid* However it reacted much more slowly. It's reaction produced heat (just like the 1B alcohol's reaction). The reaction also produced a few bubbles & condensation on the inside of the test tube. The foggy resultant of the 3B alcohol reaction was only about 1/4 the total volume of liquid in the test tube. Because of the smaller amount of resultant & the slower reaction time, but still the presence of a reaction, alcohol 3B is a 2° alcohol. It is isopropyl alcohol (2-propanol). The 3rd unknown, alcohol 2B, did not react with the HCl that was added to it. It produced some bubbles, but no more than would be expected from the simple addition of 1 liquid to another. There was a very slight increase in temperature of the test tube & a little bit of condensation was formed. However, no foggy precipitate formed. When the test tube was then placed in boiling water (w/ boiling stones added to the test tube) to see if heat caused a reaction, no foggy substance was formed. Instead, the solution turned a slightly orangish color. Since no reaction occured at all (despite heating), alcohol 2B is the 1° alcohol, isoamyl alcohol (3-methyl-1-butanol).

*when was decl.

[illegible]

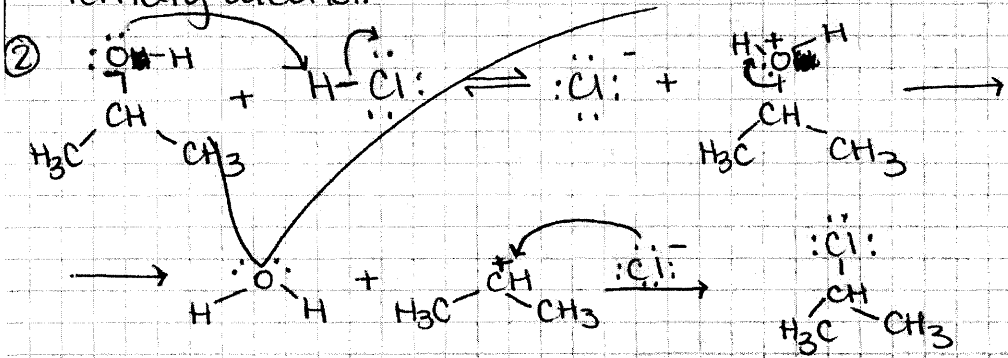
Excellent!

Excellent Sample Student Lab Notebook Continued

4/11/01 (8)

Alcohol Identification Questions

① Tertiary alcohols form ~~very~~ stable carbocations. (carbocations are the intermediate ions formed in this reaction) Because they are stable, these ions are easily formed & strong enough to react with other ions. With all those carbocations floating around in solution, the cloride ions bind with them quickly & easily, finalizing the reaction. The less stable the carbocation is, the less likely it is to react with the cloride ion in the solution, because it tends to return to its original formation. Therefore, the 1st alcohol to react is the one with the most stable carbocations - the tertiary alcohol.

② 

This reaction should occur relatively quickly although since it is a 2° alcohol, not as quickly as a 1° alcohol would react. This reaction may occur spontaneously (as in this lab) or it may need some heat to break the bonds in the 2nd step. (This is the rate-determining step.) 8° 4/17/01

③ When reacting with HCl, t-butyl alcohol would react 1st then isopropyl alcohol, then ~~isoamyl~~ alcohol (n-octyl?), and finally methanol, which won't react at all.

— You only need to correct that one mistake in question #2.

4/21/01

Poor Sample Student Lab Notebook

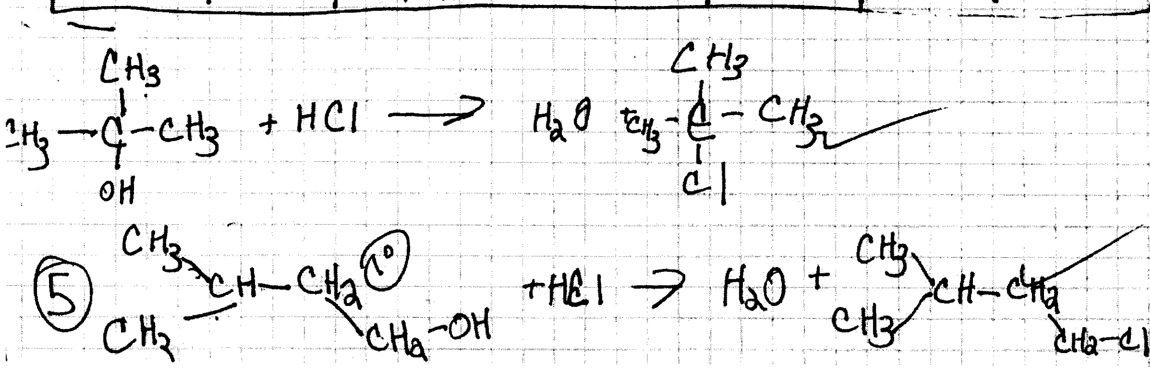
Alcohol Identification 4/11/01

[redacted]

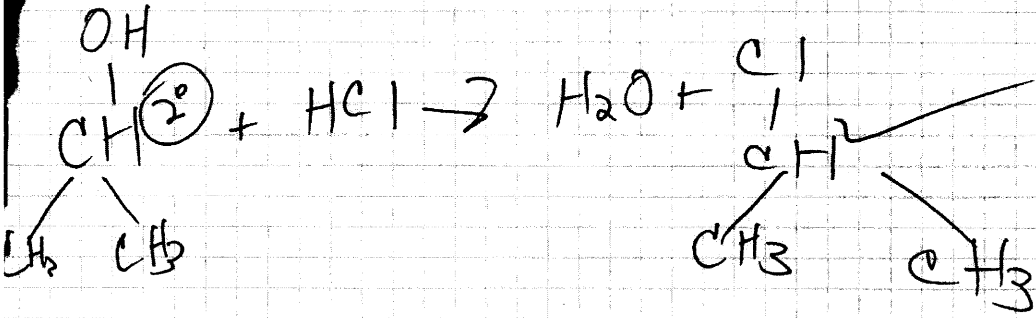
Compound Name	IUPAC Name	Molecular Wt. g/mol	Boiling Pt. °C	Density g/mL	Toxicity
isoamyl alcohol	3-methyl-1-butanol	88.15	130	.809	Irritant/Flammable
isoamyl chloride	1-chloro-3-methylbutane	106.59	99	.87	"
t-butyl alcohol	2-methyl-2-propanol	74	82.2	.79	"
t-butyl chloride	2-chloro-2-methylpropane	92.57	51	.842	"
Isopropyl alcohol	2-propanol	60.1	82.4	.785	"
Isopropyl chloride	2-chloropropane	78.5	35.7	.862	"

Volume (mL)	Moles	Grams
1 mL	.00918	.809
1	.0082	.87
1	.011	.79
1	.00910	.842
1	.0131	.785
1	.0110	.862

Water	18g/mol	18g/mol	100°C	1g/mL	1mL	.056	Not



Poor Sample Student Lab Notebook Continued



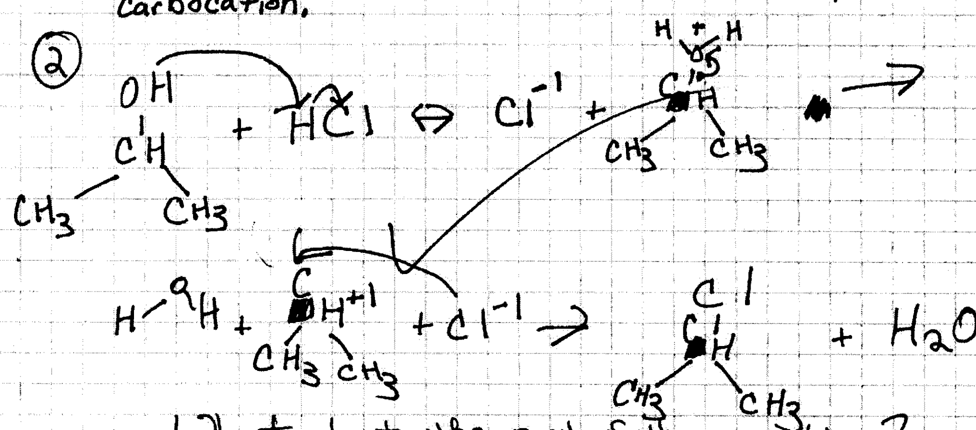
Procedure: ~~After~~ After measuring out 1 mL of each of the "mystery ~~acids~~ alcohols" 2A, B, + C we added 1 m of the 12 M HCl to each ~~alcohol~~ alcohol. 2A reacted quickly, forming 2 determinable cloudy layers and one clear layer on top. 2C reacted without encouragement (to the surprise and great delight of our instructor) forming a cloudy section at the bottom of the test tube. 2B turned very pale red when heated, yet did not form any [redacted] new layers.

Jeff

2A: 2-methyl-2-propanol
2B: 3-methyl [redacted] 1-butanol
2C: 2-propanol

Questions

1. The tertiary reacted quickly because the compound wants to form its intermediate (and very stable) carbocation.

2. 

What about the rest of the question?

3. Methanol, n-octyl, isopropyl, t-butyl
least → most

This reaction will most likely occur at high pressure and low temperature.

Appendix J

Surveys (Blank)

Name:________________________

High School Experimental Organic Chemistry

We would like you to please take a few minutes to answer these questions. This is not something we will be grading. We would simply like to get a feel for your understanding of the subject matter that will be presented. Please answer honestly.

1. Do you know what organic chemistry is? If so, what do you think it is?

2. Do you know of any other branches of chemistry? Can you name a few?

3. What do you think organic chemistry is used for? Do you think that it has many practical uses?

4. Are you interested in learning about the uses of organic chemistry? Do you wish to pursue a career in chemistry of any type?

Course Evaluation

Please circle the number that indicates the degree to which you agree with each statement. ***(5 – strongly agree, 4 – agree, 3 – neither agree or disagree, 2- disagree, 1- strongly disagree).***

1. The purpose of this course was clearly stated.	1	2	3	4	5
2. The manual presented the material in clear and easy to understand manner.	1	2	3	4	5
3. If I had questions about material I could consult the manual.	1	2	3	4	5
4. I spent the time to read the manual.	1	2	3	4	5
5. The material was presented in a sensible order.	1	2	3	4	5
6. The material learned in class related to the labs.	1	2	3	4	5
7. The labs increased my understanding of the material presented in class.	1	2	3	4	5
8. Homework assignments aided me in understanding the material.	1	2	3	4	5
9. I attempted all the homework assignments with an honest effort.	1	2	3	4	5
10. The material in this class was too hard for me to understand.	1	2	3	4	5
11. My previous knowledge of chemistry was useful to me in this class.	1	2	3	4	5
12. The material presented challenged me.	1	2	3	4	5
13. There was adequate time for each lab.	1	2	3	4	5
14. There was adequate time to learn the subject matter.	1	2	3	4	5
15. The homework assignments prepared me for the quiz and final.	1	2	3	4	5
16. We were accurately informed as to what material would be presented on the final and quiz.	1	2	3	4	5
17. I studied for the quiz.	1	2	3	4	5
18. I studied for the final.	1	2	3	4	5
19. The fact that this class was worth little academic credit caused me to put forth less effort than was necessary.	1	2	3	4	5
20. I read the manual before lecture, in order to be prepared.	1	2	3	4	5
21. I read the instructions for the labs ahead of time.	1	2	3	4	5
22. I prepared my notebook (mole table, equation, title, date, etc.) before going to the lab.	1	2	3	4	5
23. This course stimulated my interest in the subject matter.	1	2	3	4	5
24. I was exposed to new equipment in the laboratory.	1	2	3	4	5
25. I was exposed to new techniques in the laboratory.	1	2	3	4	5
26. I was shown how to use the equipment properly.	1	2	3	4	5
27. I feel more prepared to work in a laboratory than I did before.	1	2	3	4	5
28. I asked questions during class.	1	2	3	4	5
29. I felt intimidated and therefor did not want to ask questions in class.	1	2	3	4	5
30. The classroom atmosphere was appropriate.	1	2	3	4	5
31. I feel that I now have a better understanding of what organic chemistry is and what it is used for.	1	2	3	4	5
32. Working with a partner in the lab aided in my learning.	1	2	3	4	5

33. Class-time was used efficiently.	1	2	3	4	5
34. The labs were interesting.	1	2	3	4	5
35. The labs challenged me to think about the material.	1	2	3	4	5
36. The labs were not simply step-by-step instructions for me to follow.	1	2	3	4	5
37. It would have been easier to have instructions presented in a step-by-step form.	1	2	3	4	5
38. The naming game helped me learn more about naming compounds.	1	2	3	4	5
39. The distillation lab taught me important laboratory procedures.	1	2	3	4	5
40. The alcohol lab challenged me to think about chemical reactions and their rates.	1	2	3	4	5
41. The iodoform lab taught me important laboratory procedures.	1	2	3	4	5
42. The Synthesis of n-Propyl Acetate lab taught me a little bit about synthesizing organic compounds.	1	2	3	4	5

Please place the following in order from the least to most difficult. (1 being the easiest and 8 the most difficult).

_______ Naming Organic Compounds
_______ Isomerism
_______ Alcohol Identification (1°, 2°, 3°)
_______ Alkyl Halide Formation Reactions
_______ Mechanisms
_______ Identifying Functional Groups
_______ The Iodoform Reaction
_______ Esterification Reactions

Please answer these questions about your lab notebook.

1. I feel that keeping a lab notebook is an important skill.	1	2	3	4	5
2. I read the description in the manual of what to write in my notebook.	1	2	3	4	5
3. I was sure to follow the form given in the manual.	1	2	3	4	5
4. I wrote down the procedure of the lab as I went along.	1	2	3	4	5

5. Do you have any other comments on the lab notebooks?

Written Response Questions

Please answer the following questions as fully as possible.

1. Please explain the amount of effort that you put into this class.

2. What do you feel could have been done in order to stimulate you interest more in this class?

3. What did you like about this class?

4. What did you dislike about this class?

5. Do you feel that integrating the labs into the class aided your learning?

6. Do you feel that your instructors prepared you for your exam and quiz? Please explain.

7. Do you feel that you have gained a better understanding of chemistry or science in general? Please explain.

8. What do you feel you have learned or gained from this experience? Please be as detailed as possible.

9. Any other comments?

Teaching Evaluation: Starla

1.	Starla defined clear objectives for the class.	1	2	3	4	5
2.	Starla clearly stated her responsibilities in the classroom.	1	2	3	4	5
3.	Starla taught the material in an effective manner.	1	2	3	4	5
4.	She showed an in-depth understanding of the material presented.	1	2	3	4	5
5.	She encouraged students to ask questions on the subject matter.	1	2	3	4	5
6.	Starla was patient with student's questions.	1	2	3	4	5
7.	Starla did not show favoritism towards certain students.	1	2	3	4	5
8.	She made herself available to students for extra help.	1	2	3	4	5
9.	She showed an understanding of the laboratory work.	1	2	3	4	5
10.	Starla was able to maintain control of students during class time.	1	2	3	4	5

Please answer the following questions.

1. Did Starla use an effective method of teaching? Please explain.

2. Did you go to Starla for any extra help? If so, please explain the effectiveness of this meeting.

3. What do you think Starla could have done in order to be a more effective teacher?

Teaching Evaluation: Jeff

1.	Jeff clearly defined his role in the classroom.	1 2 3 4 5
2.	Jeff gave clear instructions prior to the laboratory.	1 2 3 4 5
3.	Jeff showed me how to use laboratory equipment properly.	1 2 3 4 5
4.	Jeff was able to answer my questions with regards to the laboratory equipment and the procedures.	1 2 3 4 5
5.	Jeff appeared to be familiar with the lab equipment and its functions.	1 2 3 4 5
6.	Jeff made himself available to students for extra help.	1 2 3 4 5
7.	Jeff demonstrated an understanding of the material presented in the lectures.	1 2 3 4 5
8.	Jeff demonstrated patience with students who did not understand.	1 2 3 4 5
9.	Jeff showed concern for the students.	1 2 3 4 5
10.	Jeff seemed interested in the material presented.	1 2 3 4 5

Please answer the following questions as completely as possible.

1. Did Jeff use an effective style of presenting the labs? Please explain.

2. Did you go to Jeff for any extra help? If so, explain the effectiveness of this meeting.

3. What do you think Jeff could have done in order to be a more effective instructor?

4. Do you have any additional comments?

Teaching Survey

If you have been attending MASH session led by Starla Richter either for Organic Chemistry 1 and/or 2 please take your time to fill out this survey. You may or may not know that Starla and an IQP partner will be doing their project in teaching, more specifically they will be teaching a course in introductory course in organic chemistry to high school students. This survey has been designed to give Starla an idea of how to improve her teaching style. It would be greatly appreciated if you could fill out this survey and give constructive criticism.

Please take time to answer these questions as fully as possible. All constructive criticism is welcome. Any addition comments you have are welcome.

Section A

About how many MASH sessions led by Starla have you attended? ________________

Section B

Please circle a number 1-5 indicating how you would rate Starla for the following:
1 – very low 2 – low 3 – neither high or low 4 – high 5- very high

1.	Comfort speaking to groups of students.	1	2	3	4	5
2.	The effectiveness of her overall teaching method.	1	2	3	4	5
3.	The clearness of answers to questions asked.	1	2	3	4	5
4.	Her understanding of the problems students are having and her ability to help them.	1	2	3	4	5
5.	Patience dealing with those that do not understand.	1	2	3	4	5
6.	Ability to not be judgmental of the students who don't understand.	1	2	3	4	5
7.	Display of favoritism towards certain students.	1	2	3	4	5
8.	Increasing my understanding of the material by attending her sessions.	1	2	3	4	5
9.	The effectiveness of her use of the chalkboard and other visual aids.	1	2	3	4	5
10.	Proceeding at a reasonable pace, so I am able to follow the material she is explaining.	1	2	3	4	5

Please complete other side

Section C

1. Do you find Starla to be an effective teacher? Please Explain why you feel this way.

2. Do you think that Starla has any personal habits that are distracting or take away from her teaching? (examples: playing with chalk, mumbling, standing in front of writing on the board, moving around too much, etc.)

3. Are there any suggestions that would help Starla improve the effectiveness of her teaching?

4. Other Comments.

This survey may be given directly to Starla or if you wish place it in campus mail for Starla Richter Box 355.

Appendix K

Survey (Results)

Course Evaluation							
Question #	# of Responses for Each Rating (5 to 1)					Average	Mode
	1	2	3	4	5		
1	0	0	1	6	3	4.2	4
2	0	2	2	3	3	3.7	4,5
3	0	1	1	7	1	3.8	4
4	1	2	1	2	4	3.6	5
5	0	1	2	4	3	3.9	4
6	0	0	1	6	3	4.2	4
7	2	0	4	3	1	3.1	3
8	1	0	3	3	2	3.6	3,4
9	3	0	1	1	5	3.5	5
10	3	1	4	2	0	2.5	3
11	0	2	1	4	3	3.8	4
12	0	1	1	6	2	3.9	4
13	0	0	0	8	2	4.2	4
14	1	4	2	2	1	2.8	2
15	0	0	4	5	1	3.7	4
16	0	0	2	6	2	4.0	4
17	3	1	0	3	3	3.2	1,4,5
18	3	0	0	3	4	3.5	5
19	1	2	3	1	3	3.3	3,5
20	1	1	4	3	1	3.2	3
21	1	2	1	4	2	3.4	4
22	1	3	2	4	0	2.9	4
23	3	0	3	3	0	2.7	1,3,4
24	0	0	0	4	6	4.6	5
25	0	0	0	4	6	4.6	5
26	0	0	2	3	5	4.3	5
27	2	0	3	2	3	3.4	3,5
28	0	0	0	5	5	4.5	4,5
29	8	2	0	0	0	1.2	1
30	0	0	3	4	3	4.0	4
31	1	1	2	4	2	3.5	4
32	1	1	4	3	1	3.2	3
33	0	0	2	5	2	3.6	4
34	1	2	2	3	1	3.1	4
35	1	1	2	5	0	3.2	4
36	1	4	1	1	2	2.9	2
37	0	1	4	1	3	3.7	3
38	0	1	0	8	0	3.8	4
39	1	2	1	3	2	3.3	4
40	1	2	2	2	2	3.2	2,3,4,5
41	1	2	2	2	2	3.2	2,3,4,5
42	2	0	3	3	1	3.1	3,4
Lab Questions							
1	0	2	1	3	3	3.8	4,5
2	1	0	0	2	6	4.3	5

3	1	0	0	4	4	4.1	4,5
4	1	2	3	1	2	3.1	3

Teaching Evaluation: Starla					
Question #	# of Responses for Each Rating (5 to 1)				
	1	2	3	4	5
1	1	0	1	3	5
2	1	1	0	4	4
3	2	0	2	3	3
4	1	0	1	4	4
5	0	0	2	4	4
6	1	0	4	3	2
7	0	1	2	3	4
8	0	0	0	6	4
9	0	0	1	5	4
10	0	0	3	4	3

Teaching Evaluation: Jeff					
Question #	# of Responses for Each Rating (5 to 1)				
	1	2	3	4	5
1	0	1	1	3	5
2	0	0	2	3	5
3	0	0	0	1	9
4	0	0	0	0	10
5	0	0	0	0	10
6	0	1	0	4	5
7	0	2	1	3	4
8	0	0	0	1	9
9	0	0	0	4	6
10	0	0	7	1	2

High School Experimental Organic Chemistry Survey: Results

1. Do you know what organic chemistry is? If so, what do you think it is?

- *First Day*: The study of carbon compounds and their interactions with each other.
- *Last Day*: It is the study of carbon-containing compounds, their composition, properties, and interactions with each other.

- *First Day*: Though I'm not positive, I'll hypothesize that it is the study of the fundamental compounds that are associated with living systems.
- *Last Day*: Yes, Organic chemistry is the study of carbon-based compounds. Though not all carbon-based compounds are organic, all organic compounds are carbon-based.

- *First Day*: Organic Chemistry deals with organic compounds, those containing carbon.
- *Last Day*: Chemistry that deals with carbon-containing compounds.

- *First Day*: I am not really sure what organic chemistry is.
- *Last Day*: Organic chemistry is the branch of chemistry that deals with carbon based compounds.

- *First Day*: Not much. It is (I think) the chemistry of organic substances (i.e. living or part of a living organism).
- *Last Day*: Organic chemistry is the study of compounds containing carbon.

- *First Day*: No.
- *Last Day*: Yes. Organic Chemistry is the study of organic(or carbon based, usually) materials, solutions, ect… and how they act under certain situations.

- *First Day*: It has to do with carbon?
- Last Day: Yes, It is the chemistry dealing with organic compounds, which always contain carbon.

- *First Day*: I know what the Chemistry class here has taught me. I think that It is alright.
- *Last Day*: Well, Organic Chemistry is the chemistry involving certain bonds.

- *First Day*: Organic Chemistry is the study of live structures.
- *Last Day*: Chemistry that deals with the study of carbon and things bonded to carbon.

- *First Day*: Only a little – deals w/ organic chemicals….?
- *Last Day*: Organic Chem. is the study of carbon compounds.

2. Do you know of any other branches of chemistry? Can you name a few?

- *First Day*: Nuclear chemistry, Biochemistry, Electrochemistry, Thermodynamics.
- *Last Day*: Nuclear chemistry, Physical/Inorganic Chemistry, Electrochemistry, Thermodynamics, Biochemistry.

- *First Day*: Non-organic chemistry.
- *Last Day*: Inorganic chemistry, nuclear chemistry.

- *First Day*: Inorganic, Biological, Mechanical.
- *Last Day*: Mechanical, Physical, Inorganic, Biological.

- *First Day*: Physical.
- *Last Day*: Physical chemistry, Nuclear chemistry.

- *First Day*: I can name a few: Well, no I can't.
- *Last Day*: Nuclear, inorganic.

- *First Day*: No.
- *Last Day*: No.

- *First Day*: no idea.
- *Last Day*: Biochemistry.

- *First Day*: Nuclear, Biological, Organic.
- *Last Day*: Inorganic, Molecular, Nuclear.

- *First Day*: biochemistry, inorganic chemistry.
- *Last Day*: Electrochemistry, biochemistry, inorganic chemistry.

- *First Day*: I did @ 1 pt., but not any more!
- *Last Day*: Nope.

3. **What do you think organic chemistry is used for? Do you think that it has many practical uses?**

- *First Day*: Yes, I think organic chemistry and biochemistry will have many practical uses because of the new development in genomics and DNA-related drugs.
- *Last Day*: It is probably the basis for biochemistry, which is used to advance our knowledge of medical sciences, botany, etc. (all the LIFE sciences).

- *First Day*: Medicine, biology, food processing.
- *Last Day*: I currently only know that it can be used for the synthesis of certain types of compounds such as esters, which are used to give flavors and scents to foods. It probably has many other practical uses.

- *First Day*: To study living processes, respiration etc. in organisms. It could be used to gain a greater understanding of life and to develop medicines, etc.
- *Last Day*: Medicines, food engineering, any chemistry where carbon compounds are used.

- *First Day*: I think Organic Chemistry is used in the testing of things, for the marketing of Products.
- *Last Day*: It is used to Indentify the substances that are present in organic compounds and It is the kind of chemistry that is used in the manufacturing of many products that are sold in stores.

- *First Day*: Studying how certain life processes occur at their chemical base. It's probably useful, especially in studying medicine or botany or any biology.
- *Last Day*: To study the composition of organic matter. It is used practically in drug manufacturing or vitamins.

- *First Day*: To find the composition of substances. Yes, many.
- *Last Day*: Medical advances, processes such as oil refinement, police investigations (analyzing substance.) It has many practical uses.

- *First Day*: no idea, probably.
- *Last Day*: synthesizing compounds yes.

- *First Day*: for things about the way chemistry effects humans and earth related things?
- *Last Day*: To better understand the world around us. Yes it has many uses like in medicine, food presivation, and all other things. The uses are very practical.

- *First Day*: pharmaceutical uses. Yes organic chemistry probably has many practical uses.
- *Last Day*: synthesizing organic materials for use in foods medicine etc.

- *First Day*: It is probably used by scientists developing something – meds., cures for something.
- *Last Day*: To study carbon compounds. I'm sure it's got many practical uses although I can't think of any.

4. Are you interested in learning about the uses of organic chemistry? Do you wish to pursue a career in chemistry of any type?

- *First Day*: Yes, I would like to pursue medicine or biochemistry.
- *Last Day*: Yes. I wish to pursue Biomedical Science, which involves a lot of chemistry.

- *First Day*: I'm interested in learning but do not plan to pursue this as my field of study at this time.
- *Last Day*: yes, I would like to learn about the uses of organic chemistry, but I have no related career interest.

- *First Day*: NO.
- *Last Day*: NO.

- *First Day*: I am interested in learning about the other uses of organic chemistry and might want to be a chemist.
- *Last Day*: Yes I am Interested in learning about the uses of organic chemistry and I do wish to someday pursue a career in a field of chemistry.

- *First Day*: Yes I'm interested in learning. No, I want to be a doctor.
- *Last Day*: Yes, I'm interested in learning about organic chemistry. No, I'm not interested in persuing a career in chemistry of any type.

- *First Day*: Yes I'm interested. I'm not pursueing a career in chemistry.
- *Last Day*: No. No.

- *First Day*: Yes, not sure.
- *Last Day*: No, no.

- *First Day*: yes, not sure which field but it's a possibility.
- *Last Day*: yes. I am interested in organic chemistry but I don't know if I would take a field in it.

- *First Day*: yes learning about the uses would be interesting, maybe biochemistry.
- *Last Day*: I do not plan to pursue a career in chemistry but am interested in learning more of the uses.

- *First Day*: No.
- *Last Day*: No + no.

Written Response Questions: Results

1. Please explain the amount of effort you put into this class.

-The time I was around for this class, I tried as hard as possible to catch-up with the material presented but, again time was against me and there were more pressing matters to be dealt with.

-Though this class was only worth a quarter of a credit, I was willing to put in the full amount of effort necessary to learning from it and fulfilling all requirements.

-I put as much effort forward as I do when I get dressed in the morning and if you have seen what I wear you would get the idea.

-I put in as much effort as I could into the class, and when I saw that did not work as it did in all my other classes, I put in more.

-I put more into this class than an elective, but less than an academic. I worked on stuff usually only the day we had class either in study hall before class or afterschool that day.

-I didn't put 100% effort in this class for several reasons: too much H.W. from other classes, burnt out from the rest of the year., not a full credit class, & not very interesting.

-I only studied when I had to because I knew I could pass without much effort. There were other classes that were more important to me.

-I put in a good deal of effort. I did all my homework & labs before class, although sometimes in the free period before this class. I also read material ahead of time & studied for both the quiz and test. I didn't study as much for the test though.

-I believe that this class demanded too much effort from each of the students. Because the labs were tedious. So I believe that I put in a good amount of effort.

-Very little. The only effort I put in was at the end because my mother made me.

2. What do you feel could have been done in order to stimulate your interest more in class?

-If more time had been allowed for this class it would have been even more educational.

-I would have liked to have heard more about the practical applications of organic chemistry.
-Not have this class last period 4^{th} quarter after I have P.E.

-Maybe if there were more demonstrations that could have shown what was happening.

-More labs.

-Having this class everyday. (It seemed like we just jumped into the middle of everything.)

-Although the teachers have a limited schedule – offering this class everyday may have stimulated more interest.

-Umm… not much. I would have studied a little harder for the final if this class were grade based rather than pass/fail.

-Present the work in more understandable manner so that I could go home feeling like I know what I am actually doing for homework.

-The material was dry, boring, tedious and difficult to comprehend. I do not know if this is indicative of all organic chemistry, if it was specific things we covered or if it is some fault of the instructor. I think that the pace could have been slower and things explained more thoroughly.

3. **What did you like about this class?**

-I liked the information provided and also the privilege to use the lab equipment. It looks like what you think of when you see a mad scientist in his lab. Also the purple gloves were a plus.

-I enjoyed the hands-on approach provided by the labs.

-In general I enjoyed the class and the instructors and they did a magnificent job, it was me that didn't put forward the effort.

-It was a good learning experience.

-Doing labs was fun.

-Lab set-ups were new & kind of interesting.

-The fact that it was P/F. That way it could be treated as a supplemental course to chemistry, rather than a full class.

-I enjoyed learning new materials & working with new lab set-ups. They gave me a better understanding of college-level lab procedures. Also, I have a concept of what is required in a lab book.

-Besides the cool equipment / Not Much!

-Very little. My classmates were fun and I liked wearing the gloves during the labs.

4. **What did you dislike about this class?**

-How rapidly the lessons were taught. We jumped from one thing to another quickly.

-The lab entries often seemed tedious at the beginning, but gradually became more systematic and easier to complete.

-Nothing besides that its too damn Hot.

-Some of the labs could have been done by rotating partners instead of keeping one partner for the entire quarter.

-Writing in lab notebook.

-Very cut & dry, not much time to do things, only 1 quarter long, only every other day...

-The nature of this course was to introduce us to organic chemistry in 15 or so class days. I have never liked the jack of all trades approach of covering lots of material in a short time.

-The pacing was a little off. We spent a lot of time on naming and very little on stuff that was more complicated.

-There was too much work & homework that was being demanded and I did not even understand what was being taught or any of the concepts behind the subjects that were being discussed.

-The material, the way it was taught, and the unreasonable amount of work required to pass a class worth .13 credits. I found the material boring and loathsome. The only was it would have been tolerable would have been if the instructor was fantastic and she was not. Personally, I like Starla a lot and we get along pretty well but I don't think that she is a very good teacher.

5. **Do you feel that integrating labs into the class aided your learning?**

-Yes.

-Yes, it most certainly did.

-Oh very much so labs made the class better and the purple gloves too.

-The labs helped me to understand what had been previously taught. It helped me to "see" what everything did and made much more sense.

-Yes, I didn't understand the material until I asked more questions in order to answer the questions in the lab notebook.

-Yes it did because you could apply what you learned from the book to actually doing something.

-Again, I did not fully understand the theory, - so sometimes the practial labs were just about following the procedure in a rather mechanical way.

-Somewhat. They did relate to what we were learning & taught on their own, but the labs themselves didn't seem to add to the materials in class. The lab questions did though. They related the 2 parts of the class quite well. The alcohol lab was good at integrating class & lab work.

-No, I do not think so, but then again, I did not understand what I was doing in the first place.

-No, they were just mixing chemicals, heating, etc. no excitement or learning.

6. Do you feel that your instructors prepared you for you exam and quiz? Please explain.

-Yes. They gave me the information in the notebooks, games were played in class, and worksheets helped prepare for the exam and quiz.

-Yes, all the material was properly covered in class and covered on the quiz and the test.

-Well, I'm not sure, I didn't, I'm not sure if they did or not.

-Yes. They explained everything that would be on the test.

-Yes. I myself, however, did not put forth as much effort into studying for them. I had a calculus & physics test on the same day as exam and spent more time studying for those.

-Yes, although class everyday would have been better.

-Yes, they told us what material to expect.
-Yes but more so for the quiz. This is because we spent less class time covering more materials after the quiz, but lots of class time before the quiz, esp. with naming.

-No, because we did not have enough time to learn the material and the material was not taught in a comprehensive way.

-The teaching was not very good and because of the lack of interesting material coupled with the small amount of credit awarded for passing the course I put in little or no effort. Much of this is my fault, but I do feel that the material could have been presented better.

7. **Do you feel that you could have gained a better understanding of chemistry or science in general? Please explain.**

-No, because of the brief period of learning. If the material would have been taught over a longer period of time, yes.

-I feel that I have taken previous knowledge of chemistry and applied it to a new branch.

-Yes I take chemistry and this is a step beyond so, yes I better understand things now.

-Yes this class incorporated the things that I learned in inorganic chemistry.

-Yes, I have taken chemistry prior to this course, but the chemistry class I took was not thorough. This made me feel stupid in class but this class gave me a better understanding of chemistry.

-Sort of. I feel we just jumped into the middle of organic chem. It was probably easier for those who are taking chemistry this year. 'cuz things are still "fresh." (I took chem last year.)

-Of course. I do know more now than I did about organic chemistry.

-Yes, mostly the reactions and the steps of reactions. Mechanisms helped a lot.

-Not really. I feel like I have just as much knowledge as I did when I entered the class.

-No, I learned very little in this course.

8. **What do you feel you have gained or learned from this experience? Please be as detailed as possible.**

-I have learned a few aspects of organic chemistry, such as the new namings, and also different ways to draw structural formulas.
-A sense of pride. Nah, I lie… I think that I have learned how to be a man. Nah, I lie again. I learned how to name compounds.

-Nothing.

-I learned more about lab techniques. My prior lab experience was pretty limited.

-Yes, I feel like I've learned a lot more lab techniques (which is more interesting than learning strait from the books!)

-I have learned that organic chemistry is far more complicated than inorganic chemistry.

-I learned, lab notebook set-up, basic organic chemistry, and NAMING!

-I have been exposed to new equipment.

-I have learned that under no circumstances will I be taking any science courses, especially chemistry, ESPECIALLY ORGANIC in college! I have also learned that organic chemistry is no fun.

9. Any other comments?

-WPI rocks… I think that the teachers were well prepared and very professional.

Teaching Evaluations: Results

Starla:

1. Did Starla use an effective method of teaching?

-Yes she taught as slowly and clearly as her limited time limit would allow her. She also made time after school for extra help.

-Yes, she clearly explained all the materials during lectures.

-Yes she showed that she understood and in turn taught us as if we were WPI students ourselves.

-Yes. She was able to get her point across as well as being able to know what she was talking about, was not impatient with questions.

-The teaching method was not very effective for me because of my minute prior understanding to chemistry. This was not Starla's fault. I never knew, when I was confused if it was because of how she explained it or because I was clueless.

-Yes, but I felt like we jumped into the middle of everything.

-Starla definitely knew the material and explained it well.

-Yes, She understood the material & explained it well. She wrote things on the board to back up her teaching. She made the class relatively interesting.

-No, she did not. She did not seem to fully understand what she was teaching.

-I did not think that the teaching was effective. Personally, I find it very difficult to lean difficult new materials by reading it in a manual and most of the material was learned by reading and simply gone over or reviewed in class. This hurt my chances of learning the material.

2. Did you go to Starla for any extra help? If so, please explain the effectiveness of this meeting.

-Yes. It was more confusing because of the lack of my knowledge of mechanisms.

-Yes, she effectively explained the answers to all my questions.

-Nope, I failed all by myself.

-No, I did not.

-No

-No

-No

-Yes, to ask about questions in a lab write-up. She was very helpful and answered all my questions.

-The extra help was good and I believe she teaches better in a one-on-one atmosphere than in a class.

3. What do you think Starla could have done in order to be a more effective teacher?

   -I found her very effective.

   -She could have been a little more encouraging in terms of having students ask questions.

   -Nothing. She did her best.

   -Explain things a little more in depth than she did.

   -I think this course would have been easier if the course length had been longer.

   -Had the class everyday.

   -She could have made the lectures a little different from what was written in the lab manual.

   -Spent more time on some of the more complicated material.

   -Explain the class material more effectively.

4. Do you have any additional comments?

   -She gave a little too much homework and started to act like a teacher… huh

   -The course should have been longer and everyday.

Jeff:

1. Did Jeff use an effective style of presenting the labs? Please explain.

-Yes, any questions asked he explained clearly and effectively.

-Yes, he fully explained the purpose of all equipment relative to the function of the lab and explained the proper operation of the equipment.

-Yes all lab equipment was prepared nicely and was presented in a practical way and was very effective.

-Yes. He explained everything, was not impatient with questions, always checked to see if everything was set up.

-I can only recall Jeff presenting the lab once. I think two other times Starla did it. He seemed nervous and didn't talk loud.

-Yes, although he seemed shy and quiet.

-Jeff knew what all the lab set-ups were about and explained us how to use them very effectively.

-Yes. He showed us what needed and how to set the lab up. He was also good at answering questions that were asked.

-Jeff simply answered any questioned that you had.

-Yes he knew exactly what he was doing with the laboratory equipment and procedures etc.

2. Did you go to Jeff for any extra help? If so, explain the effectiveness of this meeting.

-No

-Yes, he told me the proper procedure for using equipment in a particular lab.

-No, I didn't seeing as I had a splendid grade.

-No, I did not.

-No, I just asked questions during the lab.

-No
-No

-Not outside of class, but he answered questions during class effectively.

-Yes. When I went for help he explained what I did not understand.

-No, the only extra help I need from Jeff included specific questions during the labs and he was very effective then.

3. What do you think Jeff could have done in order to be a more effective instructor?

   -Spoke a little more. Seemed a little shy.

   -Jeff's mode of instruction was flawless.

   -Nothing as with Starla, they were gods in my eyes.

   -Nothing.

   -Spoken louder when presenting labs.

   -I think Jeff should have taught the class instead of being so quiet.

   -I do not see any short comings.

   -Maybe a bit more explaining prior to the lab so that there were fewer questions during the lab.

   -He should have explained the material that was on the board because I understood when he explained it.

4. Do you have any additional comments?

   -Jeff is god and should be head of all lab procedures. He NEVER Gave Homework.

   -(Same as those on Starla's evalution.)

Course Evaluation: Results

(Lab book question)

5. Do you have any other comments on the lab notebooks?

-I missed too many days of class and therefore missed much of what I had to do in those labs. Labs missed and time was a problem in completing them.

-They are annoying because it caused more work.

-No matter how hard I tried or how much time I spent on the write-ups there was always something wrong with them.

-I often did not know the appropriate reaction to write on the top of the mole chart. Also when I missed a day and my lab partner didn't take notes it was somewhat confusing.

-Not a bit.

Appendix L

Survey Subject Key

Survey Subject Key

This key groups the survey questions by subject.

Student Expectations of Class:

COURSE EVALUATION: #1, 16

Manual Related:

COURSE EVALUATION: #2, 3, 4

General Organization:

COURSE EVALUATION: #5, 10, 12, 29, 30, 33
WRITTEN RESPONSE: #2, 3, 4, 6

Lab Related:

COURSE EVALUATION: #6, 7, 24, 25, 26, 27, 32, 34, 35, 36, 37
COURSE EVALUATION (Lab Section): #1, 2, 3, 4, 5

Homework:

COURSE EVALUATION: #8, 9, 15

Previous Knowledge:

COURSE EVALUATION: #11, 31
WRITTEN RESPONSE: #7, 8

Time:

COURSE EVALUATION: #13, 14

Self Evaluation:

COURSE EVALUATION: #4, 17, 18, 19, 20, 21, 22, 23, 28
WRITTEN RESPONSE: #1

Material:

COURSE EVALUATION: #38, 39, 40, 41, 42

Appendix M

Final Grade Notes

Grade Calculations

Although we did not give out numeric grades to the class, we calculated them for our "last day awards." They also give an idea of the effort distibution.

Distribution:

Final Exam: *25%*
Notebook: *40%*
Homework: *20%*
Quiz: *15%*

Name	HW Avg.	Notebook	Quiz	Exam	Final Grade
John	90.3	100	89.5	86	93
James	83.3	100	92	91.5	93.4
Jimmy	30.3	100	60	75	73.8
Joseph	33.4	100	49	61.5	69.5
Jessica	92	100	95.5	89	95
Joe	56	0	70	68	38.7
Julie	98.6	100	95	90	96.5
Joey	0	0	49.5	52	20.4
Jody	37.8	100	61	71	74.5
Jenna	88.2	100	40	72	81.6

Report Card Comments

John – Pass
John showed a constant interest in the material and put forth an impressive effort to complete all the necessary work. He approached labs and assignments with the attitude of a scientist, which is very important to one who would like to become one. Had this class been grade based rather than Pass/Fail John would have received a 93%. Excellent work John… thank you so much for all your effort.

James– Pass
We were impressed with amount of effort that James put into this course. All assignments showed that he put thought and time into them. He scored very well on his tests and quizzes. James's lab book was one of the best in the class. We wished that we could have given the "A" he deserves rather than simply a "P". If we had assigned grades James would have received a 93.4%.

Jimmy – Pass
Jimmy's effort in this class was very close to non-existent. Assignments were not tried. His lab book was virtually empty up until the last few days of the class. Jimmy complained that material was too confusing before he attempted it. A few minutes of effort everyday could have amounted to a lot. At times he did seem interested in the labs, but his attitude was most frequently disruptive and counterproductive. Jimmy passed this class only because of his last minute effort to complete the required assignments.

Joseph – Pass
At the start of the quarter Joseph put forth a great effort in this class, he asked questions and tried to understand the material. As the quarter progressed his effort slacked, and rather than asking for help he simply adopted the attitude that he just couldn't do it. In reality there was not much work assigned to the students, but we were lenient with Joseph when he turned them in late. We were also lenient with his lab book towards the end, because it was clear he did it at the last minute. This class would not have been so difficult for him if he had just put in a little effort everyday.

Jessica – Pass
Jessica was a real pleasure to have in this class. Jessica had an excellent lab book, which was extremely thorough. She put in a good effort and it showed, and towards the end when her effort lagged a little bit because the class was Pass/Fail it showed as well. Even with that lagging effort Kate would have earned a 95% in this class had it not been P/F.

Joe – Fail
It is a great disappointment to have to give Joe this grade. All he needed to do was turn in his completed lab notebook to pass. His effort throughout the course was very good. We were impressed at the effort he put forward even though he missed so many classes. However, Joe simply did not fulfill the course requirements.

Julie– Pass
Julie was the best student in the class. Although she complained at times that she didn't think she would do well because of her limited chemistry knowledge, she did great! Her notebook was always on time and her homework showed great effort. It is frustrating to have to assign only a P to a student like Julie who truly would have earned a 97% in this class. She had the highest average of all the students. I hope one day she pursues a career as a scientist. (Organic chemistry is always waiting for you Julie!)

Joey– Fail
Joey seemed to make the decision early on in the course that he was not going to pass. He did not fulfill the requirements. These requirements were to have a completed and approved lab book (which involved doing all the labs), three homework assignments, a quiz, and at least a 50% on the final. Joey did take both the quiz and the final, and he passed them both. However, the rest of the work was not done, and not attempted. We knew that Joey could have passed this course and done well if he had just tried.

Jody – Pass
Jody was doing well at the beginnning of the course, she showed an understanding of the material. As the course progressed she simply seemed to adopt the attitude that she couldn't do it, but she never came to ask for help. Jody completed all requirements. We feel she could have gotten more out of the course if she had just come to ask for help so we could straighten out what was confusing her. Jody put forth a very good effort in the lab.

Jenna – Pass
Jenna did good work in this class. Her notebook was well done, although the last lab left something to be desired. She showed an understanding of the material and put forth a great effort in the lab.

Appendix N

CDS Calendar

St. Croix Country Day School

2000-2001 Calendar

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FEBRUARY 2001

SUN	MON	TUE	WED	THU	FRI	SAT
				1	2 Workshop Day Parent Conferences	3
4	5	6	7	8	9	10
11	12 Lincoln's Birthday	13	14	15	16 AG FAIR	17
18 AG FAIR	19 President's Day	20	21	22	23	24
25	26	27	28			

MAY 2001

SUN	MON	TUE	WED	THU	FRI	SAT
		1 MINI	2 GUSTO	3 WEEK	4	5
6	7	8	9	10	11 Student Art Show	12
13	14	15	16	17	18 SPRING CONCERT	19 PROM
20	21	22	23	24 Orange & White Day	25	26
27	28 Memorial Day Celebration	29	30	31		

MARCH 2001

SUN	MON	TUE	WED	THU	FRI	SAT
				1	2	3 Merit Testing Annual Dinner/Auction
4	5	6	7	8	9 Gallery Opening BINGO	10
11	12	13	14	15	16 MS/US 3rd Qtr. ends	17
18	19	20 SPRING BREAK	21	22	23	24
25	26	27	28	29	30	31

JUNE 2001

SUN	MON	TUE	WED	THU	FRI	SAT
					1 Senior Exams	2
3	4 Lower School Field Day	5	6 Lower School last day	7 MS/US last half day	8 8TH GRADE CELEBRATION	9
10 SENIOR GRADUATION	11	12	13	14	15	16
17	18 Summer Camp Begins	19	20	21	22	23
24	25	26	27	28	29	30

APRIL 2001

SUN	MON	TUE	WED	THU	FRI	SAT
1	2	3	4	5	6 Lower School 3rd Qtr. ends	7
8	9	10	11	12	13 GOOD FRIDAY	14
15 EASTER	16	17	18 NJHS Induction	19	20 Gallery Opening Senior Show MUSICAL PRODUCTION	21
22	23	24	25	26	27 MUSICAL PRODUCTION	28
29	30 MINI GUSTO WEEK BEGINS					

JULY 2001

SUN	MON	TUE	WED	THU	FRI	SAT
1	2	3 VI Emancipation Day	4 Independence Day	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27 Hurricane Supplication Day	28
29	30	31				

Shaded areas indicate classes are not in session

Appendix O

Attendance Sheet

Attendance*										
	John	Jimmy	Joseph	Jessica	Joe	Julie	Joey	Jody	James	Jenna
3/26/01										
3/28/01										
3/30/01										A
4/3/01										
4/5/01							A			
4/9/01	A	A	A	A			A			
4/11/01							A			
4/17/01					A					
4/19/01					A					
4/23/01					A		A	A	A	
4/25/01					A					
4/27/01								A		A
5/10/01			A	A						
5/14/01										
5/16/01										
5/22/01		A								
5/24/01										

* A- Absent

Appendix P

Labs NOT Used

Preparation of Soap

Procedure:

Prepare a solution of 5g *sodium hydroxide* dissolved in a mixture of 20mL of *water* and 20mL of 95% *ethanol*. Place 10g of *cooking oil, fat or lard* in a 250mL beaker and add the solution to it. Heat the mixture on a steam bath for at least 45 minutes. Prepare another 40mL solution of *ethanol-water* and add it in small portions to the reaction over a 45-minute period. Stir the mixture constantly.

Prepare a solution of 50g of *sodium chloride* in 150mL of water in a 400mL beaker. If the solution must be heated to dissolve the salt, it should be cooled before proceeding. Quickly pour the saponification mixture into the cooled salt solution. Stir the mixture thoroughly for several minutes and then cool it to room temperature in an ice bath. Collect the precipitated soap by vacuum filtration, using a Büchner funnel equipped with fast filter paper. Wash the soap with two portions of *ice-cold water*. Continue to draw air through the soap to dry the product partially. Allow the soap to dry overnight. Weigh the product.

Silver Mirror Test

In a thoroughly clean test tube place 2mL of a 5% solution of silver nitrate, and add a drop of 10% NaOH. Add a very dilute solution of ammonia drop by drop, with constant shaking, until the precipitate of silver oxide just dissolves. In order to obtain a sensitive reagent it is necessary to avoid a large excess of ammonia. This reagent should be prepared just before use and should not be stored, since the solution decomposes on standing and deposits a highly explosive precipitate.

Procedure:

The reagent must be prepared immediately before use. To prepare the reagent, mix 1mL of Tollen's solution A with 1mL of Tollen's solution B. A precipitate of silver oxide will form. Add enough dilute (10%) ammonia solution (dropwise) to the mixture to just dissolve the silver oxide. The reagent prepared can be used immediately for the test below.

Dissolve 1 drop of a liquid aldehyde or 10mg of a solid aldehyde in the minimum of bis(2-ethoxyethyl)ether. Add this solution, a little at a time, to the 2 or 3mL of reagent contained in a small test tube. Shake the solution well. If a mirror of silver is deposited on the inner walls of the test tube, the test is positive. In some cases it may be necessary to warm the test tube in a bath of warm water.