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Kenda Jo Lemont

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POLARITY, SOLUTIONS, AND SEPARATION SCIENCE

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Kenda Jo Lemont

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ABSTRACT

POLARITY, SOLUTIONS, AND SEPARATION SCIENCE

By:

Kenda Jo Lemont

This document reports teaching separate yet related topics of chemistry in a unified, thematic way. The concept of polar molecules with oppositely charged ends as the driving force behind solutions and separation science was used to help students link these important and difficult concepts. To motivate the students and help solidify the concepts, many student-directed, hands-on, visual, and relevant laboratory experiments were incorporated in instruction. I observed a positive attitude and even enthusiasm from the students about learning the concepts and performing the exercises in the unit. The evaluation instruments indicate that scores are approximately the same as those achieved in other units. However, the long-term retainment of the information was considerable, as indicated by posttests and interviews. This may be attributed to the students' use of information in motivating and memorable laboratory experiences.

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INTRODUCTION

I. Statement of Problems and Rationale for Study

Before undertaking my research, I had recently completed teaching a chapter on solutions to my general chemistry students. While planning the chapter, I realized that a great deal of the background information had been taught much earlier in a previous chapter on covalent bonding. I backtracked with my students, reviewing the concepts of polar and nonpolar molecules with them and drawing Lewis structures to determine polarity. After the review, we continued studying solutions and what causes a substance to dissolve in another substance. I felt that they understood the concept of polarity better at this point because they could use it to make predictions. Being able to apply the information helped them to better comprehend it. In addition, being confident about their knowledge of polarity helped them comprehend the forces involved in solutions.

Remembering this when contemplating a unit to modify for my thesis project, I decided to develop a comprehensive, thematic unit involving the concept of polarity and its relation to solutions and separation science. Teaching the unit in this thematic way should help students better understand all three concepts. Polarity without an application is difficult to grasp and solutions and separation science without understanding the concept of polarity is impossible to grasp. In addition to developing the unit with an overlying theme of polarity, I also decided to focus on using more hands-on material than in a typical unit. Incorporating separation science and chromatography would add an important "fun factor" into the unit. In the past, students had enjoyed working with chromatography because of the dramatic color changes and the directness and ease of the laboratory experiments. Finally, my unit also emphasized application of the content to enable students to envision and appreciate the purpose of the material they learned.

With the textbook I was using at the time, Chemistry, 1983 (Merrill Publishing Co.), I realized that it was necessary to reorganize the order that topics were presented. I had to decide when the unit should be taught because covalent bonds and polarity were presented much earlier than solutions. The only information in the chapters between polarity and solutions necessary for students to learn before the teaching of my modified unit was general information on gases. In dealing with the solubility of different states of matter, some background information on the kinetic theory was needed. The order of teaching was then decided as kinetic theory, then the combined unit covering polarity, separation science, and solutions.

After teaching the unit for one year I began teaching in a different district with a different book, Chemistry, Visualizing Matter, 1996 (Holt Publishing). Again, I had to decide where to place the unit. I was teaching one section of advanced chemistry and two sections of general chemistry. The advanced class had not covered the information contained in the unit very thoroughly the year before, so I decided to teach the unit to both classes, at different times. Both classes were using the same book, but were, of course, at different places within it. For the advanced group, I taught the unit toward the beginning of the year, when they reached the chapter on solutions and colloids. In keeping with the thematic concept of the unit, some information from an earlier chapter on covalent bonding and polarity was reviewed. For the general chemistry group, I taught the unit in the third marking period when they reached the earlier chapter covering covalent bonding and polarity. Teaching the unit to three different classes using two different books at two different levels made me realize that the unit was very adaptable. The unit can fit into a general chemistry curriculum at the point that students are ready to learn about molarity. For an advanced class, it can be taught during a unit on solutions and solubility.

This thesis focuses, again on three main concepts:

1. Laboratory based, hands-on learning
2. Contextual, real-life application of concepts
3. Unifying concept of polarity

II. Concept Summary

The information for the concepts covered in this unit was compiled from various high school chemistry textbooks as well as "Inorganic Chemistry; Principles of structure and reactivity" by James E. Huheey and "Chemistry" by Bailar, et. al. The first concept was that of polarity, or unbalanced charge of a molecule. Basically, this unbalanced charge is a result of two or more atoms sharing electrons unequally. One atom, with a higher electronegativity, will have a stronger attraction for the shared electrons and will result in that side of the molecule having a slightly negative charge. The other atom, with a low electronegativity, will have a weaker attraction for the shared electrons and a slightly positive charge. This charge difference varies depending on the atoms involved. Therefore different molecules have differing degrees of polarity, resulting in different characteristics such as reactivity, solubility, and boiling point. The polarity of molecules can be predicted by using a combination of molecular geometry and electronegativity differences. Learning these concepts related to polarity was one main objective of the unit.

Once the idea of polarity was understood, separation science, an application of this concept was introduced. Polarity, in addition to molecule size, is what allows components of a solution to be separated from one another in chromatography. The substance to be separated is concentrated in an area of the stationary phase and a solvent is passed over it. The components of the substance will move along the stationary phase at different rates, according to their attraction for the solvent, attraction for the stationary phase, and size of the molecules involved. This attraction is based on the "like dissolves like" concept of solutions. Molecules with similar degrees of polarity will be attracted to each other and therefore separation of the molecules within a sample can occur.

A natural transition to studying solutions followed the section on chromatography. Using the idea of "like dissolves like" and the knowledge gained about polarity of different substances, students predicted whether two substances would be soluble in each other. Factors affecting solubility and units of concentration were also taught in this section, with an emphasis on mathematical manipulation. From this, the idea of suspensions and emulsifiers were introduced. A demonstration on making oil and water mix by adding detergent allowed the student to realize that "like only dissolves like" can be overcome by simply introducing a kind of mediator that bridges the two dissimilar substances. Macromolecules with polar and nonpolar parts serve as this emulsifier. The polar end is attracted to the polar substance and the nonpolar end binds to the nonpolar substance. If the emulsifier is then dispersed evenly throughout the mixture, the suspension is then stabilized and the two substances remain uniformly mixed throughout. Some examples of emulsifiers were discussed, in addition to a comparison of soap and detergent.

III. Review of Pedagogical Literature

As professionals, teachers are continuously trying to improve their teaching in order to promote better student learning. We discuss with our peers methods of curriculum delivery, classroom management, and assessment, with the motive of becoming a better teacher. "What helps our students to learn more? What can we do to increase their understanding?" These questions lead us to assess both what we teach in our classes and how we teach it. Three areas in which I focused my research were: 1) the effectiveness of hands-on activities to student learning; 2) the importance of contextual teaching, or making science relative; and 3) the positive consequences in linking concepts in a unifying way.

1. The Effectiveness of Hands-on Activities in Student Learning

Teachers of all disciplines and levels go through the self-assessment introduced above, but in science specifically we are led to the question of using hands-on activities to promote learning. "How much do hands-on activities help my students learn? Does it depend on how I implement them in my curriculum? Do all students learn better by engaging in hands-on activities?" It seems that the researchers are still contemplating the benefits of laboratory activities to student learning. It will be shown that some research supports the effectiveness of hands-on activities for better student learning, some research indicates that this is not the case, and many experts agree that effectiveness is dependent on the implementation and evaluation of the laboratory experience.

Students can learn by watching and listening but some results suggest that higher achievement is associated with getting involved in a more overt manner (Tobin, 1990). Getting involved in laboratory activities can help promote intellectual development, inquiry, and problems solving skills. It can also assist in developing observational and manipulative skills and in understanding science concepts (Hofstein and Lunetta, 1982). These researchers indicate that using hands-on activities engages the students in a way that is not possible outside of the laboratory. This engagement allows for deeper understanding of the concepts and of the process of science. It seems that teachers of science agree. In a survey performed by Weiss (1987), over 75% of secondary science teachers felt incorporating laboratory activities heavily into the curriculum increased the effectiveness of the course. In addition to the opinions of teachers, other sources support the effectiveness of a laboratory-based class. In a study by Stohr-Hunt (1996), "students who engaged in hands-on activities every day or once a week scored significantly higher on a standardized test of science achievement than students who engaged in hands-on activities once a month, less than once a month, or never." The standardized test in this case was not focused specifically on science process outcomes yet the impact of increased frequency of hands-on experience was still significant. It seems that the students involved in the study became more knowledgeable by becoming more active in learning science. It is possible that the activities involved help motivate students and increase their interest in science, thereby improving their performance. In a study by Renner et. al. (1985), students in a physics class were separated into two groups. One of the groups collected and analyzed data in a laboratory experiment. The other group was given a set of data to analyze. The students who experienced the data collecting had higher achievement and liked physics better than the students who were given the second-hand data to analyze. Other researchers support the idea that laboratory experience promotes positive attitudes and improves motivation (Hofstein and Lunetta, 1982; Brownstein and Destino, 1995; Tobin, 1990). By participating and taking a more active role in the learning process, students' interest improves. They begin to question their own misconceptions and try to formulate a resolution between what they knew and what they are observing. This process of equilibration then leads to better acquisition of new concepts (Glasson, 1989).

Although implementing hands-on activities in the classroom is admired, some researchers indicate that students' results do not support it as an effective learning method. On the contrary, there is much evidence to suggest that laboratory activities fall short on achieving the potential for enhancing student learning and understanding (Tobin, 1990). "A predominance of research indicates that science laboratory activities have neither helped nor hindered students' acquisition of science" (Lehman, 1990). In this study, students' verbal interactions during laboratory activities were monitored. He found that a great percentage of student laboratory time is spent trying to figure out the procedures. This leaves little time for data taking, analysis, and interpretation of the significance of events occurring during the experiment. Glasson's (1989) study indicated that physical manipulation of the laboratory equipment was not a factor in improving declarative knowledge achievement. Students in his study were separated into two groups. One of the groups was presented data by teacher demonstrations. The other group used hands-on activities to acquire the same information. Both groups were given the same lectures, readings and class assignments. The student achievement on conceptual knowledge was not significantly different. The only area in which the groups varied considerably was in tests on procedural knowledge.

Although it seems that researchers are split on the overall effectiveness of laboratory activities, they do agree that in order for activities to be at all effective there must be substantial teacher preparation. The first step necessary in preparation is to match the objectives desired with an appropriate exercise to meet the goals. Often times the use of laboratory work fails to meet its objective because this crucial step is missing. Some science educators argue that the laboratory is only suited for certain types of knowledge acquisition and exercises other than these do not prove beneficial. "One reason for the failure of many science courses is the attempt to use the practical laboratory work for aims to which it is ill-suited, such as teaching theoretical concepts, instead of focusing on the real aims, namely the development of basic process skills, a 'feel' for natural phenomenon and problem solving skills" (Tamir, 1989). Tobin (1990) focuses on the importance of constructivism in the classroom and laboratory. He indicates that students must be free to pursue solutions to problems that interest them and construct knowledge based on these pursuits. He declares the teacher's role is to allocate tasks and the learners will determine whether or not the tasks become problems. Other researchers feel that constructivism and "doing science" are not the only effective kinds of laboratory exercises. Wilson and Stensvold (1991a) identified several student outcomes from laboratory experiences:

a) developing capabilities to perform laboratory techniques and methods in order to obtain reliable and accurate information;
b) gaining experience and learning about the universe first hand, using current scientific viewpoints, materials and processes;
c) comprehending, illustration, explaining, and applying science concepts, theories and theoretical structures;
d) learning to apply facts and principles to new and novel situations and to real world concerns using appropriate analytical, creative, and critical thinking skills; and
e) accepting new ideas while demanding testability with appropriate analysis as a basis for making reasoned judgements and decisions.

These goals, they believe, can be met using a variety of types of laboratory exercises. In their article they quote an argument of some researchers that "verification laboratories are merely recipes fostering little creative thinking and do not adequately represent true scientific effort. Students should learn to solve problems through their experience in the laboratory and the only way to do this is through true problem solving." Their response to this argument is that there are many ways of learning, many things to learn and many learning styles. They indicate that based on this, teachers must plan exercises, taking into consideration who they are planning the exercise for and what they want the learner to obtain from the exercise. They state that to be effective, "laboratory-centered instruction must reflect the nature of science, the nature of knowledge, and the nature of students."

Once a teacher has chosen an exercise that meets the intended objectives, the next step is to prepare the students adequately for the tasks in the laboratory. Tamir, (1989) proclaims that pre-lab discussion is essential for clarifying laboratory exercises and relating them to theoretical concepts. A pre-lab discussion helps students to become familiar with the procedures necessary to perform the experiment. This allows them to focus on data taking and analysis throughout the activity. Lehman, (1990) found in his study that "the procedural complexity of many laboratories would require students to refer frequently to written laboratory procedures which would function as an external memory aid. Gaps at any point in this complex process would tend to reduce the effectiveness of the activity." Demonstrating these more complicating procedures and answering procedural questions helps to prevent the gaps Lehman was referring to.

Tamir (1989) reported that inquiry oriented activities can be very demanding of students, asking them to incorporate knowledge of subject matter, manipulation of variables, and proficiency in using laboratory equipment. Having students gain a basic command of each component before integrating them increases the chance of student success. In addition to clarifying procedures, a pre-lab discussion helps to clarify the purpose of the experiment and ties in the concepts from the lecture and reading material. "Student preconceptions should be measured to structure pre-lab instruction to insure that key concepts are familiar to students prior to their participation in laboratory activities" (Wilson and Stensvold, 1993). If the focus of the laboratory exercise is one of constructing knowledge, this clarification of concepts can be verified in post-discussion, rather than in pre-lab.

Post-laboratory discussion is another important aspect in making hands-on activities effective. Helping the students to evaluate the validity and importance of their observations and draw conclusions based on their data enables the student to realize the purpose of the activity. Any questions or contradictions they developed during the course of the experiment can be addressed and resolved. Students can discuss their findings and explanations and suggest possible extensions to the experiment (Wilson and Stensvold, 1993). Tamir (1989) states that in addition to pre-lab discussion, post-lab discussion assists students in "making sense of the laboratory experiences and relating them to the relevant theoretical concepts." Tobin (1987) agrees that appropriate pre and post-lab discussions can enhance learning.

In addition to pre- and post-laboratory discussion, the teacher's level of participation during the investigation helps to ensure the success of the activity. According to Wilson and Stensvold (1993), depending on the type of activity, the teacher may monitor and direct student progress in several ways. In *generalization* activities, they can check students' perceptions, what they attend to, and what they think is not important in building a generalized explanation of events. In *resolution* activities, where students are confronted with unexpected events, findings, or questions, and try to come to resolution with them by performing student-designed experiments, the teacher's role is slightly different. The role of the teacher in this type of activity is one of technical assistance. They must be open to the pursuit of a problem and encourage students to give reasons supporting their decisions and answers. Teachers must also raise the issues of validity, reliability, accuracy, and precision during resolution activities. In *confirmation* activities, the goals are to reinforce concepts that students are already familiar with, to apply existing scientific theories, to practice laboratory techniques, and to follow directions. If students have been appropriately prepared for the procedural section of the laboratory, the teacher's role during the activity is less significant. Students can be monitored and encouraged to make connections and reflect on the importance of their findings during the accumulation of data. Then, during post-lab discussion, teachers can assess change in student perceptions and reinforce the associations students made during the exercise. In any case, the teacher needs to ensure the success of the laboratory exercise by being an appropriately active member of the activity.

The final step in planning successful laboratory exercises is evaluation. The students must be evaluated to determine the knowledge acquired and the laboratory exercise itself must be evaluated to determine its overall effectiveness. Tamir (1989) recommends that teachers incorporating laboratory work into their curriculum need to assess with innovative practical laboratory tests. Assessment using paper and pencil does not fully evaluate the knowledge gained by hands-on activities. Specific content knowledge gained by hands-on activities can be assessed in the traditional manner, but student performance assessment requires a different approach. A more authentic assessment is definitely in order (Stohr-Hunt, 1996). According to Tobin (1990) evaluation of student learning needs to focus on what students learn from laboratory activities and how students can represent their knowledge. Using paper and pencil methods, personal oral interviews and performance tests attempt to encompass the knowledge acquired, but Tobin (1990) cites cases where these measurements fall short. He aims for continued research in the use of alternative assessment tasks to determine what students have learned from laboratory activities. Involving teachers in the research, not as subjects, but as researchers would be an effective way to collect data on this topic. In this manner, science teachers would be doing science while teaching science. The coordination, teaching, and evaluation of the unit referred to in this thesis is an example of this type of science teaching and doing. Even without the structure of programs suggested by Tobin (1990), the evaluation of the effectiveness of hands-on activities can and should be performed by individual teachers. At the conclusion of an activity, the objectives that the activity was intended to address need to be analyzed. Were these goals met? If not, what aspects of them were missing? How could the exercise be changed to meet the intended objectives? Wilson and Stensvold (1993) suggest that "evaluation of labs should not be an issue of 'good or bad,' nor a question of inquiry versus cookbook, but rather an assessment in terms of the class of intended outcomes." In assessing the effectiveness of an exercise, keep in mind that the success is not only determined by student achievement in learning the concepts covered by the laboratory. In addition, we can evaluate the exercise by the analytical skills obtained and the students' attitude toward the project and possibly toward science, in general (Stohr-Hunt, 1996). If doing a particular exercise has improved a student's ability to analyze data and draw conclusions, not only has the content of his or her conclusions been learned in a way that will help him or her to remember it, but the process used can be applied to other learning situations. Also, if the student achieved success or at least enjoyed doing the activity, they will be more likely to have an open mind and more confidence when encountering a similar situation. The attitude toward science then improves.

2. The Importance of Contextual Teaching in Science

In addition to focusing on the impact that hands-on activities have on student learning, we must also focus on other aspects of effective science teaching. One such aspect is the importance of making science relevant to students. In a study by Yager and Lutz (1994), it was found that "nearly all students perceive school science as unrelated to their daily lives. They see few ties between the science they study and personal concerns such as their diets, health, hobbies, work experiences, and consumer decisions." The result of this is that students do not apply the information they "learn" in science class to their daily lives. The prior knowledge, including misconceptions, they possessed before they entered the science class has been altered very little by the time they leave. Even what we perceive as "successful" science students do not appear to be applying science. In a study cited by Yager and Lutz (1994), students of college physics and engineering were tested in order to determine how human learning takes place. They were chosen because they were academically successful and researchers assumed they would serve as an example of how successful learning occurred. The students were given difficult, real-world problems to solve and the thinking and analyzing process they used to solve the problems was studied to determine the steps involved. The results indicated, however, that 85% of the physics majors and 90% of the engineering majors could not solve everyday problems. The researchers investigated the cause of these results and found that the students had not changed their personally constructed explanations when presented with conflicting explanations in the classroom. Yager and Lutz support the idea that contextual teaching will help alleviate this problem. "Context can make problems considered in school science synonymous with real world problems. When school science classes focus on real world problems, there is a good chance that cognitive scientists will find that successful students in school science and technology are also successful in solving problems in the real world, outside of school." As science teachers, if we do not make the information we teach relative to student lives, and challenge their misconceptions, it is unlikely that this information will remain with our students.

3. The Positive Consequences of Linking Concepts in a Unifying Way

In combination with applying science to students' lives, we must also apply the concepts taught in science to each other and focus on teaching for understanding. Linking concepts to each other helps the students to learn and apply the information more successfully. A study about two effective science teachers done by Garnett and Tobin (1989) found that both teachers were successful in teaching for understanding. They used different styles to do this. One teacher promoted student independence and self-reliance in the classroom, where learning was primarily the responsibility of the student, with the teacher as facilitator. The other teacher played a more active role by explaining concepts and identifying the logical framework of the discipline. Both teachers effectively monitored for student understanding by using questioning and clarifying techniques, either in whole-group or individual settings. Students were called upon to explain or justify their answers. Both teachers focussed on tying new concepts to those which had been previously learned. Linking new material to prior information enhances the probability of meaningful learning.

Teaching for understanding by making new information relative to students' lives and to other areas of science, as well as allowing learning to occur by engaging students in laboratory activities is the focus of my unit. In reorganizing the order of delivery of information, I was attempting to link new information to that which had been previously learned, thereby increasing the probability of meaningful learning. Organizing concepts to allow better connection between them assists students in developing deeper, more long lasting learning. The overlying theme of polarity that I have employed in teaching this unit allows students to make connections and better understand the concepts of polarity, separation science, and solutions individually, and in connection with each other. In addition to making these connections between concepts, I incorporated contextual learning throughout the unit. By applying the information being taught and learned to real world situations, I was expecting to increase student retention of information and application of it to their lives. Some examples of this include:

1. A laboratory involving chromatography has a real-life purpose of finding a cancer-preventing yellow dye.

2. The students study vitamins and their comparative solubility in body.

These examples indicate the direction toward applied science that the unit has taken. Applying new concepts to circumstances that students can relate to helps them to assimilate this information and retain it. Another way to help students to apply and remember information is to have them engage in memorable laboratory experiments and activities. These activities serve many functions, as described in the previous sections. One important function that I was striving for was student motivation and engagement. Creating an activity in which the students can be an active participant increases the chances that they will become engaged in learning the concepts. If they are engaged, they are more likely to formulate questions, identify conflicts in their prior knowledge, and find ways to resolve these conflicts. It is this resolution that helps to create long-term retention of the information. In addition to motivating students to become active learners, executing labs helps to create a visual memory. The chances seem slim of a student exclaiming, "Oh, I remember that day last year when we took those notes and learned how to do those problems!" Yet, I had students one year after being taught the unit who said "Oh, I remember that lab where we made those T-shirts with different colored ink on them!" Then they proceeded to recall the information they learned about polarity from doing the activity. Students learn in various ways. Some learn by asking questions and listening to answers. Some learn by doing things themselves. Some learn by watching others. Most learn by using a combination of styles. This combination demands that we as teachers use many teaching styles. If we were teaching one student at a time, we could assess the learning style that best fits that individual and teach using that style all the time. This, of course, is not the kind of situation we have in the classroom. By varying the styles we use throughout the presentation of a particular unit, we are increasing our chances of finding something that works for everyone at some point.

IV. Demographics of Classrooms

The three classes that were my study group are similar in many ways. Even the two communities in which the districts are located are similar. The first district is a class B school, from here on referred to as I.C., with approximately 550-600 students enrolled in the 9-12 high school. The location is classified as rural, with many farms, dirt roads, and students bused in. The socioeconomic status of the community is generally middle class. A considerable percent of the population commute to larger surrounding cities or suburbs for work.

The second district is a class A school, from here on referred to as H., with approximately 1100 students enrolled in the 9-12 high school. The city itself is not that large but the school district covers a large surrounding area of smaller towns and townships. Again, a considerable number of the students are bused in. There is a large variation in the socioeconomic status of the community. They range from lower middle class to upper middle class. There is a considerable representation of single parent families in the community. Commuting into surrounding cities or suburbs for work is common.

The classes within these two districts are similar also. The first group I taught the unit to, in I.C., consists of three general chemistry classes with fifty-seven students total. Fifty-three of these students were juniors with two seniors and two sophomores included. Thirty-three of the fifty-seven students are female. The minority populations are not represented very well within these chemistry classrooms. Less than 6% of the I.C. study group are minorities (Hispanic, Japanese, or other non-Caucasian). The average g.p.a. for the classes of students was 3.32. When I surveyed some of these students in two physics classes the following year, all except one were planning on attending a four-year college or university full time after graduating. The exception was planning on attending a junior college. Not all the students from the unit were in the physics classes for the survey, but chemistry is generally taken by college prep students. I am assuming that the actual percentage of students planning on attending a four-year college or university would not vary much from the physics class survey.

The second group of students the unit was taught to are from the second district, and will be collectively referred to as group H2. These ten students were enrolled in advanced chemistry and were all seniors. Their average g.p.a. for the group, consisting of five females and five males was 3.46 and all were planning on attending a four-year college or university full time. All ten were in their second year of chemistry with nine of the ten having taken it the previous year. Of the ten, one is Hispanic and one is Black.

The final group of students consisted of two general chemistry sections with forty-three students total, from here on referred to as H1. Five of the forty-three were seniors and the remaining thirty-eight were juniors. Their average g.p.a. was 3.37 and all forty-three were planning on attending a four-year college or university full time upon graduation. The class consisted of twenty-five females and eighteen males. Again, the minority population was not well represented with less than ten percent of students being Black, Hispanic, or other non-Caucasian.

IMPLEMENATATION OF UNIT

The unit was taught three times, first at I.C., with three general chemistry classes, then the following year at H, initially with the advanced chemistry class, and later with two general chemistry classes. The order of implementation for the three groups can be seen in Figures 1 and 2.

I. I.C. Implementation

A. Polar Molecules

At I.C., the unit was begun with a review assignment of the differences between covalent and ionic bonds and determining which are present in certain molecules. After this overview, Lewis structures were then reviewed. To this review was added the new concept of assigning partial charges to determine whether an entire molecule was polar.

The "*Models of Covalent Compounds*" (Appendix A1) activity was assigned. The students had to construct the models of several molecules, using ball and stick model kits. They also had to write each molecule's Lewis structure, calculate electronegativity differences, assign partial charges, determine the geometry of the molecule, and then determine its

Concept	*Activity*
Polar Molecules	Predicting Polarity Practice Assignment (textbook)
	Models of Covalent Compounds Lab
Chromatography	Ink Pen Chromatography Activity
	Extraction of Candy Coatings Lab
	T-shirt Chromatography Lab
	Test – Polarity and Chromatography
Solutions	Molarity Calculations (textbook)
	Quiz – Molarity Calculations
	Effect of Temperature on Solubility Lab
Colloids and Emulsifiers	Soap, Oil, and Water Demonstration
	Test – Solutions, Colloids, and Emulsifiers

Figure 1: I.C. Order of Implementation

Concept	*Activity*
Solutions	Demonstration – Types of Mixtures
	Molarity Calculations (textbook)
	Quiz – Molarity Calculations
	Spectrophotometry Lab (textbook, H2 only)
	Effect of Temperature on Solubility Lab (H1only)
Polarity	Predicting Polarity Practice Assignment (textbook)
	Models of Covalent Compounds Activity
Chromatography	T-shirt Chromatography Lab
	Extraction of Candy Coatings Lab
Colloids and Emulsifiers	Soap, Oil, and Water Demonstration
	Unit Test

Figure 2: H1 and H2 Order of Implementation

polarity, taking in consideration the information they had just acquired about the molecule. They did this for 13 compounds, and then answered post-lab questions regarding models of covalent compounds. The purpose of this assignment was to allow the students to model the three dimensional nature of molecules. Determining the polarity of a molecule, whether it has two distinct, oppositely charged ends, is much easier when physically holding a representation of the molecule. Associating this model with a Lewis structure helps the students to visualize molecular shapes when the kits are not available for student use. Visualizing the three dimensional shapes of molecules can be very difficult and having a hands-on exercise certainly makes this concept more concrete.

B. Chromatography

The discussion then led to applying the concepts discussed above to chromatography. A short lab from the Merrill textbook, "*Ink Pen Chromatography*," was performed. Students separated the component dyes of different ink pens using a variety of solvents and conclusions were drawn about the relative polarities of the inks based on which solvents could separate them. A post-lab discussion helped to ensure that students grasped the concept of chromatography so that they could apply these concepts in more complicated labs in the near future.

At this point, another laboratory exercise, "*Chromatography Lab -- Extraction of Candy Coatings,*" (Appendix A3) was introduced. In this exercise, students extract the color from various hard-shelled candies and attempt to find which one(s) have a specific yellow dye in them. The fictional premise in the introduction of this laboratory is that the yellow dye is a cancer-preventing agent. The students' objective is to find other candy coatings that might contain the same yellow dye. This is a two-day lab in which students can achieve great success at "real chemistry." Students were assigned three different colors or kinds of candies to extract. When the laboratory work was complete, groups shared data to complete the comparison of all the colors of all the candies and a post-lab discussion followed. The students expressed their approval of this colorful, hands-on experience. Having a laboratory exercise with a real-life theme allows the students to comprehend the usefulness of the information they are obtaining. Even in this overly simplified "find the cancer preventing dye" scenario, the application of chromatography was readily comprehended by the students.

Following this exercise was another colorful chromatography lab called "*T-shirt Chromatography*" (Appendix A2). Here, the students brought in cotton T-shirts from home and made various designs on them with permanent markers. Different solvents were dripped slowly onto the shirts to separate the component colors of the inks. This exercise allowed students the freedom to explore and learn on their own. They could make hypotheses on which solvents would cause which inks to separate and then draw conclusions on why their hypotheses were or were not supported. The discovery method of learning can encourage students to be scientific thinkers.

At the conclusion of this exercise the students completed a review sheet, covering the previous concepts discussed. A class review and then a test (Appendix B2) covering polarity and chromatography was given. Students were required to explain the concept of polarity and predict the polarity of compounds, given their electronegativity values. In addition, questions were asked about chromatography and what type of solvents will work for what type of substances. Students were required to draw Lewis structures and assign polarity to molecules.

C. Solutions

Application of these concepts to solutions was the next transition for this class. The discussion began with a review of the vocabulary of solutions, (solute, solvent, miscible, etc.) and then led to what causes solutions to occur. Having been introduced to the concept of "like dissolves like" in dealing with chromatography, they quickly came to the conclusion that a polar substance could dissolve other polar substances and nonpolar could dissolve nonpolar. They were given formulas of different compounds and were asked to predict their relative solubilities based on their comparative polarities. Making these predictions allowed them to apply new and old information to solve a problem. Even when their predictions were not supported, learning was achieved.

This was followed by the quantification of solubility using molarity, molality, and mole fraction. Sample problems were done together in class, with the difficulty of the problems gradually increasing and the dependence of the students on teacher direction decreasing. Then a small problem set from the textbook was completed. Students worked together in small groups to solve the problems, requesting help when they needed it. After several problem sets were assigned and reviewed, a quiz (Appendix B1) was given.

Once the quantification of solubility was mastered, the question of the effect of temperature on solubility was introduced. "Does increasing the temperature make more solute dissolve or less? Does it depend on the solute and the solvent?" After they made predictions the students performed an experiment titled "*The Effect of Temperature on Solubility*" (Appendix A5). Various amounts of ammonium chloride were dissolved in test tubes containing a constant volume of water. The temperatures at which the substance began to precipitate out of solution were measured. After collecting this data, the students plotted it to produce a solubility curve. They then made predictions about the solubility of ammonium chloride at other temperatures and compared their graph to a standard. In this exercise, students were asked to think ahead of time about what would happen in the experiment and make predictions on the results. This process allowed ownership of the knowledge. Having made a prediction, they seemed to be quite interested in whether or not they were right. In the event that they were wrong, they tended to question the results and find out what was wrong with their earlier logic. Also, comparing experimental results to standards helps promote careful laboratory techniques. If their results are far from what they expected, the students can see it themselves and can repeat the experiment.

D. Colloids and Emulsifiers

Finally, the question arose, "What happens if two things are not soluble in each other; can we do anything about it?" To introduce and answer this question, a demonstration was performed. First, oil and water were mixed to demonstrate a suspension. When the suspension settled, soap was added and the mixture was shaken. The oil and water remained as a colloidal suspension. "Did the soap change the chemistry or polarity of either of the substances?" The soap simply acted as a bridge, linking the nonpolar oil to the polar water. Performing the demonstration was a visual example of emulsification. Students can see the process of emulsifying occurring, which helps them to better understand it, and they can attach a visual memory to the content, allowing them to remember and relate it to new information. The students were then given a review assignment from the textbook, which addressed these final concepts of emulsifiers and colloids. The answers were discussed in class and then a test (Appendix B3) was given.

II. H1 and H2 Implementation

The following year, I changed school districts and taught the unit to an advanced chemistry class, group H2, during first semester, then to my two general chemistry classes, group H1, during the third marking period. In addition, a co-worker taught this unit at the same time to her two general chemistry classes. The order of the unit was changed from the first time it was taught and a few other changes were made (see Figures 1 and 2). One major difference was that learning of the unit was measured with two major tests the first time (at I.C.) and only one test for the next two presentations (at H). The unit took a little less than five weeks the first time it was taught and a little over five weeks the next two times. Also, although this unit coordinates well with most general chemistry texts, using a different text changes assignments and discussions to a certain degree.

Previous to the teaching of the unit, the advanced chemistry class, H2, had some knowledge of solutions, polarity, and separation science from their first year of chemistry. In addition to this background, they had covered concepts of thermodynamics and gases, which the general chemistry class did not have previous to the teaching of my unit. These concepts helped the advanced students to apply the concepts of kinetics to solutions but I don't believe this is a prerequisite for the polarity, solutions, and separation science unit.

A. Solutions

The unit, in both the H1 and H2 groups, was initiated by a discussion with a demonstration, "Types of Mixtures" (Appendix A5). The demonstration involved using four mixtures to introduce students to solution terminology. The conclusion of this discussion led to an introduction of concentrations of solutions. The different ways that concentration can be expressed were discussed and then sample calculations were performed for molarity (moles/L) concentration units. There were homework problems, quizzes, and a laboratory to ensure the assimilation of this information. The H2 group performed a basic *spectrophotometry lab exercise* from the textbook. They attempted to find the concentration of an unknown sample of iron (III) chloride by graphing the absorption data of their standards and comparing the unknown to their graph. The data was inconclusive, at best, so a different exercise was selected for the H1 group. They performed the laboratory exercise, *"The Effect of Temperature on Solubility"* that was also executed at I.C.

B. Polarity

Following the teaching of molarity, the idea of what causes a solution to occur was discussed. Why did some things dissolve in water and some didn't? Could we predict what was going to dissolve and what wasn't, for a given solvent? At this point, polarity was discussed once again. The students had prior knowledge about polar bonds, but not polar molecules. Several examples of these predictions were given, using Lewis structures and assigning partial charges to atoms. Then the "*Models of Covalent Compounds*" activity with molecular model kits was assigned. The discussion then led to using this material to predict solubility of different compounds.

C. Chromatography

The natural transition from this point was "What can we do with this information?" It was time for an application of solubility principles, chromatography. First, the "*T-shirt Chromatography*" laboratory exercise was performed. The third time this exercise was attempted by me it became an outside, picnic table lab. The fumes are a little overwhelming for four hours of chemistry labs. After completion of the lab exercise and write up, we moved on the a lab the students affectionately call "*The Candy Lab*." Like the I.C. group, the H1 and H2 groups also enjoyed this of this colorful, hands-on experience.

D. Colloids and Emulsifiers

Finally, the concept of emulsions acting as a bridge between polar and nonpolar substances was discussed. The demonstration involving oil, water, and soap was performed, creating a visual representation of a working emulsion. The students were assigned to find the names of several products at home that contained emulsifying agents and identify, from a list, the type of agent in each of them. This helped the students realize that chemistry is not just in chemistry class.

Other applications of solutions were discussed, such as vitamin solubility. Those vitamins that are soluble in water are much less likely to be ingested to a toxic level by the body because they get flushed out of the system. However, fat-soluble vitamins like A and E, can reach toxic levels because the liver does not break them down as easily. The students readily applied this to their own vitamin taking practices. At this point, the students were given a review assignment. The answers were discussed in class and a test (Appendix B4), covering the entire unit, was given the following day.

III. Teaching Practices

I altered my normal practices in a few ways when teaching this unit. First was using laboratory exercises and hands-on activities as a basis of instruction. Implementing student-directed learning through laboratory work is extremely important, but also extremely time-consuming. Through my research summer at Michigan State University I found the time to test student labs, modify them and even do a little creating. Being able to take the time to develop and then implement a cohesive unit was in a sense, my own experiment. Just as students learn more by actually doing the experiment, (even if they know what the results should indicate) I also learned by doing. I knew (and still know) that laboratory work is an essential part of learning science. But knowing it and seeing the effect of it are two different things. I found that teaching this unit has been a big push for me to implement more student-directed learning throughout the rest of the chemistry curriculum. The difficult part is to be able to find or create labs that directly tie in with the concepts covered in lecture/discussion. If this association does not occur, laboratory exercises can still be fun, but not relevant.

Another technique incorporated in the unit was focusing on a theme, polarity, the cause of solutions to occur (or not.) Students were introduced to the concept of polarity or polar covalent bonds in the chapter preceding this unit. They could calculate, given an electronegativity chart, whether a given bond was ionic, polar covalent, or nonpolar covalent. The depth to this information was missing, however. The "SO WHAT?" was not answered in the previous chapter. The idea was to build on their previous (and fresh) knowledge of this concept, to repeat it, apply it, and repeat it again. In this manner the concept of polarity would be better understood because the students could see what it relates to and how it can be used to predict something. The concept of a theme is like a circle. Learning about solutions could not be done without learning about polarity and polarity could not be thoroughly understood without applying it to a principle such as solutions or chromatography. The main reason I focused on the use of themes in this unit is because I believe that is the way we all learn. When incorporating new information, we find the file in our brains where this new stuff will fit. The more we learn about it, however, the more files we need to put it into. Learning is being able to access those files and relate them to each other to better understand "the big picture."

Using themes is something I have done in the past, in order to provide a better explanation to students. Focusing on it, however, has made me realize that it is something I need to continuously strive for because it enhances the learning process tremendously.

The final focus of my unit was to teach contextually. In the past, I have found that students respond well to contextual teaching so I try to implement it in any unit, but I wanted to make it a particular area to accent in this unit. Teaching in context and relating the information presented to student's lives helps make the learning personal for students. Knowing how the information that they are learning can be applied brings relevance and purpose to acquiring the knowledge. In this unit, the contextual teaching was evident in the laboratory exercises. For example, using chromatography to identify a specific dye in "Extraction of Candy Coatings" mirrored how chromatography might be used outside of the chemistry classroom. Also, by creating a standard graph in "The Effect of Temperature on Solubility" students gain a better perspective on how these standard graphs are actually prepared, giving them a more realistic perspective of the information the graph contains. Discussions throughout the unit, such as the one about vitamin solubility in the body, also helped to relate the concepts students were learning to their own lives.

EVALUATION

This unit was an effective way to teach polarity, solutions, and separation science as substantiated by several types of assessment. One was simply my observation of student involvement, motivation, and attitude. Also, a student survey (Appendix C3) was given to the H1 and H2 group, asking about their overall impression of the unit and perception of their own understanding of the unit. In addition, student scores on pretests, unit tests, unit work (labs, homework, etc.), and posttests were evaluated. Finally, two students were interviewed about their opinions and content understanding of the unit. The compilation of these assessments aided in the overall analysis of the effectiveness of the unit.

I. Student Surveys

In the student survey given to H1 and H2 students 92 % agreed or highly agreed that the labs helped their understanding of the material and the other 8 % were indifferent, at worst (Table 1). Eighty-two percent of students agreed or highly agreed that the labs motivated them to learn the material whereas 12 % were indifferent and 4 % disagreed. Student also seemed to believe that the labs tied in well with the instruction: ninety

Table 1: Student Survey Results from H1 and H2
n = 50

1 – highly disagree 2 – disagree 3 – indifferent 4 – agree 5 – highly agree

Percentages rating	1	2	3	4	5
1. I found this unit to be organized.	0	4	10	58	28
2. I found the labs helped my understanding of the material.	0	0	8	40	52
3. I found it easy to make connections and draw conclusions between polarity and chromatography.	2	4	20	58	16
4. I found the labs tied in well with the instruction.	0	0	10	42	48
5. I found the labs motivated me to learn the material	0	4	12	50	32
6. The demonstrations proved beneficial in under-standing concepts.	0	0	8	54	38
7. My understanding of the material in this chapter is greater than material from previous chapters.	0	16	38	38	8
8. I understand the effect polarity has on whether or not a solution will occur.	0	14	8	52	26
9. I understand the difference between a polar covalent bond and a nonpolar covalent bond.	0	12	14	48	26
10. I understand how an emulsifier works.	4	2	8	56	30
11. I understand the difference between a detergent and a soap.	2	8	6	46	38
12. I understand the practical applications of chroma-tography.	2	4	6	60	28
13. I understand how electrons could be shared unequally in a covalent bond.	0	12	22	48	18
14. I understand how molecular geometry is used to determine molecular polarity.	2	10	20	42	26

percent agreed or highly agreed with this statement and 10 % were indifferent. Relating the demonstrations to the course work was important to the students based on the fact that 92 % of them agreed or highly agreed that the demonstrations proved beneficial in understanding concepts. The other 8 % were indifferent. The students also rated the organization of the unit relatively high, with 86 % agreeing or highly agreeing that the unit was organized, 10% indifferent, and the other four percent disagreeing. The ratings for the effectiveness of the thematic approach were positive, but not quite as high as the laboratory/demonstration evaluation. Seventy-four percent agreed or highly agreed that they found it easy to make connections and draw conclusions between polarity and chromatography. Twenty percent were indifferent and 6 % disagreed or highly disagreed. Seventy-eight percent of students agreed or highly agreed that they understood the effect polarity has on whether or not a solution would occur. Eight percent were indifferent and 14 % disagreed. Seventy-four percent agreed or highly agreed that they understood the difference between a polar covalent bond and a nonpolar covalent bond. Fourteen percent were indifferent and 12 % disagreed.

The students were also invited to make written comments about the organization of the unit and the support of the labs and demonstrations. One student wrote, "The labs worked well. Things being discussed in the chapter could be understood more when we could visually see how what we learned applied to the lab." Another stated, "I thought the organization was wonderful. I liked how we'd get a small amount of notes and then an assignment to do on our own. I felt like I learned on my own terms, my own way so I had a better understanding." The same student also had positive comments about the labs and demonstration. "The lessons led up to the lab and provided enough information for self-direction when we got to the experiments. It is helpful to see the concepts." More positive comments were, "I think that the labs did help. Yes, they did tie in with the instruction. I was surprised to find that they did help with my understanding." "I don't think that it could have been much better." "Yes, I found it relatively easy to connect concepts from the chapters, like covalent bonds, electronegativity differences, etc. The demonstrations and labs are very helpful. They tie in directly with the material and let us see through our own eyes what is going on. The responsibility given to us and the neat demonstrations definitely motivated me."

The few negative comments about the organization of the unit were generally in reference to the confusion of skipping around in the book. The students who had a hard time following the chapter jumping thought that better-defined notes would help avoid the confusion.

The students were also asked about their perception of their own understanding of the unit (Table 1). In comparing their understanding in this unit compared that in others, 84 % agreed, highly agreed, or were indifferent that it was greater in this unit. This indicates that 84 % felt they learned as much or more in this unit as in others. The remaining 16 % disagreed, or thought they understood more in other chapters. When asking about specific topics, the highest self-evaluation was regarding chromatography. Eighty-eight percent of the students surveyed agreed or highly agreed that they understood the practical applications of chromatography, 6 % were indifferent and 6 % disagreed. This was most likely due to the number of experiments involving chromatography. Also rating high were the students' opinions on their understanding of emulsifiers. Eighty-six percent agreed or highly agreed that they understood how an emulsifiers works. The students might remember this well because of the demonstration involving soap as an emulsifying agent between oil and water. Also, this subject was covered toward the end of the unit, so it might be easier to remember. In contrast, sections on electron sharing and molecular geometry, which were taught in the early stages of the unit, had the two lowest individual topic ratings.

Sixty-six percent agreed or highly agreed to their understanding of how electrons could be shared unequally in a covalent bond and 68 % agreed or highly agreed to their understanding of how molecular geometry is used to determine molecular polarity.

In the written response portion of the survey, these numbers were supported by comments. The question asked in the survey was "How did your understanding in this unit compare to previous units? How did your scores compare?" Some answers follow.

"I do pretty average in all chemistry chapters. I average a B to A- for the chapters. This chapter was not difficult at all."

"My scores were the same and so was my understanding, but my scores do not accurately affect my understanding because I always manage to understand the unit and still get low scores."

"My understanding is really beginning to increase. Especially compared to last year. My scores could still be better, but that is mainly my fault."

"My understanding of this unit might have improved a little. My scores were about the same. This unit was more fun."

"I understood very well, and very easily. I was more comfortable with this unit and also scored better, I believe."

“I think I had a better understanding this time around. My test scores were all higher than I thought. They would be a very pleasant surprise.”

“I feel I learned more from the labs than the other chapters.”

“I think I understood this chapter more, that in the sense that I will remember it longer. I usually remember the information until we take a test, then its gone.”

“This unit was much more exciting and was made much clearer. There was a lot of information given in this unit, but it seemed more organized and well planned out. My scores didn’t change much, but the impact was much greater.”

Although the above comments are generally positive, there were some students that did not feel that the unit was a success for them. “I think I’m a bad example, but I didn’t have an easy time with this unit. I didn’t do good on the test.” “I did bad (sic.). My score was lower than the previous unit.” “My understanding compared to the previous units was lesser. My scores seemed about the same, though.” “(My understanding was) not good. My test grade was the worst yet, a B-.”

The students’ impression of their own knowledge improved compared to that from previous units. In comparing the scores on this unit to marking period grades, I found that they were quite similar. For I.C., the unit average was 79 % and a marking period not including the unit averaged 82 %. In the H1 group, the unit average was 83 % and the marking period average was 84 %. The results were similar for the H2 group with the unit average at 85 % and a marking period average of 88 %. These scores indicate to me that the students performed similarly to previous units. Even though all three groups scored a little lower on this unit than a marking period average, this was not significant enough to lower my perception of the success of the unit. The marking period averages include current event scrapbooks, which tend to bring the students' grades up slightly. General chemistry students do not easily understand the concepts presented in this chapter, so the fact that the scores are slightly lower is not necessarily unexpected. A more accurate representation of unit success would be to compare the scores achieved by students taught the "old" unit to those taught the "new" unit. However, since the "new" unit is a compilation of concepts from different chapters, this data would not be possible to obtain. More important than test scores, in determining the success of the unit, are retention scores and student attitudes.

II. Interviews

In addition to the surveys, casual comments, and observations, student attitudes were measured by interviews. I interviewed two above average female students, one from I.C., one from H1, and a co-worker from H. who taught the unit to her general chemistry students. I decided not to interview a student from the advanced group because the comparison might not be fair, since those students had one more year of chemistry background. In retrospect, I feel that the information gained from this interview would have outweighed any bias by the advanced student. The three interviews were informative and interesting, in different ways.

The first interview was with “Allison”, a student from H1. Allison is an above average student, earning 84 % average on her tests for the year and 88 % average marking period grade. For this unit, she scored 91 % on the test and 92 % for the unit average. Her opinion of the labs in this unit was very high. She said, “The labs were cool. They showed how the reactions worked.” At the end of the interview, I asked her if she had anything else to add and she volunteered, “I really liked the labs that we did. They were fun.”

She also felt that the labs and demonstrations added to her understanding of the unit. When asked about her understanding of this unit compared to others she commented, “some parts (I understood) more cause of labs, but basically about the same.” When I was questioning her on how to make two immiscible substances form a solution, she mentioned that soap could be used. She remembered that soap was an emulsifier “…because you put it in with the corn oil and the water and when you added soap to that it stayed mixed and before it wouldn’t.”

In addition to asking her opinion of the unit, I asked questions to determine how well she understood the content. I began by asking her what polarity was and she replied, “when an element (sic.) has a positive and negative end.” I asked her how she would determine the polarity of a substance and she stated, correctly, that she would make a Lewis structure. She was however a little confused on the specifics of assigning partial charges to the elements involved in the bond. We moved on to how polarity affects solutions. She said that if the polarities were not the same, “solutions won’t occur. Like dissolves like; polar dissolves polar and in some circumstances, nonpolar dissolves nonpolar.” I probed by asking her how a polar solution occurs and she replied, “The positive end of one (substance) is attracted to the negative end of the other and pull each other apart.” We moved on to how concentration is measured and she remembered it was in units of molarity, or moles per liter. She then proceeded to solve a molarity problem for me, explaining her steps as she did so. The problem involved solving for molarity of 33.5 grams of sodium chloride dissolved to make 350 milliliters of solution. Following is her thorough and correct explanation.

"First you start with what you're given. You put 33.5 grams of sodium chloride ... per 350 milliliters. Then you have to get it to moles over liters so you write that at the end and it all equals that. So you have to convert grams to moles so you put grams on the bottom of the chart ... and one mole goes over that. And you have to find out how many grams are in that (sodium chloride) so you look on the periodic table and add it up and then sodium chloride is 58.44 grams. Once you have that converted, you have to convert milliliters to liter... One thousand milliliters goes on top of one liter cause one liter has to be on the bottom and they all have to cancel out. Then you multiply everything through on the top and divide by everything on the bottom."

She also showed good recollection of the laboratory exercises, their purpose, and the concepts involved. I asked her about the purpose of the T-shirt lab and she replied, "to show how chromatography works and how the polarity ... of the substance you put on the shirt and how it is affected by different polarities of the substance you put on the shirt, like liquids, and how it pulled apart different colors." She remembered that the inks were nonpolar and therefore the solvents that moved them were nonpolar. I asked her if water would separate the colors in the inks and she said, "no, because water is polar and the inks were nonpolar." She summarized the main points of the candy chromatography lab recalled that the separation in the chromatography was caused by, "the polarities of different substances."

In discussing emulsions, she remembered that they worked to join a polar and a nonpolar substance, but was a little confused in her explanation of how this worked. "Because they're all mixed up and they're not actually staying. It forms around of them and it like gels around it sort of and it makes the whole thing be a positive or a negative, whatever it needs to be to stay with the other one." The lack of accuracy of this explanation is probably due to the fact that it was not covered as thoroughly as some of the other concepts in the unit. In addition, although a demonstration was performed, the students did not do any experiments with this topic.

The other student interview was performed at I.C. approximately 10 months after the unit was taught. I returned just after spring break to re-test students from the two physics classes that had taken chemistry the previous year. During this time, I also interviewed "Kari", a chemistry student from the previous year. Kari was an above average student with a wide range in test scores which reflected her interest in the content being taught. Her test grades average 87% for the year, varying from 74% to 98%, and her marking period grades averaged 83 %, varying between 72% and 94%. During this unit she earned an 85% unit test average and 89% for the unit average. Kari's recollection of the unit was that "it was difficult to understand." Throughout the interview it was apparent to me that some concepts were difficult for her to understand and remember. However, she did recollect a considerable amount about chromatography and polarity from the experiments. I asked her if she thought that doing the labs helped her to learn and remember the concepts. She said, "If I didn't remember having such a fun time doing the T-shirts, I really wouldn't have remembered about the polarity of it. If we had just done the unit it would've been so easy to misplace that little memory." She also said that the labs were "the best labs we did because ... there was more involved and a lot of color."

In questioning Kari about the content of the unit, she definitely showed less retention than Allison. This is understandable given the amount of time that had passed since the teaching of the unit. Initially, she seemed to remember very little, but as the interview progressed and her memory was triggered by the conversation, her responses for some content areas improved. I started by asking her what she remembered about the unit. She stated, "that it was difficult to understand." I asked her what she remembered about the labs and she recalled quickly the T-shirt laboratory. "We drew on the T-shirts with ink pens and put stuff on them to make them run, like nail polish remover and things like that. I asked her what caused the colors to run and she replied, "the polar and nonpolar characteristics." She also recalled the candy chromatography lab and summarized the general procedure and purpose. When I asked her how chromatography works, she initially replied, "I don't know." I redirected with asking her about polarity and she responded, "If the substance has positive and negative ends, it attracts itself to another substance and it will allow it to be separated, like pulled apart. If you put black on a T-shirt and you put the nail polish remover on it the nonpolar, no, the polar particles in the color and the polar particles in the nail polish remover will attach themselves and as the nail polish remover runs it will separate the colors out of the black."

For a student who thought the unit was "difficult to understand," her explanation of how chromatography works was quite accurate. The main discrepancy was that she stated incorrectly that the markers were polar. She eventually corrected herself when, later, I asked her whether water would work to separate the colors of the T-shirts. She responded, "No, because the markers are nonpolar and water is polar. They (the colors in the markers) only stick to stuff like nail polish remover and alcohol that are nonpolar."

Initially when I asked Kari how salt dissolves in water, she replied, "I don't know." Later, as she warmed up, I asked her what polarity has to do with solutions. She responded, "If they are polar or nonpolar. If they're alike they'll mix and if they're not, they won't. Like oil and water." I asked what makes two polar things mix in each other and she stated, "They have a positive and a negative end so the positive end of one will hook to the negative end of the other." Then I went back to why does salt dissolve in water and she said, "the positive end of the salt hooks to the negative end of the water and it pulls it apart."

In addition to her knowledge on polarity, solutions, and chromatography questions, Kari remembered some things about emulsions, problem solving, and determining the polarity of a molecule using Lewis structures. These concepts were not remembered as vividly or as accurately.

I asked her how soap makes oil and water mix. She responded, "The soap can hold on to the oil and allows it to ... all I remember about the soap is that it sticks to dirt and it allows it to wash away because the water doesn't stick to the dirt because the dirt is nonpolar." The demonstration performed with oil, water, and soap could be part of the reason for this recollection.

In solving molarity problems, Kari's memory definitely needed refreshing. The concept of moles, molar mass, and molarity were only vaguely familiar. After these concepts were reviewed, Kari's recollection of the units cancellation method of solving molarity problems returned. She needed a little guidance on where to begin, but then solved the molarity problems accurately. I asked her if using that problem-solving method worked well for her and she said, "Yes, we used it in physics. Mr. D. didn't use it but we were like, 'no, this is what we're used to,' so he used it. It makes it easier."

I asked Kari how we would determine whether a molecule was polar or not (for example CH_3Cl.) She responded, "Don't we draw dot diagrams?" This was encouraging, yet she needed help in actually drawing the Lewis structure for the example. The second example, CCl_4, was quickly solved correctly as nonpolar, "because it doesn't have a positive and a negative end."

In addition to the two general chemistry students, I also interviewed was my co-worker, "Ms M." Ms M. and I do much of our chemistry planning together so she was willing to teach the unit to her two chemistry sections parallel to mine. Her comments before, during, and after the unit proved beneficial as did the formal interview with her. In general, Ms. M.'s comments about the unit were extremely positive. She thought the laboratory exercises and demonstrations were excellent motivators. When asked specifically about the labs from the unit and their effectiveness both motivationally and educationally, she had several comments.

"The labs were great. They tied into concepts as well as allowing the kids to have a little bit of fun." "The candy lab was really great and straightforward and I think the kids really could grasp well the ideas that dyes are used in different things. The added twist of the cancer preventing agent put some reality in it." "The T-shirt and the candy lab were both really good authentic assessments."

III. Data

The unit scores in reference to knowledge gained were indicative of the success of the unit. The scores used to assess the knowledge gained by the students were a pretest (Appendix C1), the unit test average (one unit test for H1 and H2, and two unit tests for I.C.,) the unit average (including labs, homework, etc.,) and a posttest. As you can see in Figure 3, the I.C. pretest average was about 25 %, the unit test average was 77 %, the unit average was 79 % and the posttest average was 60 %. The posttest for I.C. (Appendix C2) was given about ten months after the conclusion of the unit, during the following school year. The test was given to the students in two

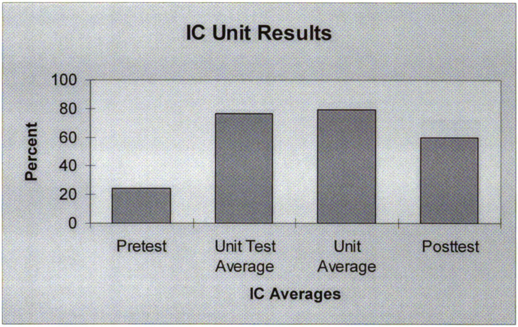


Figure 3: I.C. Assessment Results

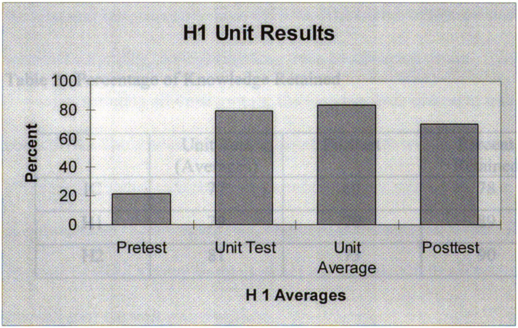


Figure 4: H1 Assessment Results

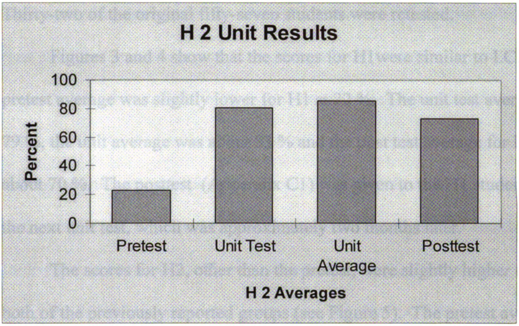


Figure 5: H2 Assessment Results

Table 2: Percentage of Knowledge Retained

	Unit Test (Averages)	Posttest	Percent Retained
IC	77	60	78
H1	79	70	89
H2	81	73	90

physics classes that had been in my chemistry classes the previous year. Thirty-two of the original fifty-seven students were retested.

Figures 3 and 4 show that the scores for H1were similar to I.C. The pretest average was slightly lower for H1 at 22 %. The unit test average was 79 %, the unit average was about 83 % and the post test average for H1 was about 70 %. The posttest (Appendix C1) was given to the H1 students after the next unit test, which was approximately two months later.

The scores for H2, other than the pretest, were slightly higher than both of the previously reported groups (see Figure 5). The pretest average was about 23 % but raised to about 81 % for the unit test average. The unit average was about 85 % and the posttest (Appendix C1), again given after the next unit test, was quite high at 73 %. The higher scores for this group were not surprising, considering they were an advanced group.

In averaging all three groups, the increase from pretest to unit test was about 56%. The amount of knowledge after the unit was taught should definitely be higher than the prior knowledge, yet a gain of 56 % on average is considerable. More significant, I believe, is the post test score. The students retained a considerable amount of information, from 2 months to 10 months after the unit was taught.

I determined the retention percentage for the study groups by dividing each student's posttest score by their unit test score. These percentages were then averaged for each group. The posttest given to the students was not the same as the unit test, but the content covered in each was similar enough, I believe, to make a comparison for this calculation. In comparing the unit test to the posttest, an impressive amount of knowledge was retained by the students (Table 2). In the I.C. group, the percent retained was about 75%. In this group, not all the students were retested because the posttest was given the following year to the students taking physics. The actual retention might be slightly lower, based on the trend of higher ability chemistry students proceeding to physics the next year. The H1 group had a retention average of 88 %. The retention scores from the H2 group were even more impressive, 96 %. The higher percentage retained from the two H groups can be attributed, at least in part, to the timing of the posttest.

IV. Laboratory Assessment

Because I was particularly interested in laboratory exercises as key to learning I also evaluated them. I compared the objectives I was attempting to teach to the outcomes of the activities. I assessed the four main activities: *The Models of Covalent Compounds*; *T-shirt Chromatography*; *Extraction of*

Candy Coatings; and *The Effect of Temperature on Solubility*. For all four of the labs my objectives were similar. I wanted students to be able to:

1. acquire and develop laboratory skills specific to each activity;
2. draw conclusions based on observations;
3. improve comprehension of concepts covered in the unit;
4. apply information using analytical, creative, and critical thinking skills; and
5. express a positive attitude toward the experience and science in general

These goals applied to all the labs, even though they were not all the same style of exercise. Using Wilson and Stensvold's (1993) definitions, *The Effect of Temperature on Solubility* and *The Extraction of Candy Coatings* can be considered *confirmation* activities. The purpose of these activities was to reinforce concepts of solubility and chromatography which students were already familiar with. The *Models of Covalent Compounds* exercise was a *generalization* activity where students were trying to build a generalized explanation of how molecular structure affects polarity. The *T-shirt Chromatography* lab most closely resembles a *resolution* activity, with the students designing their own experiments to test the separating abilities of different solvents with different inks.

Assessing the success of each activity was done in a few ways. Goal #5, students expressing a positive attitude toward the exercise was evaluated by observation. Throughout the laboratory experiments positive comments were made and student involvement was 100%. For the T-shirt lab, some students wanted to finish their shirts after school or at home, even though there was no minimum requirement of decoration completion. Students also enjoyed the Extraction of Candy Coatings. Students expressed that they liked "playing with the model kits" during the Models of Covalent Compounds exercise. They found that it helped them "… to picture the structures easier." Although the responses were not as enthusiastic, the overall attitude during the Effect of Temperature on Solubility was also positive. The students enjoyed watching for the crystals to "crash" out of solution. Some heated the solution again to observe it a second time.

I evaluated goal #1 by monitoring the laboratory and assisting students in manipulating equipment and performing procedures. For most of the labs, the students were self-sufficient and self-directed. In addition, the Models of Covalent Compounds exercise was evaluated for the H1 and H2 groups by adding a lab practical to the unit test. Students had to construct a given molecule with the model kit, draw the corresponding Lewis structure, assign partial charges, and state whether the molecule was polar or non polar and why. Of fifty-two students tested, thirty-four scored 5 out of 5 or 100% on this section. The overall average on the model construction portion of the test was four point four out of five or 88%.

Assessing goals 2, 3 and 4 was more difficult. The ability to draw conclusions, improve comprehension, and apply information was most easily evaluated by looking at how students answered questions about the labs and concepts relating to them. In general, I was quite pleased with the majority of the open-response questions all four of the labs. Students comprehended a great deal of the content and most explained it well.
For example, students were asked "What factors affect how the components of each ink separate?" in the post-lab of T-shirt Chromatography. Most students were accurate with responses such as these.

"The factors that affected how the ink separated were the colors' attraction to the solvent, the ink's polarity and the solvent's polarity."

"What solvents you used, the amount of compounds in the ink and if the polarities are similar or not"(sic.)

"The number of compounds, the solvent, an the polarity differences all affect how the components of each ink separate."

Even the responses that were not completely accurate were close but just not thorough enough. "What kind of alcohol you use with the color affects how the ink separates." "The type of alcohol used and the marker type affect this." "The solvent and the number of compounds" (sic.)

DISCUSSION AND CONCLUSIONS

There were several aspects of this unit that I felt were particularly effective in conveying key information. The laboratory activities, especially, were quite useful for the students to process and apply information. "T-shirt Chromatography", "Extraction of Candy Coatings", "Models of Covalent Compounds", and "The Effect of Temperature on Solubility" were four successful activities from this unit, as measured by student interviews, teacher observations, and written responses in laboratory reports.

The T-shirt exercise, I believe, was extremely effective. Both of the students interviewed recalled it vividly, and also remembered the concepts applied in the lab. When questioned, the students explained the reasoning for the separation of colors at the molecular level. The student responses on laboratory questions indicate that the principles of chromatography were understood. I believe that if the students that were engaged in this exercise were asked about chromatography a few years from now, they would probably be able to recall the main concepts.

The T-shirt lab could be made even more effective with a few changes. The activity calls for a pre-lab exercise of using different colored inks and various solvents on filter paper to use as a test run before the T-shirts. This step of the lab could be emphasized more and the students could develop a more specific plan from this pre-lab. They could state a hypothesis about specific inks and specific solvents that they are planning on testing in the second part of the lab. Then a formal laboratory report could be written, comparing the results of the inks on paper with those on the T-shirts, rather than just answering the questions on the lab sheet. This would allow the concept of the stationary phase to be investigated a little more thoroughly. The main downfall to this idea is the amount of pens and solvents used would be greater. Also, the ventilation must be very effective or the students should work outside, as we did for the H1 group.

Another exercise that I feel worked well was the "Extraction of Candy Coatings" chromatography experiment. The student involvement was quite high in this lab. The students were working hard, but had few questions. They seemed to enjoy working with a specific goal in mind: "find the cancer preventing yellow dye." This gave a definite purpose to the exercise and also enabled them to see a possible real-life application of the chromatography concept.

When discussing with Ms. M. aspects of the unit that need improvement or expansion, she felt that the candy chromatography laboratory exercise could be expanded. One of the lab questions asks the students if they think other substances might contain this yellow dye and what they might be. One suggestion by Ms. M. was that we have a post-lab exercise where students can test these predictions and see if, in fact, they do contain the same yellow dye. The difficulty of this might lie in the extraction process. Some research would need to be done to see of other candies or food substances could be used in the same extraction process as the M & M's and Skittles.

Another exercise that I think was helpful to the students was the "Models of Covalent Compounds" activity. Although this activity is not quite as memorable as the previous two, it is effective, none the less. It allows students to visualize atoms and molecules more easily than in drawings or pictures. These kits assist students in learning how to make Lewis structures of molecules. Later they can make these Lewis structures without the kits. For my H1 and H2 group, I added a practical to the test. Students had to construct a given molecule with the model kit, draw the corresponding Lewis structure, assign partial charges, and state whether the molecule was polar or non polar and why. As stated in the evaluation section, the success rate of the evaluation was high.

The "Effect of Temperature on Solubility" lab exercise was another effective task for the students. Before doing the exercise, the students had been using solubility charts to answer questions such as how much potassium chloride would dissolve in 100 g of water at 75 °C. In the laboratory, they measured the solubility of ammonium chloride and used their data to create their own solubility chart. They then answered questions, using their own chart as well as a standard. This exercise was designed to help them better understand what a solubility graph is and how the data on it was determined. This activity makes charts and tables a little less mysterious.

Although the areas of the unit covered by these four exercises were well developed and effective, there are some areas that need some improvement. The unit evaluation for H1 and H2 was quite comprehensive and, I believe, needs to be separated into two, shorter tests or assessments. The scores at I.C. where the unit assessment was divided into two are not much different than H1 or H2, but the student apprehension was lower. For the H1 and the H2 group, the students were quite nervous about the test because, "so much has been covered since the last test." Though the unit seemed long to them, there are even more additions that could and should be made that would lengthen it more. These supplements could not be added without separating the assessment into at least two sections.

One such addition to the unit would be a lesson with a laboratory on emulsions. The students were very interested in the concept of emulsifiers. A laboratory experiment would capitalize on their interest and expand the quality and quantity of information obtained and remembered about emulsifiers and how they work.

Also, adding an exercise that would allow the students to use the concept of molarity would greatly aid in their understanding. An activity that might work involves having students make varying volumes of dilutions of different molarities. Preparing these solutions might help make the concept of molarity more tangible to the students. In addition, using a tangible object to represent a mole and manipulating it with various volumes might aid the students who have difficulty grasping derived units such as molarity.

Overall, I was quite pleased with the effectiveness of this unit. Having taught it three times, I modified it a little each time, continuing to improve it. The success, I believe, is due to the thematic and hands-on approach used throughout the unit. The concepts involved in polarity, solutions and separation science are not easy ones for beginning chemistry students to understand. Tying them together and showing their relevance to each other by using good laboratory materials helps make the concepts a little easier to grasp. When I was interviewing my co-worker, Ms. M., I asked her what she thought of the thematic approach to this unit. She replied, "It always seemed really disjointed teaching it separately. And from all other texts that I've taught it which do separate all that stuff out, it was a hard concept to grasp. So, even for me, it pulled it together more, teaching it this way."

In addition to the theme, the lab work was a large reason for the success of the unit. The effectiveness of the laboratory exercises indicated to me the importance of visual and tactile learning. The unit scores didn't necessarily reveal this to me. The students from all three groups scored about the same as they did on previous units. What lead me to believe that labs are so important were the student interviews, my observations of students in class, and the students' written responses to laboratory questions. Before discussing the unit with students, I realized that labs were important. Not until analyzing my results and interviewing students did I realize the importance of a good lab in lab instruction. Not only does it help to engage students with different learning styles, it helps to create a memorable experience. When this memorable experience is recalled, with it comes the information obtained from the experience. When returning from a vacation, looking at the pictures you took brings back memories other than just those on the pictures. Yet the pictures serve as a trigger, even years from now, for the details from that vacation. I believe that laboratory experiences that are well planned and coordinate with the concepts being taught provide this same function. This realization will definitely affect my teaching as a whole. Every unit will be planned with this approach, knowing how much labs make a difference.

APPENDIX A

Activities, Experiments, and Demonstrations

1. The Models of Covalent Compounds
2. T-shirt Chromatography
3. Chromatography Lab – Extraction of Candy Coatings
4. The Effect of Temperature on Solubility
5. Demonstration – Types of Mixtures

Appendix A1: The Models of Covalent Compounds

Introduction

Why should people care about the shapes of molecules? Consider that the properties of molecules, including their role in nature, depend primarily on molecular structure or shape. Molecular shape determines a compound's boiling point, freezing point, viscosity and reactivity.

The molecular geometry of a molecule can be determined by examining the central atom and identifying the number of atoms bonded to it and the number of unshared electron pairs surrounding it. The shapes of molecules can be predicted by assuming the electron pairs around a central atom will position themselves to allow for the maximum amount of space between them. Why would they do this?

Covalent bonds can be classified by comparing the difference in electronegativities of two bonded atoms. The greater the difference, the more polar the bond. (When the difference gets greater than 1.67 the bond becomes more ionic than covalent.) In a polar covalent bond, the electrons are more attracted to the atom with the greater electronegativity, resulting in a partial negative charge on that atom. The atom with the smaller electronegativity then acquires a partial positive charge.

Molecules made up of covalently bonded atoms can be either polar or nonpolar. The geometry of the molecule contributes to the determination of whether it is polar or nonpolar. For example, if polar bonds are symmetrically arranged around a central atom, their charges cancel each other and the molecule in nonpolar. There are essentially no positive and negative poles or oppositely charged ends to the molecule so therefor it is not polar.

Ball and stick models can be used to demonstrate the shapes of polar molecules. In this activity, you will construct models of covalent molecules and predict the geometry of each molecule. (The shapes will be one of the following types: Linear, Bent, Pyramidal, Tetrahedral, or Trigonal Planar.) You will also draw electron dot structures, assign partial charges and predict whether the molecule is polar or nonpolar.

Pre-Lab Discussion

1. What is a covalent bond? ____

____

2. What is a dipole? ____

____

3. What two factors determine whether a molecule is polar or not? ____________________

____

4. Calculate the electronegativity difference and predict the type of bond for the following examples: (Use the electronegativity chart in your textbook as a reference.)

a. Na –Cl ______________________

b. C – H ______________________

c. S – O ______________________

d. N – N ______________________

Problem

How can the polarity of covalent molecules be predicted from their geometry and the types of bonds they contain?

Materials

ball and stick model set

Procedure

1. Construct ball and stick models of the following compounds: (Remember each of the holes in each ball will be filled if your model is correct.)

H_2	HBr	H_2O
NH_3	CH_4	HClO
N_2	CH_3NH_2	CH_3Cl
H_2CO	C_2H_2	HCOOH
HCN		

2. Set up a Data Table horizontally on a blank sheet of paper. Use the sample below as a reference for the necessary headings. For each of the preceding compounds, complete the Data Table.

3. When you are finished, take apart your models and put them back in the box with all balls of the same color together. Show your set to the teacher before placing it back on the shelf. Then answer the questions at the end of the worksheet.

Sample Data Table: Structure and Polarity of Covalent Molecules

Formula	Electron Dot Structure	Electronegativiy Difference		Structural Formula w/partial charges	Shape	Molecular Polarity
		Bond	Difference			

Post Lab Questions

1. Explain how you used the molecular shapes to predict molecular polarity. Support your answer with examples from the results of this investigation.

2. List the advantages and disadvantages of using ball and stick models to construct molecules.

3. Based on your results, predict the type of bonding, molecular geometry, and molecular polarity of the following molecules:

a. HI

b. SCl_2

c. NH_3

d. CO_2

4. The polarity of a substance can have a great effect on its reactivity and solubility. A rough rule of thumb for solubility is "like dissolves like." Knowing this general rule, what can you predict about the polarity of alcohol if you know alcohol dissolves water? Also, knowing that water alone will not dissolve a greasy stain, what does that tell you about the composition of the stain?

Revised from:
"Models of Covalent Compounds," Lab 22, Laboratory Manual, Chemistry: Connections to Our Changing World, Upper Saddle River, New Jersey, Prentice Hall, 1996, pp. 117-120.

Appendix A2: T-shirt Chromatography

Introduction

In this lab you are going to experiment with different solvents to find the best separation techniques for the components of permanent inks. You will use a T-shirt (washed and dried, even if it's new) from home and create designs with different pens. Then, you will attempt to separate these inks into their component colors with a variety of solvents. Before you start, you might wish to experiment with the inks and solvents on filter paper in order to better predict the colors or patterns you will find on your shirt.

Problem

How can you separate a mixture using chromatography?

Materials

permanent markers, several colors (Sharpies work great)
T-shirt
coffee can
plastic pipet or eye dropper
2-propanol (30-50%)
fingernail polish remover
ethanol (30-50%)
filter paper
petri dish

Procedure

Filter paper extraction: (if desired)

1. Obtain a piece of filter paper and fold it in half. Create a wick by cutting two slits in the paper about 2 cm apart. Cut from the edge of the paper to the crease. Cut the wick in half.

2. Using the pen you wish to test, make a semi-circle with a radius of about 3 cm, across from the wick. Let it dry and trace it again with the same pen to concentrate the ink.

3. Pour about 5 mL of the solvent you wish to use into the bottom of a petri dish. Place the filter paper on top of the petri dish and bend the wick down so it is in the solvent. Put the top on the petri dish and wait for the solvent to more toward the edge of the paper. Observe and record the colors extracted as well as the pen and solvent used.

4. Repeat with as many of the pens and solvents you wish to test.

T-shirt Extraction

1. Stretch a single thickness of cloth of your T-shirt over the top of the jar or can. Pull the cloth taut and secure it with a rubber band.

2. Select a marker and make a pattern of dots or lines near the center of the stretched fabric.

3. Fill a dropper with the desired solvent and slowly drip it in the center of the fabric. Do not drip it on your design, just near it. Continue dripping the solvent onto the cloth until the solvent has spread to the edge of the can or jar.

4. Allow the wet section to dry.

5. Repeat steps 1-4 with each of the other markers, using different colored markers each time to make another set of dots or patterns. Vary the solvent you use as well.

6. After all the chromatography patterns have developed, allow the T-shirt to dry completely.

7. Dispose of any excess solvent as directed by your teacher. Rinse out the can or jar with water. Clean up your work area and wash your hands before leaving the laboratory.

8. At home, your can iron the T-shirt to help set the inks. For the first machine washing, wash the T-shirt by itself in cold water in case any of the inks run.

Data

Observations

Color of Pen	Solvent	Results

Questions

1. Why was it necessary to stretch the cloth taunt? What do you think would have happened if the cloth had remained loose?

____

____

____

2. Which marker contained the greatest number of compounds? The fewest? How were you able to tell?

____

____

____

3. What factors affect how the components of each ink separate?

____

____

____

4. Overall, which solvent worked best for separation? Use your data to support your answer.

____

____

____

5. Predict what would have happened in the investigation if a polar solvent had been used.

____

____

____

6. Are "permanent" markers truly permanent? Explain.

____

____

____

7. Chromatography is often used to identify unknown compounds. Explain how this might be done.

____

____

____

Further Investigation

1. Cotton was used in this investigation. Find out if other fabrics work equally well. With the approval and supervision of your teacher, try this investigation using swatches of rayon, wool, silk, or polyester.

2. Research the uses of chromatography in measuring and monitoring pollutants in air and water. Prepare an oral report to present to your class.

Revised from:
"T-shirt Chromatography," Laboratory Manual, Chemistry: Connections to Our Changing World, Upper Saddle River, New Jersey, Massachusetts, Prentice Hall, 1996, pp. 235-238.

Appendix A3: Chromatography Lab—Extraction of Candy Coatings

Introduction

Fictional Scenario

The FDA just discovered that a certain yellow dye used in food coloring serves as a preventative treatment for cancer. If maintained in a balanced diet, the consumption of a small amount of the dye daily will prevent the onset of certain types of cancer. We were sent a sample of this yellow dye, but it is not enough for the whole class to consume. The goal of this lab is to find what candy might contain this dye, then we can eat the candy and be saved from cancer. The candies available for testing today are Skittles and M & M's.

In this investigation you will use two separation techniques to determine the colors contained in each of the dyes in candy coatings. In the first part of the investigation, you will use wool yarn in a series of chemical reactions to separate the dyes from sugar, chocolate, and other non-dye substances in the candy.

In the second part of the investigation you will explore the makeup of the dyes by using a separation technique called paper chromatography. In this technique a solvent dissolves the dyes and carries them along a piece of filter paper. Different chemicals will have different rates of travel. You will also run a chromatogram for the known yellow dye and compare results.

Pre-lab discussion

Read the entire laboratory investigation and the relevant pages of your textbook. Then answer the questions that follow.

1. Write a hypothesis predicting which of the candies, if any, will contain the cancer preventing yellow dye.

____

____

____

2. How are you going to test your prediction?

____

____

____

____

3. What is the chemical definition of a compound? A mixture?

____

____

____

____

4. How will a compound and a mixture behave differently in paper chromatography?

___

___

___

5. What causes separation of components in paper chromatography?

___

___

6. What does it mean to "decant" the liquid with the dissolved dye in it?

___

___

7. What is the purpose of the paper wick?

___

___

Problem

Which Skittles and M & M's contain the same yellow dye as the fictional cancer preventing yellow dye?

Materials

Part A

safety glasses
laboratory apron
hot plate
60 cm wool yarn
beaker, 150 mL
tap water
4 small candies each of three different colors
3 large test tubes
test tube rack
graduated cylinder, 10 mL
distilled water
acetic acid, 3M
6 small test tubes
tongs
stirring rod
paper towel
ammonia water, 1%
3 watch glasses

Part B

micropipet
filter paper, 11 cm diameter
scissors
ruler
graduated cylinder, 10 mL
developing solution
4 petri dishes and covers
4 toothpicks

Safety

Wear your safety and lab apron at all times during the investigation. Never eat any foodstuffs in the laboratory. Acetic acid and ammonia can irritate or burn your skin. Do not rub your eyes or touch your skin without first washing your hands. If these solutions contact your skin or clothing, wash the area with large amounts of water and notify your teacher.

The solutions used in Part B are extremely flammable. Be sure there are no burner flames in the laboratory. Turn off the hot plate during Part B. Be sure to keep your petri dishes covered when the chromatogram is running to minimize fumes in the laboratory.

Procedure

Part A

1. Put on your goggles and lab apron. Fill a 150 mL beaker one-third full of tap water and place it on the hot plate. Turn on the hot plate and start the water to boil. Meanwhile, place four small candies of the same color in a large test tube. Place four of a different color in another test tube and four more of still another color in your third test tube.

2. Pour 7 mL of distilled water into each test tube with the four candies. Add 3 drops of concentrated acetic acid to the water-candy mixture. CAUTION: *Concentrated acetic acid can irritate or burn your skin. If you spill any, rinse the affected area immediately with large amounts of cold water and report the spill to your teacher.*

3. When the colored coating dissolves, slowly pour, or decant, the liquid dye from each large test tube into three small test tubes. Make sure the candy or any other solid residue remains behind in the large test tube. Discard the candy and other solid residue into a paper towel and then into the garbage. DO NOT POUR THE CANDY CLUMPS INTO THE SINK!

4. Using a stirring rod, add a 20 cm piece of woolen yarn and 3 drops of concentrated acetic acid to each liquid-dye mixture.

5. Place the test tubes into the boiling water bath for about 5 minutes or until most of the dye becomes absorbed by the yarn.

6. With test tube tongs, take the test tubes out of the boiling water and place them in the test tube rack. CAUTION: *Never touch hot glassware with your bare hands.* Remove the yarn from the test tube with the stirring rod. Rinse the yarn under tap water for about 1 minute. This removes the remaining acid so that the ammonia base can work completely.

7. Pour 5 mL of ammonia water into each of three small clean test tubes. CAUTION: *Avoid breathing the ammonia vapors.* Submerge the rinsed yarn into the ammonia water.

8. Place the test tubes with the yarn and the ammonia water in the boiling water bath for about 5 minutes or until most of the dye from the yarn has dissolved in the ammonia-water solution. The solution should turn the color of the dye. Remove the yarn with a stirring rod and rinse with water. Put the yarn in a paper towel and dispose of it in the waste basket.

9. Use tongs to remove the test tubes containing the ammonia-water-dye solution from the beaker of boiling water. Pour each dye solution into a watch glass.

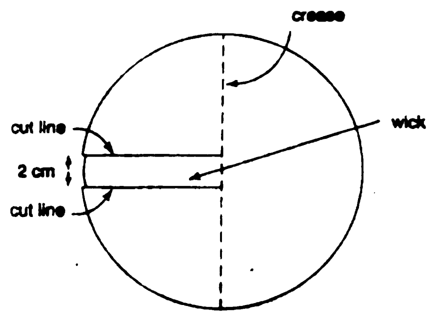
10. On a piece of white paper, write your group names and hour and place it on a designated area of the side counter. Carefully move the three watch glasses and set them on the white paper until tomorrow.

11. Dispose of the excess acid solution in a container provided by your teacher. Save the ammonia solution and put it in your drawer. Clean up your work area and wash your hands before leaving the laboratory.

Part B

12. Put on your goggles and lab apron. Retrieve your watch glasses from the side counter. If all the liquid evaporated, add 3-5 drops of the ammonia-water solution in each glass and swirl carefully to dissolve the dye into solution.

13. Obtain a piece of filter paper and fold it in half. Unfold the paper and cut a 2 cm wide wick in the paper by making two cuts from the edge to the crease in the middle. Your filter paper with wick should look like the figure below. Do this with three more pieces of filter paper to end up with one chromatography set for each dye you extracted plus one for the fictional cancer preventing yellow dye. Label each filter paper in pencil near the cut line for the dye your will be separating on that paper. Also, draw a line in pencil across from the wick, parallel to the crease. This will be the "starting line" for the dye.



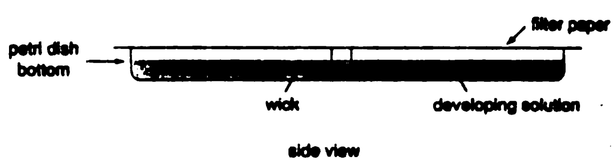
14. Dip the end of a toothpick into one of your dye solutions and make a very small spot of dye on the filter paper where the wick meets the rest of the paper, behind the line you drew. Using three more toothpicks, do the same with your other two dyes and the yellow sample from your teacher. Allow the spots to dry. Repeat at least five times on the same spot to concentrate the dye on the filter paper. Make the spots as small as possible. Record the initial color of the spots.

15. Using a graduated cylinder, measure and pour 8 mL of the developing solution into the bottom half of each of four petri dishes.

16. Cut the wick in half crosswise and bend it down to make a stand. Place it into the developing solution, as shown below. Carefully place the other half of the petri dish over the filter paper, not allowing the wick to be crushed or flattened. Allow to develop for about 30 minutes, making observations.

17. Observe how far your dye traveled from the original spot and mark the outer limit of the solvent with pencil.

18. Dispose of all your solvents as directed by your teacher. Clean up your work area and wash your hands before leaving the laboratory.



Data Table 1

	Sample 1	Sample 2	Sample 3	Yellow Dye
Type of Candy				
Color of Candy				
Initial Color of Spot				
Observations During Separation				
Final Color of Spot				
Colors Present After Developing				
Distance Traveled by Solvent				
Distance Traveled by Dye				

Complete the following data table by pooling your data with that of other students in the class.

Data Table 2

Type of Candy	Color	Component Colors	Compound or Mixture?
M & M's	blue		
M & M's	green		
M & M's	red		
M & M's	orange		
M & M's	brown		
M & M's	yellow		
Skittles	purple		
Skittles	red		
Skittles	orange		
Skittles	green		
Skittles	yellow		

Questions

1. Which dyes tested were compounds? Which were mixture? How could you tell?

2. Why was it important to keep the spot applied to your filter paper as small as possible?

3. What would have happened if the entire filter paper and not just the wick had sat in the developing solution?

4. Which candy(ies) did you determine had the same yellow dye as the known cancer preventative? How did you come to this determination?

5. Was your hypothesis of which candy contained the yellow dye correct or incorrect?

6. What other sources can you think of that might contain this yellow dye? Justify why you think these products might contain it.

7. Do you think the coatings of the candies you tested are make with the same type of food coloring sold in grocery stores? How could you test your hypothesis?

Chromatography Lab – Extraction of Candy Coatings – Teacher Preparation

This lab is designed to be used during a unit on solutions, but could be used when discussing the differences between compounds and mixtures. The concepts of polarity and "like dissolves like" are applied using chromatography. The lab fits nicely into two class periods, but the students have to be ready to start immediately on the first day.

Materials (15 lab groups)

PART A

45 large test tubes, 18x150 (a little smaller work as well)
M & M's and Skittles (one lb. of each was plenty for 4 classes)
11-cm di.
15 test tube racks
15 graduated cylinders, 10 mL
375 mL distilled water
30 mL acetic acid, 3.0 M in dropper bottles
90 small test tubes, 13 x 100 mm
1 skein of white wool yarn
15 hot plates (or burners and ring stands)
tap water
15 pairs of tongs or forceps
15 stirring rods
300 mL ammonia water (NH_3, 1%)
45 watch glasses or evaporating dishes

PART B

15 micropipets (or one in the NH_3)
60 pieces of filter paper,

scissors
60 petri dishes
rulers
pencils
300 mL developing solution
teacher prepared "cancer-preventing" dye(see below)

To make "cancer-preventing" dye:

Follow the procedures in the student lab for extracting the color from the candies using three sets of yellow Skittles. This should be plenty for four or five classes, especially if you supervise the dispensing of it.

To make Ammonia-Water:

10% by volume household ammonia
90% by volume distilled water

To Make Developing Solution:

57% by volume butanol
15% by volume household ammonia
14% by volume distilled water
14% by volume methanol

*Store both solutions in containers with screw caps. Do not work near any heat sources.

Additional Tips:

Make sure the students mark a line in pencil on the filter paper to indicate the initial location of the dye. They need to do this before the extraction begins. (It is not in their directions.) Also, they should draw a line after the chromatogram is finished at the leading edge of each color extracted and at the solvent edge. The solvent edge is especially important to do on day 2 because the next day the edge will not be visible anymore.

In order in ensure all colors are tested, it is a good idea to assign them the day before. (No one seems to want to do the brown M & M and it has the greatest separation!)

Revised from: "Candy Coatings: Compounds or Mixtures?", Chemistry: Connections to Our Changing World Laboratory Manual, Upper Saddle River, New Jersey, Needham, Massachusetts, Prentice Hall, 1996, pp. 35-40.

Appendix A4: The Effect of Temperature on Solubility

Introduction:

Hot tea can dissolve more sugar than iced tea, and warm water dissolves less oxygen than cold water. The maximum amount of any solute that can dissolve in a given amount of solvent is called its solubility, and this depends on temperature.

The solubilities of gases always decrease with increasing temperature. For liquids and solids, solubilities generally increase with increasing temperature, as is the case with sugar in tea. However, there are a number of exceptions to this, two examples being cerium sulfate, $Ce_2(SO_4)_3$, and lithium carbonate, Li_2CO_3. For these ionic solids, solubility decreases with increasing temperature.

In this activity, you are to determine the effect of temperature on the solubility of ammonium chloride, NH_4Cl, in water. After collecting data at various temperatures, you will plot the data to produce a solubility curve showing how the solubility of ammonium chloride varies with temperature. This, then can be used to predict the solubility at other temperatures.

Purpose:

How does the solubility ammonium chloride in water vary with temperature?

Materials:

Apron and safety goggles	Ring stand, ring, and wire gauze
Four medium-sized test tubes	Laboratory burner and matches
Test tube rack	Thermometer
Grease Pencil	Ammonium chloride (NH_4Cl)
One 10-mL graduated cylinder	Medicine dropper
Filter paper	Glass stirring rod
Spatula	Supply of ice
Balance	Graph paper

Procedure:

*Before beginning, read throughout the entire lab, then set up a data table.
*Wear goggles and aprons.

1. Obtain four medium-sized test tubes, a test-tube rack, and grease pencil. Label the test tubes 1 through 4, respectively.

2. As accurately as possible, determine the mass of a piece of weigh paper. Record the value in the data table. Use this weigh paper on the balance when measuring out your NH_4Cl.

3. To each of the test tubes, 1 through 4, you want to add samples of NH_4Cl having the following masses: 3.5 g, 4.5 g, 5.5 g and 6.5 g. It is not necessary that your samples be exactly these masses; it is necessary that the values be within 0.05 grams, and that you determine the masses as accurately as possible. Use a spatula to add or remove small amounts of the solid from the weigh paper. Record the mass values in the data table.

4. Fill a 400-mL or 600-mL beaker about three-fourths full with water to use as a hot-water bath. Place the beaker on a piece of wire gauze on a ring clamped to a ring stand. Place a thermometer in the water and begin heating while you proceed to step 5. The goal is to heat the water to 90°C.

5. Put 10.0 mL of distilled water in a 10-mL graduated cylinder. Use a medicine dropper to bring the bottom of the meniscus right to the 10.0 mL line. Add this water to test tube 1. Repeat this procedure, adding 5.0 mL of water to each of the test tubes.

6. Stir each of the test tubes with a glass stirring rod, rinsing and drying the stirring rod in between each solution. There will probably be solute remaining in test tubes 2, 3 and 4. Place all three test tubes in the hot water bath.

7. While test tubes 2-4 are heating up, place test tube 1 in a beaker containing ice water. Place the thermometer in the test tube and observe. When crystals first appear, note the temperature of the solution.

8. Take test tube 2 out of the hot water bath and observe. If all the solute is gone, place the thermometer in the test tube and hold up to a light. Watch for the very first signs of crystallization, and then immediately note the temperature. If crystallization begins too quickly, or you do not catch it the instant it begins, redissolve the precipitate and repeat until you are able to determine the temperature at which crystallization begins. Record this in the data table.

9. Repeat step 8 for test tubes 3 and 4. If necessary, stir the mixtures with a stirring rod to make all the solute dissolve before beginning crystallization.

Post lab

1. Change data to grams NH_4Cl per 100 grams of H_2O. (Assume the water is 1.0 g/1.0 mL.)

2. Graph this data. Make g NH_4Cl/ 100g H_2O the y axis and temperature, 0 to 100, the x axis. Use graph paper.

3. Using your extrapolated graph, how much NH_4Cl could dissolve in 100g of H_2O at 100°C?

4. Using the Handbook of Chemistry and Physics, find the solubility of NH_4Cl at 100°C.

5. Calculate the percentage error between your experimental value (#3) and the theoretical value (#4).

6. Calculate the molality (moles solute/kg of solvent) of each sample.

Appendix A5: Demonstration – Types of Mixtures

Materials:

4 large test tubes
vegetable oil
table sugar
isopropyl alcohol
magnesium oxide
tap water

Procedures:

Mix a small amount of each of the first four substances listed with a small amount of water in each of the four test tubes. Put the following terms on the board for the students to see: solute, solvent, miscible, soluble, insoluble, immiscible, and suspension. Have the students describe, on paper, each of the four mixtures using as many of the terms as possible. After they have attempted this, discuss the meaning of these words by explaining what happened in each test tube.

APPENDIX B

Quiz and Unit Tests

1. Molarity and Solubility Quiz
2. I.C. Unit Test #1 – Polar Molecules and Chromatography
3. I.C. Unit Test #2 – Solutions and Colloids
4. H1 and H2 Unit Test

Appendix B1: Molarity and Solubility Quiz

NAME ___________________________________

Using the solubility chart provided, answer questions 1-3.

1. At what minimum temperature will 60.0 grams of NH_4Cl dissolve completely?

2. How much RbCl will dissolve at 80°C?

3. If 120 g of LiCl is dissolved in 100 g of H_2O at 90°C and is cooled to 20°C, how much precipitate will be formed?

4. What is the molarity of a solution containing 15.6 g of Li_2SO_4 in 200 mL of solution?

5. How many grams of KCl are required to make 250 mL of a 0.350 M solution?

6. How many mL of solution are required to use 44.6 g of LiCl to make a 1.75 M solution?

7. Calculate the molarity of a 7500 mL of solution containing 2515 g of $NaNO_3$.

Appendix B2: I.C. Unit Test #1

Name ________________________________

Unit Test #1 -- Polar Molecules and Chromatography

_____ 1. Substances composed of nonpolar molecules are generally _____.
a. solids
b. molecular solids
c. liquids with high boiling points
d. gases

_____ 2. The _____ of a dipole can be described by its dipole moment.
a. strength b. length c. polarity d. duration

_____ 3. _____ bonds, unless symmetrically arranged, produce polar molecules.
a. Sigma b. Covalent c. Polar d. Pi

_____ 4. Atoms covalently bonded with _____ differences in electronegativity will have large polarity.
a. large b. small

_____ 5. _____ force is the type of van der Waals force which exists between two nonpolar molecules.
a. Dispersion b. Dipole-dipole c. Intramolecular d. Induced dipole

_____ 6. A bond in which one of the atoms attracts the shared pair of electrons more strongly than does the other is a(n) _____ bond.
a. nonpolar covalent b. metallic c. polar covalent d. ionic

_____ 7. Which of the following covalent bonds would be the most polar? (The electronegativity values are as follows: h, 2.20; C, 2.50; N, 3.07; Cl, 2.83; O, 3.50.)
a. H--C b. H--N c. H--Cl d. H--O

_____ 8. As the dipole moment increases, the strength of the forces between the molecules _____.
a. varies at random b. increases c. decreases d. remains constant

_____ 9. Weak forces that may hold molecules to each other are termed _____.
a. covalent bonds
b. van der Waals forces
c. resultant forces
d. coordinate bonds

_____ 10. A nonpolar molecule that has had its electron cloud distorted by the proximity of a polar molecule is called a(n) _____.
a. dipole b. complex ion c. isomer d. induced dipole

_____ 11. In chromatography, the mixture to be separated plus the liquid or gas in which it is dissolved is known as the _____.
a. substrate b. filtrate c. dispersion medium d. mobile phase

_____ 12. Chromatography is an example of _____.
a. fractionation b. precipitation c. segmentation d. allocation

_____ 13. A convenient method for the separation of substances based on differences in polarity and attraction for a medium is called _____.
a. distillation
b. fractional crystallization
c. chromatography
d. filtration

_____ 14. Which of the following is a separation technique used to analyze volatile liquids by employing an inert gas as the mobile phase?
a. column chromatography b. paper chromatography c. gas chromatography

_____ 15. Which of the following types of particles would interact to produce a dipole-induced dipole force?
a. two polar molecules
b. one polar and one nonpolar molecule
c. two nonpolar molecules
d. two polyatomic ions

_____ 16. Which of the following bonds is the least polar? (The electronegativities are as follows: C, 2.50; O, 3.50; Cl, 2.83; Si, 1.74; N, 3.07)
a. C--O b. O--Cl c. Si--O d. N--O

_____ 17. Among molecules of comparable molecular mass, as the dipole moment increases, the boiling point of the substance _____.
a. varies at random
b. increases
c. decreases
d. remains the same

_____ 18. Which of the following forces is the greatest contributing factor to van der Waals forces?
a. dipole-dipole b. dispersion c. dipole-induced dipole d. intramolecular

_____ 19. As the dipole moments of molecules of comparable mass increase, their melting points _____
a. increase
b. decrease
c. remain the same
d. increase and then decrease

Match the descriptions in Column I with the proper type of chromatography in Column II.

Column I		Column II
a. Solvent moves on strip by capillary action.	_____	20. thin layer
b. Varying amounts of contamination in helium produce varying amounts of electric current	_____	21. column
c. A glass plate is coated with packing.	_____	22. paper
d. A sample in solution is added to the tube containing packing material	_____	23. gas

Draw Lewis structures for each of the following molecules, label partial charges, and determine whether each is polar or nonpolar.

24. CH_3Br

25. HI

26. NH_3

27. H_2O

28. Arrange the following types of substances in order of increasing boiling points. Put a one (1) below the substance with the lowest boiling point, a two (2) under the second lowest and a three (3) under the substance with the highest boiling point.

noble gas atoms	polar molecules	nonpolar molecules

Fill in the blanks correctly. Use each of the listed words once.

chromatography	dipole	polar bond
induced dipole	van der Waals forces	fractionation
dispersion forces		

29. _____ is a method of separation based on adsorption. ____________________

30. _____ are weak forces that may hold together groups of molecules. ____________________

31. _____ is the overall process of separating parts from a whole. ____________________

32. A(n) _____ is a molecule that has temporarily become a dipole because of the presence of another nearby dipole. ____________________

33. A(n) _____ is a covalent bond in which one atom attracts the shared pair more strongly that the other. ____________________

34. A(n) _____ is a molecule with unsymmetrical charge distribution ____________________

35. _____ result from temporary dipoles. ____________________

Answer each of the following:

36. Describe one of the experiments you did and how chromatography was used. Use the terms stationary phase and mobile phase in your description.

37. The solvents used in the T-shirt lab smelled up the lab. How is this evidence of their degree of polarity?

38. How is it possible to have a nonpolar molecule that contains polar bonds? Explain and give an example.

39. Explain how two completely nonpolar substances can be attracted to each other enough to turn into a liquid. (Liquid nitrogen for example.) Discuss the forces involved in this attraction.

Appendix B3: I.C. Unit Test #2

Name______________________________

Unit Test #2 — Solutions and Colloids

_____ 1. In a solution, the substance being dissolved is the _____.
a. solvent b. solute c. mole fraction d. hydrate

_____ 2. The most common solvent is _____.
a. alcohol b. benzene c. water d. acetone

_____ 3. The process by which solvent molecules surround solute particles is _____.
a. efflorescence b. solvation c. displacement d. deliquescence

_____ 4. Which type of substance will probably dissolve in a nonpolar substance?
a. nonpolar b. polar c. ionic d. metallic

_____ 5. The attachment of water molecules to dissolving molecules and ions is _____.
a. hydrationb. dissociation c. hydrogenizing d. synergy

_____ 6. A carbonated soft drink is an example of which type of solution?
a. liquid solute and liquid solvent b. gaseous solute and liquid solvent
c. liquid solute and solid solvent d. liquid solute and gaseous solvent

_____ 7. Ethylene glycol (antifreeze) and water are completely miscible. If you mix 20 cm^3 ethylene glycol with 10 cm^3 of water in a graduated cylinder, you would expect to see _____.
a. one homogeneous solution
b. a mixture with a distinct boundary layer one-third of the way from the bottom of the cylinder
c. a mixture with a distinct boundary layer two-thirds of the way from the bottom of the cylinder
d. a mixture with a diffuse boundary layer one-half of the way from the bottom of the cylinder

_____ 8. A solution in which an undissolved substance is in equilibrium with the dissolved substance is called a(n) _____.
a. dilute solution b. supersaturated solution
c. saturated solution d. unsaturated solution

_____ 9. Which of the following would **not** affect the rate of solution of a solid in a liquid?
a. heating the solution b. shaking the solution
c. grinding up the solution d. increasing the pressure on the solution

_____ 10. The solution process of most solids is _____.
a. endothermic b. exothermic c. isothermic d. unrelated to temperature

_____ 11. The study of the properties of matter whose particle size in at least one dimension lies between 1 nm and 100 nm is _____.
a. nuclear chemistry b. colloid chemistry
c. physical chemistry d. analytical chemistry

_____ 12. Which of the following combinations would most increase the solubility of a gas in a liquid?
a. increase the pressure and decrease the temperature
b. increase the pressure and increase the temperature
c. decrease the pressure and decrease the temperature
d. decrease the pressure and increase the temperature

_____ 13. The concepts of molarity and molality are alike in that both _____.
a. are based on the total volume of the solution
b. express the amount of solute in moles
c. are mass/mass relationships
d. are volume/volume relationships

_____ 14. Which of the following is a comparison of moles of solute to moles of solution?
a. molarity b. molality c. percent by mass d. mole fraction

_____ 15. A crystal of copper sulfate is added to copper sulfate solution. After 15 minutes, the crystal is observed unchanged in the bottom of the solution. On the basis of this observation, the solution is best described as _____.
a. supersaturated b. dilute c. saturated d. unsaturated

_____ 16. Mayonnaise is an example of a liquid dispersed in a liquid and is therefore classified as a(n) _____.
a. emulsion b. gel c. aerosol d. sol

_____ 17. Small drops of wax dissolved faster in hexane than a block of wax would because the drops of wax have more _____.
a. polarity b. energy c. surface area d. enthalpy of solution

_____ 18. Which of the following explains the ability of water to dissolve ionic substances?
a. There are two hydrogen atoms for every one oxygen atom.
b. Hydrogen and oxygen are covalently bonded.
c. Oxygen has six electrons in its outermost energy level.
d. Water molecules are polar.

_____ 19. The addition of I_2 crystals to water is an example of _____.
a. polar solvent - polar solute b. polar solvent - nonpolar solute
c. polar solute - nonpolar solvent d. nonpolar solvent - nonpolar solute

Match the description of the solutions with the correct concentrations.

20.	4 moles of solute in 2 dm^3 of solution	_____	(a) 4 molar
21.	2 moles of solute in 4 kg of solvent	_____	(b) 2 molal
22.	2 moles of solute in 0.5 dm^3 of solution	_____	(c) 2 molar
23.	2 moles of solute in 1 kg of solvent	_____	(d) 0.5 molal

In the following table, indicate (yes or no) if a solution would be likely to occur.

	Solute type	Solvent type	Does solution occur?
24.	polar	nonpolar	_____
25.	nonpolar	nonpolar	_____
26.	polar	polar	_____
27.	nonpolar	polar	_____

28-31 Explain why the above solutions occur or don't occur.

32-34 You are given three aqueous mixtures and told that one is a suspension, one is a solution, and one is a solution, and one is a colloid. Describe what steps you would follow to determine which mixture is which.

35-37 You are given a solution of salt water that could be saturated, unsaturated, or supersaturated. Describe how you would determine which of the three solutions this is.

38-41 Calculate the number of grams of solute needed to make 250 cm^3 of $0.350 M$ Na_2SO_4 solution.

42-45 Calculate the molarity of a solution containing 10 grams of NaOH in enough water to form 600 cm^3 of solution.

46-49 49.0 grams of H_2SO_4 are added to 250 grams of water. Calculate the molarlity of this solution.

50-53 Calculate the mass of solute needed to add to 500 g of H_2O to make a 0.35*m* $SnBr_2$ solution.

54-57 Calculate the mole fraction for each component in a solution containing 45.0 g of CH_3COOH in 200.0 g C_2H_6O.

Appendix B4: H1 and H2 Unit Test

Name ______________________________

Unit Test – Solutions, Polarity, and Chromatography

_____ 1. Substances composed of nonpolar molecules are generally _____.
a. solids   b. molecular solids   c. liquids with high boiling points   d. gases

_____ 2. The _____ of a dipole can be described by its dipole moment.
a. strength   b. length   c. polarity   d. duration

_____ 3. In a solution, the substance being dissolved is the _____.
a. solvent   b. solute   c. mole fraction   d. hydrate

_____ 4. The most common solvent is _____.
a. alcohol   b. benzene   c. water   d. acetone

_____ 5. The process by which solvent molecules surround solute particles is _____.
a. efflorescence   b. solvation   c. displacement   d. deliquescence

_____ 6. _____ bonds, unless symmetrically arranged, produce polar molecules.
a. Sigma   b. Covalent   c. Polar   d. Pi

_____ 7. Atoms covalently bonded with _____ differences in electronegativity will have large polarity.
a. large   b. small   c. zero

_____ 8. A bond in which one of the atoms attracts the shared pair of electrons more strongly than does the other is a(n) _____.
a. nonpolar covalent bond   b. metallic bond
c. polar covalent bond   d. ionic bond

_____ 9. Which type of substance will probably dissolve in a nonpolar substance?
a. nonpolar   b. polar   c. ionic   d. metallic

_____ 10. The attraction of solvent molecules to solute particles and the consequential separation of the solute is called _____.
a. hydration   b. dissociation   c. hydrogenizing   d. solvation

_____ 11. A carbonated soft drink is an example of which type of solution?
a. liquid solute and liquid solvent   b. gaseous solute and liquid solvent
c. liquid solute and solid solvent   d. liquid solute and gaseous solvent

_____ 12. Dry cleaners use tertachloroethylene, C_2Cl_4, to dissolve oil, grease, and alcohol because C_2Cl_4 _____.
a. is soluble in water   b. dissolves ionic compounds
c. is a polar molecule   d. is a nonpolar molecule

_____ 13. Which of the following combinations would most increase the solubility of a gas in a liquid?
a. increase the pressure and decrease the temperature
b. increase the pressure and increase the temperature
c. decrease the pressure and decrease the temperature
d. decrease the pressure and increase the temperature

_____ 14. The concepts of molarity and molality are alike in that both _____.
a. are based on the total volume of the solution.
b. are mass/mass relationships
c. express the amount of solute in moles
d. are volume/volume relationships

_____ 15. If an ink separates into two or more colors using chromatography, the ink must be _____.
a. a mixture
b. a compound
c. an element
d. nonpolar

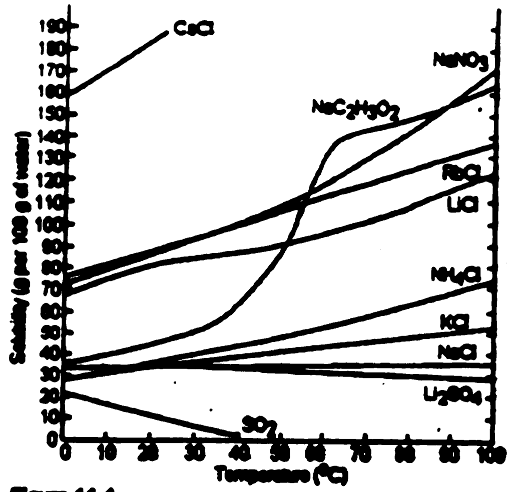


Figure 11-1

_____ 16. In Figure 11-1, the solubility of $NaNO_3$ increases by approximately _____ g per 100 g of water when the water's temperature rises from 10°C to 90°C.
a. 50
b. 80
c. 120
d. 160

_____ 17. In Figure 11-1, heating a saturated solution of Li_2SO_4 in 100 g of water from 10°C to 90°C would result in _____.
a. 5 additional grams of Li_2SO_4 going into solution
b. 80 additional grams of Li_2SO_4 going into solution
c. 5 additional grams of Li_2SO_4 leaving the solution
d. no change in Li_2SO_4 concentration

_____ 18. In Figure 11-1, _____ would be unsaturated.
a. 40 g of KCl in 100 g of water at 80°C
b. 40 g of NaCl in 100 g of water at 90°C
c. 145 g of $NaNO_3$ in 100 g of water at 45°C
d. 105 g of RbCl in 100 g of water at 45°C

_____ 19. A crystal of copper sulfate is added to a copper sulfate solution. After 15 minutes, the crystal is observed unchanged in the bottom of the solution. On the basis of this observation, the solution is best described as _____.
a. supersaturated
b. dilute
c. saturated
d. unsaturated

_____ 20. Particles in an emulsion are _____.
a. smaller that the particles in a suspension
b. larger than the particles in a suspension
c. smaller than the particles in a solution
d. the same size as the particles in a suspension

_____ 21. Adding lecithin to an oil-water mixture _____.
a. causes the oil and water to separate
b. changes the oil into soap
c. prevents the water from evaporating
d. keeps the oil and water mixed

_____ 22. Which of the following covalent bonds would be the most polar? (The electronegativity values are as follows: H, 2.20; C, 2.50; N, 3.07; Cl, 2.83; O, 3.50).
a. H--C
b. H--N
c. H--Cl
d. H--O

_____ 23. A convenient method for the separation of substances based on differences in polarity and attraction for a medium is called _____.
a. distillation
b. fractional crystallization
c. chromatography
d. filtration

_____ 24. Among molecules of comparable molecular mass, as the dipole moment increases, the boiling point of the substance _____.
a. varies at random
b. increases
c. decreases
d. remains the same

_____ 25. The addition of I_2 crystals to water is an example of ____.
a. polar solvent -- polar solute
b. polar solvent -- nonpolar solute
c. polar solvent -- nonpolar solute
d. nonpolar solvent -- nonpolar solute

Match the description of the solutions with the correct concentrations.

_____	26. 4 moles of solute in 2 L of solution	(a)	4 molar
_____	27. 2 moles of solute in 4 kg of solvent	(b)	2 molal
_____	28. 2 moles of solute in 0.5 L of solution	(c)	2 molar
_____	29. 2 moles of solute in 1 kg of solvent	(d)	0.5 molal

In the following table, indicate (yes or no) if a solution would be likely to occur.

Solute type	Solvent type	Does solution occur?
30. polar	nonpolar	_______
31. nonpolar	nonpolar	_______
32. polar	polar	_______
33. nonpolar	polar	_______

34-37. Explain why <u>each</u> of the above solutions occur or don't occur.

38-40 You are given a solution of salt water that could be saturated, unsaturated, or supersaturated. Describe how you would determine which of the three solutions you have.

41-42 What characteristics make soap a good emulsifying agent?

43-44 Why is detergent a better choice than soap for laundering with hard water?

45-47 What factors should be considered before taking vitamin supplements? Why?

48-50 Calculate the number of grams of solute needed to make 250.0 mL of a 0.350*M* Na_2SO_4 solution.

51-53 Calculate the molarity of a solution containing 10.0 grams of NaOH in enough water to form 600.0 mL of solution.

54-56 How many mL of solution can be made by using 73.6 g of $Mg(NO)_3$ to make a 0.25 M solution?

57-59 What is the molarity of a solution that contains 22.5 mg of $SnBr_2$ dissolved to make 25 mL of solution?

60-64 Describe how you would prepare 1500 mL of a 0.50 M solution of $Cu(SO_4)_2$.

Model Construction

FORMULA ________________ Name ________________________________

After receiving a formula from your instructor, go to an unoccupied lab station where you will find a model kit. Assemble your model, answer the following questions, and LEAVE your assembled compound AND this sheet at the lab station. Return to your desk and complete the rest of your test.

Questions

1. Draw the electron dot diagram (Lewis dot structure) for your compound.

2. Assign partial charges to the above diagram.

3. Is your compound polar or nonpolar? Why?

APPENDIX C

Pretest, Posttests, and Survey

1. Pretest, I.C., H1 and H2; Posttest H1 and H2
2. Posttest I.C.
3. Survey H1 and H2

Appendix C1: Pretest I.C., H1 and H2; Posttest H1 and H2

Name ______________________________
Date ________ Class _____________ Hour ____

1. How is boiling point related to bond strength?

2. What is a polar covalent bond?

3. What is chromatography?

4. If you wanted to separate two polar substances in a dye, what type of solvent would you try?

5. What is the difference between a solute and a solvent?

6. What determines whether two substances will dissolve in each other?

7. What is an emulsifier? Give an example of one, if you can.

8. How does a detergent work?

9. Is $CHCl_3$ a polar molecule? Why or why not?

10. Is CCl_4 a polar molecule? Why or why not?

11. What are some applications for chromatography?

Appendix C2: I.C. Posttest

Name______________________________

_____ 1. In a solution, the substance being dissolved is the _____.
a. solvent b. solute c. mole fraction d. hydrate

_____ 2. The most common solvent is _____.
a. alcohol b. benzene c. water d. acetone

_____ 3. The process by which solvent molecules surround solute particles is _____.
a. efflorescence b. solvation c. displacement d. deliquescence

_____ 4. Which type of substance will probably dissolve in a nonpolar substance?
a. nonpolar b. polar c. ionic d. metallic

_____ 5. The attachment of water molecules to dissolving molecules and ions is _____.
a. hydrationb. dissociation c. hydrogenizing d. synergy

_____ 6. A carbonated soft drink is an example of which type of solution?
a. liquid solute and liquid solvent b. gaseous solute and liquid solvent
c. liquid solute and solid solvent d. liquid solute and gaseous solvent

_____ 7. Ethylene glycol (antifreeze) and water are completely miscible. If you mix 20 cm^3 ethylene glycol with 10 cm^3 of water in a graduated cylinder, you would expect to see _____.
a. one homogeneous solution
b. a mixture with a distinct boundary layer one-third of the way from the bottom of the cylinder
c. a mixture with a distinct boundary layer two-thirds of the way from the bottom of the cylinder
d. a mixture with a diffuse boundary layer one-half of the way from the bottom of the cylinder

_____ 8. A solution in which an undissolved substance is in equilibrium with the dissolved substance is called a(n) _____.
a. dilute solution b. supersaturated solution
c. saturated solution d. unsaturated solution

_____ 9. Which of the following would **not** affect the rate of solution of a solid in a liquid?
a. heating the solution b. shaking the solution
c. grinding up the solution d. increasing the pressure on the solution

_____ 10. The solution process of most solids is _____.
a. endothermic b. exothermic c. isothermic d. unrelated to temperature

_____ 11. The study of the properties of matter whose particle size in at least one dimension lies between 1 nm and 100 nm is _____.
a. nuclear chemistry b. colloid chemistry
c. physical chemistry d. analytical chemistry

_____ 12. Which of the following combinations would most increase the solubility of a gas in a liquid?
a. increase the pressure and decrease the temperature
b. increase the pressure and increase the temperature
c. decrease the pressure and decrease the temperature
d. decrease the pressure and increase the temperature

_____ 13. The concepts of molarity and molality are alike in that both _____.
a. are based on the total volume of the solution
b. express the amount of solute in moles
c. are mass/mass relationships
d. are volume/volume relationships

_____ 14. Which of the following is a comparison of moles of solute to moles of solution?
a. molarity b. molality c. percent by mass d. mole fraction

_____ 15. A crystal of copper sulfate is added to copper sulfate solution. After 15 minutes, the crystal is observed unchanged in the bottom of the solution. On the basis of this observation, the solution is best described as _____.
a. supersaturated b. dilute c. saturated d. unsaturated

_____ 16. Mayonnaise is an example of a liquid dispersed in a liquid and is therefore classified as a(n) _____.
a. emulsion b. gel c. aerosol d. sol

_____ 17. Small drops of wax dissolved faster in hexane than a block of wax would because the drops of wax have more _____.
a. polarity b. energy c. surface area d. enthalpy of solution

_____ 18. Which of the following explains the ability of water to dissolve ionic substances?
a. There are two hydrogen atoms for every one oxygen atom.
b. Hydrogen and oxygen are covalently bonded.
c. Oxygen has six electrons in its outermost energy level.
d. Water molecules are polar.

_____ 19. The addition of I_2 crystals to water is an example of _____.
a. polar solvent - polar solute b. polar solvent - nonpolar solute
c. polar solute - nonpolar solvent d. nonpolar solvent - nonpolar solute

Match the description of the solutions with the correct concentrations.

20. 4 moles of solute in 2 dm^3 of solution _____ (a) 4 molar

21. 2 moles of solute in 4 kg of solvent _____ (b) 2 molal

22. 2 moles of solute in 0.5 dm^3 of solution _____ (c) 2 molar

23. 2 moles of solute in 1 kg of solvent _____ (d) 0.5 molal

In the following table, indicate (yes or no) if a solution would be likely to occur.

	Solute type	Solvent type	Does solution occur?
24.	polar	nonpolar	_____
25.	nonpolar	nonpolar	_____
26.	polar	polar	_____
27.	nonpolar	polar	_____

28-31 Explain why the above solutions occur or don't occur.

32-34 You are given three aqueous mixtures and told that one is a suspension, one is a solution, and one is a solution, and one is a colloid. Describe what steps you would follow to determine which mixture is which.

35-37 You are given a solution of salt water that could be saturated, unsaturated, or supersaturated. Describe how you would determine which of the three solutions this is.

38-41 Calculate the number of grams of solute needed to make 250 cm^3 of 0.350M Na_2SO_4 solution.

42-45 Calculate the molarity of a solution containing 10 grams of NaOH in enough water to form 600 cm^3 of solution.

46-49 49.0 grams of H_2SO_4 are added to 250 grams of water. Calculate the molarlity of this solution.

50-53 Calculate the mass of solute needed to add to 500 g of H_2O to make a 0.35*m* $SnBr_2$ solution.

54-57 Calculate the mole fraction for each component in a solution containing 45.0 g of CH_3COOH in 200.0 g C_2H_6O.

Comments:

What do you remember most about the solutions, polarity, and separation science unit? What did you learn? Describe.

Appendix C3: Survey, H1 and H2

Answer the following questions honestly. Circle the number, 1-5, which best indicates your opinion.

1 - highly disagree   2 - disagree   3 - indifferent   4 - agree   5- highly agree

1.	I found this unit to be organized.	1	2	3	4	5
2.	I found the labs helped my understanding of the material	1	2	3	4	5
3.	I found it easy to make connections and draw conclusions between polarity and chromatography.	1	2	3	4	5
4.	I found the labs tied in well with the instruction.	1	2	3	4	5
5.	I found the labs motivated me to learn the material.	1	2	3	4	5
6.	The demonstrations proved beneficial in understanding concepts.	1	2	3	4	5
7.	My understanding of the material is this chapter is greater than material from previous chapters.	1	2	3	4	5
8.	I understand the effect polarity has on whether or not a solution will occur.	1	2	3	4	5
9.	I understand the difference between a polar covalent bond and a nonpolar covalent bond.	1	2	3	4	5
10.	I understand how an emulsifier works.	1	2	3	4	5
11.	I understand the difference between a detergent and a soap.	1	2	3	4	5
12.	I understand the practical applications of chromatography.	1	2	3	4	5
13.	I understand how electrons could be shared unequally in a covalent bond.	1	2	3	4	5
14.	I understand how molecular geometry is used to determine molecular polarity.	1	2	3	4	5

Comments:

Please comment on the organization of the polarity/solutions/separation science thematic unit. Did you find it easy to make connections? Draw conclusions? Etc.?

Discuss the helpfulness of the labs and demonstrations in this unit. Did they tie in with the instruction? Did they add to your understanding? Motivate you to learn? Etc.?

How did your understanding in this unit compare to previous units? How did your scores compare?

Please comment, in general, on my teaching style. What things work for you, what doesn't? Feel free to make suggestions on areas for improvement.

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