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APPLYING FOOD AND OTHER HOUSEHOLD MATERIALS TO BEGINNING CHEMISTRY EXPERIMENTS

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APPLYING FOOD AND OTHER HOUSEHOLD MATERIALS TO BEGINNING CHEMISTRY EXPERIMENTS

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ABSTRACT

APPLYING FOOD AND OTHER HOUSEHOLD MATERIALS TO BEGINNING CHEMISTRY EXPERIMENTS

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The purpose of this project was to determine whether experiments involving common household materials would help increase student understanding and retention of main chemistry concepts. Throughout the year, beginning chemistry students performed various experiments, some involving food chemistry and others involving standard chemicals. All of the experiments that involved common household materials were introduced into three units: *Unit 1: Introduction to Chemistry and Measurement; Unit 2: Matter, Solutions,* and *Energy; Unit 3: Chemical Naming and the Mole Concept.* The developed labs contained twelve in-class experiments and three take-home experiments. At the end of each semester, the students were assessed on concepts related to the fifteen experiments. Overall, the experiments were well received by the students. The grades and surveys showed the experiments to be effective in helping students learn and remember certain chemistry concepts.

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INTRODUCTION

I. Rationale

Since my first year of teaching, I have asked my students one extra credit question on their final exam: to reflect back over the past year of chemistry and comment on what they liked most and suggest possible improvements that could be made to the course. As you can image, I often receive a wide gamut of responses from: "If I chose a major in college that had anything to do with chemistry, I would be insane," to, "I liked everything about the class." Yet, the one student response that continually surfaced paper after paper was "I really liked the labs. I wish we could have done more labs." In addition, most students' favorite experiments were the ones that involved food.

The student requests for more labs were the primary reason I chose to redevelop my laboratory program for general chemistry. However, this was not my only reason. A majority of my students took chemistry in the tenth grade. I have found most students at this age are not ready for advanced labs because they lack maturity and require lab skill training. Both of the aforementioned are necessary before students are ready to use regular laboratory equipment. Overall, there was a need to redesign labs that would be at their level of interest and ability.

A final reason to redevelop my experiments came from students questioning how chemistry concepts relate to their every day world. Even though students did experiments, they did not seem to see the relationship between unfamiliar chemicals and the chemistry concepts. For example, students rarely remember a neutralization experiment involving hydrochloric acid and sodium hydroxide. Yet most students can recall a freezing point depression experiment between salt and water that allowed them to make ice cream. By the end of the year, the experiments and concepts that students remembered seemed to be the few experiments we did that involved some type of food.

The goal of creating new experiments for first semester chemistry using common materials (Appendix A) was to improve student understanding and retention of key chemistry concepts. By redeveloping most of the first semester labs, I hoped to set a stronger foundation for more involved labs second semester. In addition, I wanted my students to see that learning chemistry can be fun.

There were three units involved in the food-based experiments during first semester: (1) *Introduction to Chemistry and Measurement*, (2) *Matter, Solutions, and Energy*, and (3) *Chemical Naming and the Mole Concept*. The two other units that were taught during the first semester were not included in the laboratory study. Those units were based on atomic structure and periodic trends.

The same five units were taught first semester as in the past years. The only difference was the addition of common materials into the experiments and the introduction of three lab styles (open-ended, cookbook, and take-home). The seven-step lab format (Appendix B) remained the same as in the past years: title, purpose, materials, procedure, data analysis, conclusion, and learn. Many more new experiments were also added to these units. The same unit tests were used as in the past years (Appendix C).

II. Scientific Background

There were two main reasons for reconstructing my current semester one experiments. One reason was to integrate more hands-on activities. The other reason was to make my classroom chemistry experiments more practical by using food and household materials.

Sir Francis Bacon is the founder of the experimental method in science. Prior to his work in the 1600's, "scientific laws" were still being derived by Aristotelian inductive reasoning (Frank, 1990). Through induction, events were observed and explained without testing to be true or false. Since testing was the basis for the experimental method, the idea was a bit controversial. Eventually the technique of experimentation became accepted.

By the 1870's teachers realized the impact experiments would have on their students. Professor William James Beal at Michigan State

University was one of the first college professors to use hands-on teaching with experiments. He developed an interactive laboratory focused on teaching and observation of the world through botany (Telewski, 1999). As a result of his efforts the Botanical Garden and Arboretum was founded on the campus of Michigan State University and now bears his name. Professor Beal holds the record for the longest running experiment.

Students learn very little about science by just watching teachers demonstrate science. When students are actively involved in science they become motivated about science. Students gain a vested interest in doing a science activity by predicting, participating, and thinking (Penick, 1991).

Experiments in my classroom are always done in pairs. By having students work together, they learn the importance of sharing information, interacting with other students, and team cooperation. Other teachers of chemistry, who use cooperative learning strategies, found students become more active in the learning process (Robblee, 1991) and learn in a more productive atmosphere (Nelson, 1996).

Chemistry and experiments go hand in hand. Yet, some chemistry programs have very few experiments. Many reasons include safety issues, high cost of chemicals, and lack of time. For this reason teachers have developed alternatives to experiments, including videos, demonstrations, and interactive computer activities. Yet, studies by

Bradley, Durback, Bell, and Mungarulire (1998) show that these materials "are not a substitute for personal, hands-on experiences."

A key part to developing my labs was to minimize cost, waste, and time needed to perform the experiment. Therefore, most experiments are based on a microscale method. According to Brother Carmen V. Ciardullo, C.M.(1992): "To microsize means: less time is needed to perform, prepare, and clean up an experiment; less equipment, materials and storage is needed; less danger is present."

In the past, my students have done labs that provided them with the procedure. The students merely did the experiment and filled in the desired outcome. These traditional labs were designed to follow a specific recipe and are often called "cookbook labs." When redesigning the new experiments, two more lab styles were included: open-ended and take-home.

Open-ended experiments give the students the problem but not the procedure. The students must design their own procedure. They must analyze the given situation and reason out what direction to take. Often students are less confident with this type of problem because they are more familiar with the experiments that tell them what to do (Robblee, 1991).

Take-home experiments are designed for the student to do the experiment at home, either alone or with a group of chemistry students.

The experiments use materials that the student should already have around the house. The objective is for students to see that chemistry is found in their own home and that they could share their experiment with a family member.

Another focus of the experiments was to involve food or some other application to the every day world. Applications and analogies are only useful if the students can relate to them. Historically scientists have used analogies to explain important concepts (Glynn and Takahashi, 1998). Yet, the application must be such that it will increase student understanding.

Students have difficulties relating chemical concepts to their every day world. Research done at Purdue University by Gayle Nicoll (1997) showed:

> ...that students are entering college and pursuing degrees in the sciences without fully grasping the scientific meanings of technical words. They are attempting to go through their undergraduate careers without understanding one of the fundamental ideas in chemistry... It would therefore be useful for educators to emphasize more "real world" applications of chemistry, especially for students who are not science majors.

Nicoll goes on to explain that all levels of students may benefit when real world relationships are used to link chemistry concepts to every day life. In another study, Sumrall and Brown (1991) found when using real world activities that students become more motivated and curious about chemistry.

The integration of food science into the chemistry classroom has many memorable real world applications. Susan J. Barkman (1996) found that food science is directly connected to chemistry and many other sciences. She believes that when using food sciences not only are "the possibilities for different experiments and learning experiences endless," but they are also, "an excellent method of bringing science into students' daily lives."

In another classroom, Elise Hilf Levine (1996) found that by using candy in experiments and demonstrations students are motivated and interested in learning. The lab disposal is easy, because students eat the results! For safety reasons, food based experiments should not be done in a chemistry lab, but in an alternative location.

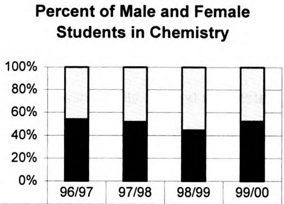
Within the last few years, books such as *Chemistry in the Community* (1998) and *Chemistry in the Marketplace* (1998) have focused on chemistry relationships to the every day world. Students need to relate science to their daily lives to set a strong foundation of understanding. When you apply thinking to observations, it is amazing what can be done. "Science teaching should be directed to every day thinking. We should understand what is around us." (Potchen, 2000)

III. Demographics

The Elkton-Pigeon-Bay Port school district, where I teach, is located approximately sixty miles from Bay City at the top of Michigan's Thumb. The consolidated rural district covers 237 square miles and enrolls about 1,300 students per year. During the 1999-2000 school year, the high school had 456 students in ninth through twelfth grade of which the majority are Caucasian (94%).

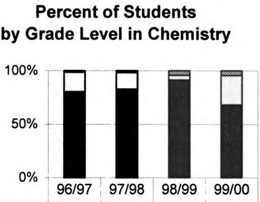
I teach general chemistry, advanced chemistry, and physics to tenth through twelfth graders. General chemistry is comprised mainly of tenth grade students. It is an elective science class so the enrollment varies year to year between two or three sections. The time allotted for each class period is on the average fifty minutes.

The current study, during the 1999-2000 school year, included three sections of chemistry, each with 23 students. Out of the 69 students who were involved in the research 48% were female and 52% were male; 4% were seniors, 28% were juniors, and 68% were sophomores. In past school years, the number of students and the grade breakdown varied slightly. The following graphs show chemistry enrollment for the past four years.



	96/97	97/98	98/99	99/00
□ Female	35	28	26	33
■ Male	41	30	21	36

Figure 1: Chemistry enrollment by gender.



	96/97	97/98	98/99	99/00
▩ Senior	1	1	2	3
□ Junior	14	9	2	19
■ Sophmore	61	48	43	47

Figure 2: Chemistry enrollment by grade level.

IMPLEMENTATION

I. Basic Outline

The lab book I developed, using food and household materials, was integrated into three preexisting units for first semester general chemistry. The three surveys (Appendix D) and fifteen redesigned labs (Appendix A) were the only new materials added to each of the units. Most of the redesigned labs required one to two class periods to complete. This work was a direct result of my research at Michigan State University.

To assess each unit, the students completed a test over the main chemistry concepts. Each unit assessment remained the same as the previous year. The tests consisted of various question forms, including matching, short answer, true/false, fill in the blank, and problems.

On the following page is a detailed outline of what activities took place in each of the modified units. The appendix where each activity is located is also included.

Table 1: Outline of activities

	Appendix
Overall Pre-Survey	D3
Unit 1: Introduction to Chemistry and Measurement	
Lab 1: Observation Skills: Peanut Possibilities	A1
Lab 2: Metric Measurement Madness	A2
Lab 3: Density Dilemma	A3
Unit 1 Take-Home Lab: Density Bottle	A4
Assessment: Unit 1 Test	C1
Unit 2: Matter, Solutions, and Energy	
Lab 4: Separation of Iron, Sugar, and Sand	A5
Lab 5: Properties of Solutions: Ice Cream Depression	A6
Lab 6: Powder Potential: Chemical & Physical Changes	A7
Lab 7: Junk Food Energy	A8
Unit 2 Take-Home Lab: Solutions	A9
Assessment: Unit 2 Test	C2
Overall Mid-Survey	D3
Unit 3: Chemical Naming and the Mole Concept	
Lab 8: Chemical Formulas	A10
Lab 9: Formulas for Smarties®	A11
Assessment: Unit 3 Test A	C3
Lab 10: Percent of an Oreo®	A12
Lab 11: How Thick is Aluminum Foil?	A13
Lab 12: Water of Crystallization	A14
Unit 3 Take-Home Lab: Molarity	A15
Assessment: Unit 3 Test B	C4
Overall Post-Survey	D3
Concept Retention Survey	D1
Concept Association Survey	D2
End of the Year Concept Retention Survey	D1
End of the Year Concept Association Survey	D2

II. Objectives

Since Chemistry I is an elective science class, many of the general objectives set by *Michigan Essential Goals and Objectives for Science Education (MEGOSE)* (1991) and the *Michigan Curriculum Frameworks* (1996) have already been taught in a previous science class. However, past experience showed that students still had difficulty with some of the required science concepts to be taught in Michigan. For this reason, the first two units of chemistry provided students with an overview of those basic concepts. The following labs are grouped with the respective objectives from the *Michigan Curriculum Frameworks* (1996):

- Lab 1 & 6: All students will measure and describe the things around us. (IV.1)
- Lab 2 & 3: Describe and compare objects in terms of mass, volume, and density. (IV.1)
- Lab 2: Recognize and explain the limitations of measuring devices (I.6)
- Lab 3 & 4: Designing an experiment using quantitative data (I.6)
- Lab 4, 5, 6. 7: Describe and analyze ways in which matter changes (IV.2)
- Lab 7: How changes in matter are related to changes in energy (IV.2)

The third unit in this course is more closely aligned to only chemistry objectives. Two of the most important chemistry topics of the year are taught in this unit: naming compounds and the mole concept. Other objectives include determining a percent error, calculating a mass percent, and finding the formula of a hydrate.

In summary, the goal of the new experiments was to integrate more every day materials to relate to students' lives and to include different styles of lab. Each unit contains one open-ended experiment and one take-home experiment. The remaining experiments were all cookbook experiments. All of the experiments followed a formal lab format (Appendix B). Out of the fifteen experiments, students were required to write four formal write-ups on their own.

The following table lists the common material, lab type, and main chemistry concept associated with each experiment. The symbol "F" after a lab type designates a formal lab write up was required.

Table 2: Experiment information

Lab	Common Material(s)	Lab Type	Chemistry Concept
1	peanuts	Cookbook	observation
2	Starburst®, pennies, water	Cookbook	measurement
3	plastic, water	Open-ended(F)	density & percent error
Unit 1	vegetable oil, water	Take-home	density
4	iron, salt, sand, water	Open-ended(F)	separation
5	ice cream (milk, sugar, coffee creamer, vanilla)	Cookbook	freezing depression
6	baking soda, starch, salt, sugar, water, vinegar, iodine, Pixy Stix®, baking powder, powdered sugar	Cookbook	chemical & physical changes
7	Cheese Nip®, potato chip, corn chip, pop can, water	Cookbook	energy & specific heat
Unit 2	fudge, sugar, tea	Take-home	solutions
8	m&m's® Christmas candies	Cookbook	chemical formulas
9	Smarties®	Cookbook	molecular & empirical formulas
10	Oreo® regular & double stuffed	Open-ended(F)	percent composition
11	aluminum foil	Cookbook	Avogadro's #
12	epsom salt	Cookbook (F)	hydrate analysis
Unit 3	sugar, water, Kool-Aid®	Take-home	molarity & moles

III. Laboratory Description & Analysis

Each of the following experiments are located in Appendix A: *Experiments Using Household Materials for Beginning Chemistry Students.* After each experiment is a list of any references used or modified for creating the lab. I used many of the referenced experiments as an impetus to spark ideas for redesigning labs more suitable for my general chemistry class. The resulting lab format and design of each experiment is all my own.

During all experiments, students worked with a partner. I required each student to be responsible for his or her own laboratory report. The lab results for all students is summarized in Appendix E. For student comments on each experiment, I examined the same nine students' papers. Three papers came from each hour, representing one high achieving student (H), one average achieving student (A), and one low achieving student (L). Targeted chemistry concepts are included in the discussion of each lab.

Unit 1: Introduction to Chemistry and Measurement

Lab 1: Observation Skills: Peanut Possibilities (Appendix A1)

The first lab of the year was an observation activity performed on the third day of class. The experiment can easily be done in one class period. Prior to the lab, we discussed the different types of observations that can be made by scientists: qualitative observations using your senses and quantitative observations using numbers.

Students were given a piece of string, a ruler, and a peanut and asked to write at least twenty observations about their peanut. In addition, students classified each description as qualitative or quantitative. As a final check, all of the peanuts were collected and placed on a table. Then the students traded their list of observations with another group and tried to find that group's peanut. Students quickly realized whether or not they had detailed enough observations to find the peanut.

The questions in the conclusion stressed the importance of being observant and accurately expressing what you see. The students also used a ruler to gather data, even though specific instructions had not been given in-class. The students did not eat the peanuts that everyone handled, but they ate the extra peanuts I had on hand.

Overall, 84% of the 69 students scored an A on this experiment (Appendix E1). No one scored less than a C. The students who lost points on the experiment did not have enough observations, incorrectly classified the observations, or did not explain answers to the conclusion questions. Some of the students did not see a use for the string in the experiment. If the groups were short on time and observations, I would ask them these questions: Is the peanut two-dimensional or three-dimensional? What can you measure using a string? How can you use the ruler and string together to take measurements?

There was only one group of students who could not locate another group's peanut based on the given observations. This group had only listed ten general observations. As a whole, most of the students had difficulty describing the peanut with twenty observations in fifteen minutes. For this reason, I did not penalize students unless they had less than fifteen observations. In the future, I will lessen the required number to fifteen observations.

Student comments on what they learned from Lab 1:

- Being descriptive is important when looking for something. (A)
- Good observation is important so others know what you are talking about. (H)
- The more specific the observation the easier it is to find the peanut. (L)
- This is one nutty experiment. (H)

Lab 2: Metric Measurement Madness (Appendix A2)

The second lab was a series of measurements performed on the eleventh day of class. The experiment was done in one class period, but required an additional ten to fifteen minutes on the next day to wrap up unanswered questions. The weeks preceding the lab were spent learning about precision, accuracy, significant numbers, and conversions. This lab was designed to show how all of these concepts relate to three basic measurements: length, mass and volume.

In a pre-lab discussion students were informed about laboratory precision and care related to the equipment they would use in the lab.

> Length: A meter ruler can be read to 0.02 cm.
> Mass: A digital balance is very sensitive to small masses.
> Our balances can weigh to 0.01 g, but not more than 400 g.
> (A stapler is too heavy to weigh on our balance!)
> Volume: A graduated cylinder has a protective plastic ring at the top of the glass and is read from the bottom of the curve (meniscus) to 0.1 mL.

Students measured their height with a meter stick, massed two different pennies with a digital balance, and determined the volume of an irregular and regular solid using a Petoskey stone and Starburst® respectively.

This experiment introduced students to basic laboratory equipment that would be used in future labs. Students measured familiar items: themselves, money, Michigan's state stone, and candy. The analysis questions were related to each measurement the students performed and had them apply the concepts to other measurements that could be made.

Overall, 30% of the 69 students scored an A on the second experiment, 51% scored a B, and 16% a C (Appendix E2). Two students scored less than a C because they turned in an incomplete lab. The students who lost the most points on the experiment did not record their answers in the correct significant numbers and forgot to put units with the measurements. Other points were lost for incorrect answers to the analysis questions and for being too general in the conclusion. As a whole, students had more difficulty with this experiment. In the future, I plan to emphasize units and precision more before the experiment. Students were very excited to get to the end of the experiment to measure and eat their Starburst® fruit candy.

Student comments on what they learned from Lab 2:

- I learned how important exact measurements are. (A)
- We learned that the metric system is very easy to understand. (H)
- I learned how to measure an object precisely. (A)
- I learned how to properly measure with metric instruments. (H)

Lab 3: Density Dilemma (Appendix A3)

The third lab was the first open-ended lab experiment and took students through their first formal lab write up. The lab related to density was started on the seventh day of class and completed on the twentieth. The lab can be done in two class periods, but may require an additional day to have students finish the formal write-up. During the first day students wrote the procedure and performed the experiment. In the second day, students gathered and analyzed the class data. The lab took us a few days longer due to various conflicts with school related activities.

The students learned about density and how to calculate it the week before the lab. The lab introduction is the only background information the students received about the relationship between density and plastic recycling symbols. The students were to create their own procedure to determine the density of the unknown plastic that draws on lab techniques and skills learned during Lab 2.

The lab guided students through the analysis of the data. The students gathered the data from the whole class and made a graph. To find the average value for the density of the unknown plastic, the students calculated the slope of the graph. Once the density value is determined, the unknown plastic was identified and the percent error calculated. The students also described any sources of error.

Not only did students design their own experiment to determine the identity of an unknown, but they also interpreted the results of a graph and explained experimental errors of the lab. Overall, 26% of the 69 students scored an A on the third experiment, 51% scored a B, and 17% a C (Appendix E3). Four students scored less than a C because they turned in an incomplete lab or they did not do the assignment. The most common errors on the experiment were from students not recording the correct significant numbers, forgetting to put units with the measurements, and being too general in the purpose and conclusion. Other points were lost because the graph did not have labels on the axis and students forgot to make general observations.

As a whole, students had some problems with this experiment. Some errors carried over from Lab 2 and other mistakes were made because this was a more involved experiment than the two previous experiments. This was one of the harder experiments in the lab book. After doing the experiment with students, I found the analysis section to be a little confusing. This portion of the experiment will be reworded before it is used again next year.

Student comments on what they learned from Lab 3:

- I learned how to find percent error. (A)
- I found what plastic was made of and found out the density of our plastic. (L)
- We learned that not all pieces of plastic are the same... (A)
- During the experiment I learned how to find the density of an unknown object. (H)
- I learned how to get a more exact answer by taking the average of the group analysis. (H)

Unit 1 Take-Home Lab: Density Bottle (Appendix A4)

The students were sent home with instructions to make a density bottle out of two solutions and a 20-oz bottle. The recommendation was to use water and some type of cooking oil. The students could work with a group or by themselves. The goal of the take-home lab was to get students to share the experiment with their family members and other chemistry students.

Most of the students did share the experiment with a family member. Overall, 68% of the 69 students scored an A on the first take-home experiment and 15% scored a B (Appendix E4). Seven students scored less than a B because they turned in an incomplete lab or they did not do the assignment. A few students lost points for turning in the lab assignment after the due date.

I had hoped students would make these bottles and want to keep them as a chemistry "treasure". However, once the student brought the bottle to class to prove they had completed the assignment, the bottle became a part of the chemistry room. Although density bottles are a colorful display in my classroom, one does not need sixty bottles. In the future, I plan to micro-size the experiment by using small hotel shampoo bottles.

The most common student comment from what students learned during the Unit 1 take-home Lab was: "I learned that the density of oil is less than water."

Unit 2: Matter, Solutions, and Energy

<u>Lab 4</u>: Separation of Iron, Sugar, and Sand (Appendix A5)

The fourth lab of the year, based on separation, was done during the sixth week of school and was another open-ended lab requiring a formal lab write-up. The lab required three days to complete. During the first two days, the students wrote the procedure and performed the experiment. On the final day students worked on the formal report and completed a student check sheet (Appendix F), which reminded them of anything they may have left out of the formal lab report.

A few days before this lab, students took notes on matter and the breakdown of matter. Through demonstrations and discussion, students were introduced to various separation techniques, such as filtering and decanting. Another separation method I showed them was how to remove iron from Total® cereal using a magnet.

The lab sheet gave instructions on how to make the mixture of iron, sugar, and sand, and the materials the students may use to separate the mixture. Similar to Lab 3, the students created their own procedure that draws on lab techniques and skills learned previously. Students calculated the percent error in the separation at the completion of the experiment.

After calculating the percent of error, students saw how good their lab skills really were. Most of the students did an excellent job with the separation; they had a few errors compiling the results in a formal write-up. Overall, 28% of the 69 students scored an A on the fourth experiment, 42% scored a B, and 26% a C (Appendix E5). Only three students scored less than a C because they turned in an incomplete lab or they did not do the assignment. By far the most common error on the experiment was students forgetting to record general observations. Another area that caused students to lose points was not showing a sample calculation with their data.

Students really enjoyed the experiment, but did not like the lab write-up. I had done a similar experiment in previous years, using salt instead of sugar. I found the students had huge errors with the salt separation so I decided to try sugar instead. While the sugar did dissolve better, it burned when removing the water. In the future, I will most likely use salt.

Student comments on what they learned from Lab 4:

- I learned how to use different lab instruments to separate the iron, sand, and sugar. (H)
- In this experiment I learned how to write-up a lab and separate different substances. I have a much better understanding of those two things now after I have completed the lab. (A)
- I learned how to calculate my percent errors and ways to improve them. (H)

Lab 5: Properties of Solutions: Ice Cream Depression (Appendix A6)

The fifth lab, addressing properties of solutions, was done during the seventh week of school and required one class period. Students learned about colligative properties related to solutions the day before the activity. Since this experiment allowed students to eat the product, the lab was done away from the chemical lab stations using kitchen equipment. The lab also required a cooler to hold several gallons of milk and ice throughout the school day.

Students rotate through a material collection line and after about twenty minutes of flipping the bag the ice cream will become firm. Students did not need any instructions on what to do with the end result of this experiment. The analysis questions talked students through what happened to the milk solution to make ice cream.

Everyone turned in this lab report. As a result, 51% of the 69 students scored an A , 33% scored a B, and 14% score a C (Appendix E6). Only one person scored less than a C. Most of the students who lost points on the experiment did not record general observations during the making of the ice cream. A few students thought ice cream was homogeneous. I think this links back to the confusion with homogenized milk.

This experiment was the students' favorite and the messiest experiment of the year. In the past years, I had students make ice cream as an end of the year activity, without recording data or tying the activity into a unit. The activity was much more organized with the lab sheets and students really seemed to understand freezing point depression and properties of solutions.

Student comments on what they learned from Lab 5:

- The salt mixed with ice helps the ice stay even colder. (A)
- I learned you can make ice cream without an ice cream maker. (A)
- Salt lowers the freezing point of water. (L)
- I learned the importance of salt in this experiment. (A)

Lab 6: Powder Potential: Chemical & Physical Changes (Appendix A7)

One class period was required for the lab and a portion of another day to complete the analysis. Prior to the activity, students had observed a demonstration on chemical and physical changes. The demonstration, called "A Reaction in a Bag," showed students three things to look for in a chemical change: color change, gas evolution, and temperature change.

Each student group should have access to eight vials of powder and three bottles of solutions. During the first part of the experiment, students were asked to react and analyze four known kitchen powders (salt, sugar, starch, and baking soda) with three common household liquids (water, vinegar, and iodine solution). In part two of the experiment, the students were given four powders with unknown composition (Pixy Stix ®, powdered sugar, baking powder, and an unknown mixture I created from the known powders) to react with the three liquids. The students analyzed these powders to determine if any of the known kitchen powders were present. In the final part of the experiment students mixed two powders (Pixy Stix® and baking soda) with water and analyzed what happened. Students were rewarded with a Pixy Stix® once they had completed the experiment.

The lab results showed that 32% of the 69 students scored an A , 54% scored a B, and 13% score a C (Appendix E7). Only one person scored less than a C. Most of the students had difficulties analyzing the results of part one and two. I think the problems arose from the wording on the lab sheet. I revised the lab sheet and retried the analysis portion of the experiment. The students seemed to understand the new version better.

There were a few minor problems with two of the reactions. When I reacted the Pixy Stix® powder with the iodine I observed a slight reaction. However, when the students did the same reaction, there were no observed results. A similar outcome was observed for the reaction in part three. If the students did not mix enough of the two powders, the reaction was too small to observe. I plan to increase the amount of powders used in part three in future labs.

Student comments on what they learned from Lab 6:

- Powdered sugar contains starch. (A)
- I learned I don't like this stuff. (L)
- I learned how to pay attention and observe carefully. (A)
- I learned what household powders make a chemical change when added to certain liquids. (A)

Lab 7: Junk Food Energy (Appendix A8)

The final lab for unit two focused on energy. The experiment required two days: one for experimenting and one for analyzing the results. The day before the lab, students were introduced to energy conversions between joules and Calories, along with specific heat calculations.

The lab instructions guided students through a calorimetry experiment using a pop can with water and a piece of junk food for the energy source. The students chose what junk food they wanted to use: a potato chip, corn chip, or Cheese Nip®. The students gathered various mass and temperature readings before and after the burning of the junk food. Once the data was collected the students were guided through calculations on the lab sheet. Finally, the students calculated a percent error based on the energy content indicated on the food package. Students then described sources of error.

This lab was definitely well received by the students, especially since it involved fire and food. Overall, 52% of the 69 students scored an A , 30% scored a B, and 9% score a C (Appendix E8). Six students scored less than a C. The students did a much better job recording general observations on this experiment than they had done in the past. However, students still made mistakes recording measurements to the correct precision and with units. Students either did all of the calculations correctly or did them all wrong. Several students also did not summarize their results in the conclusion.

This lab was not designed to arrive at accurate calorimetry results, although many students did do several trials. Percent errors were very high, but this allowed students to think about the many sources of experimental error. Also, students reasoned ways to redesign the apparatus to yield better results.

The favorite junk food to burn was the Cheese Nip®. By the end of lab most students had done at least one trial using a Cheese Nip®. Other student comments on what they learned from Lab 7:

- I learned how to determine how much energy is in a sample of food. (H)

- We learned how to get the energy of our favorite junk food and how to convert between kJ and C. (H)
- I learned to find out how much energy was in a Frito®. (A)

Unit 2 Take-Home Lab: Solutions (Appendix A9)

The students were sent home with the instructions to make either sweetened tea or homemade fudge. While the students were making the appropriate solutions, they were asked at various points to record observations and classify the solution and mixture. The students again were given the option of working with a group or by themselves and were asked if they shared the experience with their family members and other chemistry students.

As with unit 1, most of the students shared the experiment with a family member. Overall, 38% of the 69 students scored an A on the second take-home experiment, 33% scored a B, and 9% scored a C (Appendix E9). Fourteen students scored less than a C. Six of those fourteen did not do the assignment. Most of the students lost points for not making observations and mixing up the classifications of the solution and mixture. In class the students seemed to understand the concepts of homogeneous and heterogeneous solutions. They also seemed to understand saturated, unsaturated, and supersaturated solutions. However, when they had to analyze the solutions out side of class they were not as successful.

The most common student response from what they learned during the Unit 2 take-home Lab was: "Heating substances can change the solubility."

Unit 3: Chemical Naming and the Mole Concept

Unit three is actually the fifth unit of the first semester of beginning chemistry. There are two units that fall between unit two and unit three of this study: Atomic Theory and Periodic Trends.

Lab 8: Chemical Formulas (Appendix A10)

The first lab of unit three was done during the sixteenth week of school and focused on writing chemical formulas. The experiment required one full day. Prior to the experiment the students were to have already memorized several polyatomic ions, learned the rules associated with writing formulas, and learned how to determine oxidation numbers.

The experiment was really an activity that guided students through writing the chemical formula for twenty compounds using cards and m&m's® Christmas candies. The first step was for students to fill out all of the ion cards. For example, the card with the word aluminum would have Al^{+3} written on it. Next the students use the cards to create a formula for the given compound. The number of cards needed for a formula depends on the charge of the cards. The students would then use the m&m's® to represent the charges, red for positive and green for negative. When the charges were equal the number of green and red candies would be equal and the student could write the formula.

Students did a fine job on this activity, with 67% of the 69 students scoring an A, and 23% scoring a B (Appendix E10). Only seven students scored less than a B. A few students had difficulties using parentheses and subscripts on the formulas. A majority of the students felt the m&m's® candies helped them to write the formulas because they could see the number of ions and this kept them organized. Other students felt they could do the experiment without the candy because it just slowed them down.

In the past, this activity was simply a worksheet that students completed as homework. I found that students seemed to work harder and understand more by developing the formulas as an in-class activity. However, I do not know if the candy is necessary. The lower level students seemed to grasp naming much faster by using the cards and the candy, but the upper lever students found using the candy to be pointless. However, both groups enjoyed eating the candy when the lab was complete.

Student comments on what they learned from Lab 8:

- I learned to make formulas out of ions. (L)
- I learned how (to) equalize the charge of ions to form a chemical formula. (H)
- I learned to create formulas in an easy fun way. (H)

- I learned how to combine various ions and create various formulas… It was one sweeeeet experiment! (H)

Lab 9: Formulas for Smarties® (Appendix A11)

As a sequel to lab 8, lab 9 continued to focus on writing chemical formulas. This is a short experiment that required only half a period and was done the same week as lab 8; students were still working on naming and writing formulas to compounds. This experiment also had students look at the difference between molecular and empirical formulas.

This experiment also was an activity that had students examine rolls of Smarties®. Students created chemical symbols for the Smarties® based on the colors. After counting the number of each color the students arrived at a "molecular formula" for the Smartie®. Students may also be able to deduce an empirical formula for the same Smarties® "compound".

Students did an outstanding job with 97% of the 69 students scoring an A (Appendix E11). The remaining scores were all B's. Students did not have any problems with this experiment, especially once they could eat the candy.

In the future I plan to revise this experiment by adapting it more to empirical formulas. Not a single Smarties® "compound" yielded an empirical formula. Instead of using the small plastic rolls of Smarties®, I would like to try the Sweettarts® that come three to a package. I think the colors will be more repetitive.

Student comments on what they learned from Lab 8:

- No smartie packs are alike. (L)
- I learned how to make chemical formulas using smarties. (A)
- The difficulty it is to find equal compounds and formulas. (A)
- I learned that not all smarties are created equal. (H)

Lab 10: Percent of an Oreo® (Appendix A12)

The third lab of unit three focused on mass percent and was done before students left for Christmas break. This lab was an open-ended lab requiring a formal lab write-up. It required two days: one day for students to write their procedure and another for students to complete their lab write-up. Prior to the experiment, students were introduced to molecular weights and how to calculate the mass percent of elements in a compound.

The accompanying lab sheet proposed the question: Does a double stuffed Oreo® cookie really have double the cream? Students were given a set of materials including a regular Oreo® and a double stuffed Oreo®. Students were responsible for writing their own procedure to arrive at the answer to the proposed question. Since students could use a chemical balance, they were given fresh Oreo® cookies to eat at the conclusion of the experiment.

Most of the students quickly arrived at a procedure and had no problems collecting the data. Overall, 52% of the 69 students scored an A on the experiment, 32% scored a B, and 14% a C (Appendix E12). Only one student scored less than a C because they turned in an incomplete lab. The most common error on the experiment was that students did not show the mass percent calculation. Some students lost points for not including all of the results in their conclusion

Students really seemed to be into the experiment, but again had some difficulties with the lab write-up. I had done a similar experiment in the past, but comparing a reduced fat Oreo® to a regular Oreo®. Student results varied when answering the double stuffed Oreo® question, but as long as the data supported their results they were not penalized.

Student comments on what they learned from Lab 10:

- That it can be fun to weigh stuff and find how much you get in a cookie. (L)
- I learned to be exact in my measurements and record my data carefully... (L)
- I learned that they actually double the cream in a double stuffed Oreo and I learned how to figure that out. (A)
- This experiment taught me that advertising claims are sometimes true and other times advertising claims are just to encourage people to buy their products. The Oreo Company is not just using the claim that the double stuffed cookie contains twice the amount of cream for advertising, the claim is true. (H)

<u>Lab 11</u>: How Thick is Aluminum Foil? (Appendix A13)

The fourth lab of unit three focused on the mole concept and was done during the nineteenth week of school after Christmas break. The lab required one day. During the week before the experiment, students had their first encounter with the mole concept and learned how to do conversions related to the concept.

One goal of the experiment was to determine the thickness in atoms of a piece of aluminum foil. Students also were to calculate the number of atoms in the entire aluminum sample. For the experiment, students were given a piece of aluminum foil and a cylinder of aluminum and asked to collect various measurements. From the data, students performed the required calculations.

Most of the students seemed interested in determining the outcome of this activity; however the results indicated that many of them were forgetful after the two week break. Overall, 32% of the 69 students scored an A on the experiment, 25% scored a B, and 22% a C (Appendix E13). The remaining students scored less than a C. The most common error was that students did not show units on the data they collected. A few students lost points for answering only a portion of the analysis questions.

Overall, students did not take time to double-check the lab before I graded the assignment. The format of the lab seemed a bit cumbersome so I reformatted the lab. A final addition I plan to make in this lab is to use a miniature peanut butter cup as the source for the aluminum foil. There was not a student comment section on this version of the lab.

Lab 12: Water of Crystallization (Appendix A14)

The last lab of unit three was performed at the start of second semester as an extra topic on hydrates. The students were given three class days to perform the experiment and required to do a formal write-up. The topic of hydrates is used to tie together first semester concepts with second semester concepts. Prior to the lab, students learned how to name hydrates and calculated the percent of water in hydrates.

Students determined the amount of water in Epsom salt ($MgSO_4 \cdot nH_2O$) by finding the mass of the salt before and after heating. The students then calculated the amount of water in the salt and compared the experimental value to the value printed on the container of Epsom salt.

The students did a great job on this experiment. The only students who scored less than a C did not turn in the lab. Overall, 51% of the students earned an A; 32 % of the students earned a B; 14% of the students earned a C (Appendix E14). The main errors in the lab reports came from mistakes in the conclusion. Students forgot to answer the purpose of their lab by stating the complete formula of the hydrate with any error.

Student comments on what they learned from Lab 12:

- The heating of magnesium sulfate crystals results in the loss of water in the crystals. (A)
- ...I also learned that moisture does evaporate when you are warming something whether it is a under a low flame or a high flame. (L)

- To heat thoroughly for best results. (L)
- ...I also learned how to determine an empirical formula of a material with water inside. It was a hot experience. (H)

Unit 3 Take-Home Lab: Molarity (Appendix A15)

Since the end of the semester was near and many of my students were getting the usual winter cold, the last take-home lab was designed around drinking lots of fluids. The students were sent home with lab instructions to make a pitcher of Kool-Aid®. While drinking the beverage, they were asked to calculate the molarity of the solution. In order to make the molarity of Kool-Aid® a little more interesting, I also asked the students to calculate the molarity of sugar of their favorite soda pop and compare the two solutions.

As with the other take-home experiments, the students were given the option of working with a group or by themselves and asked if they shared the experience. Most of the students did share the experiment with a family member. Overall, 90% of the 69 students scored an A on the third take-home experiment (Appendix E15). Six students scored an F because they did not do the assignment. There were only minor errors in the calculations of molarity. Almost one third of the students were surprised by the amount of sugar in soda pop. This was by far the most talked about take-home lab during the year.

The most common student response from what they learned during the Unit 3 take-home Lab was: "I learned that there is more sugar in pop than in Kool-Aid."

EVALUATION

I. Overview

Various assessments were used to evaluate the overall effectiveness of introducing the household-based experiments to my classroom. For each unit, I compared unit test scores from the current school year, 1999-2000, to the previous school year, 1998-1999. Each unit test was the same over the two-year period. In addition, I also compared semester one and two grades for all of my students over the past four years.

Students responded to three different surveys. The first survey was a student opinion survey (Appendix D) that compared student responses over the relevance of experiments and the relationship of experiments to every day materials. Students were asked to agree or disagree with sixteen statements. A pre-, mid-, and post-project survey was conducted. For the mid- and post-survey a second free response section was added. The second and third survey evaluated student's retention and association of common materials related to chemistry concepts (Appendix D). The purpose of the survey was to see if students remembered chemistry concepts associated with the common materials used in each experiment. The survey was done twice, once after all of the labs had been completed and returned, then again at the end of the school year. The results can be found in Appendix G.

When evaluating the individual experiments I used two methods: grades earned on each experiment (Appendix E) and a second portion of the student opinion survey (Appendix D). The grades corresponding to each experiment were documented in the previous section, *Laboratory Description & Analysis*. Using the student opinion survey, I compared student opinions on the best and worst experiments. Students only answered the second portion during the mid- and post-survey.

II. Unit Test Results

The first unit of the year introduced students to the basic concepts of chemistry and measurements. The test over this unit (Appendix C1) consisted of forty-eight questions (for a total of 100 points), including matching, short answer, true/false, fill in the blank, and problems. Materials covered during lecture and in the laboratory related directly to the test. The questions focused on terms, observation skills, laboratory safety, laboratory equipment, density, significant numbers, units, and metric conversions. The results (Figure 3) show that grades during the Unit 1 test improved during the 1999-2000 school year when the new material was introduced. The average score of the 1999-2000 school year was 88% and the 1998-1999 school year was 85%. Both groups were the same academically, even though the 1999-2000 group was larger in size.

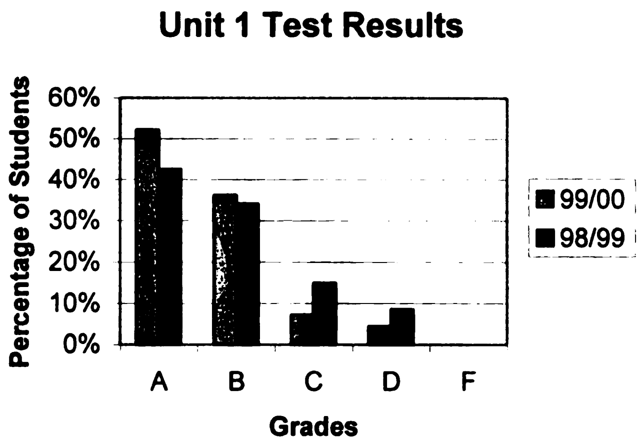


Figure 3: Test grades for Unit 1: Introduction to Chemistry and Measurement

The second unit introduced students to matter, solutions, and energy. The test was worth one hundred points and consisted of thirty-three questions (Appendix C2). The questions included matching, short answer, fill in the blank, graph interpretation, and problems. Materials covered during lecture and in the laboratory related directly to the test. The questions on the test focused on terms, classification of matter, chemical or physical changes, energy conversions, and interpreting solubility using a graph. The test results (Figure 4) indicated that grades during the Unit 2 test did improve during the 1999-2000 school year for the B and C range, but not the A range. The average scores for the two years were about the same. The average score of the 1999-2000 school year was 81% and the 1998-1999 school year was 83%.

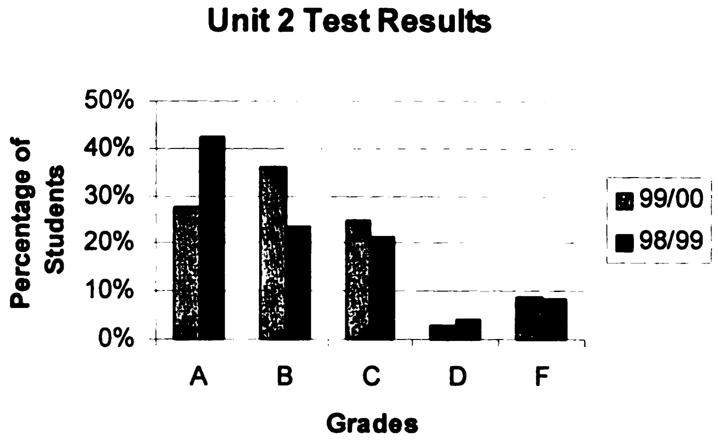


Figure 4: Test grades for Unit 2: Matter, Solutions, and Energy

The third unit introduced students to chemical naming and the mole concept. This unit had two tests: one covered the naming, worth one hundred points (Appendix C3); the other the mole concept, worth forty points (Appendix C4). The naming test consisted of twenty-three questions, including multiple choice, fill in the blank, and short answer. The questions focused on oxidation numbers, naming compounds, and writing chemical formulas. The mole concept test contained seven questions and was entirely problems. Students had to calculate a percent composition, empirical formula, molecular weight, molarity, and mass to mole problem. When grouping both tests together, the results indicate a pattern similar to the Unit 2 test. The grades during the 1999-2000 school year for the B range improved, but the A range declined (Figure 5). The average scores for the two years were about the same. The Unit 3 average test score for the 1999-2000 school year was 81% and for the 1998-1999 school year was 80%. Students during the 1999-2000 school year averaged higher because they scored 4% higher on the mole test than the previous year.

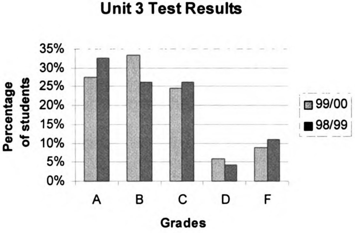


Figure 5: Test grades for Unit 3: Chemical Naming and the Mole Concept

III. Semester Results

Since the unit test scores from the past two years were very similar, I analyzed the overall semester grades students earned over the past four years. The students during this four year period were taught the same basic materials and were graded the same. Since the summer of 1996, when I started the program at Michigan State University, I had gradually been picking up more practical experiments and integrating them one by one into my classroom. The 1999-2000 school year was the first year students were introduced to many new labs, along with redesigned labs that were used in the past.

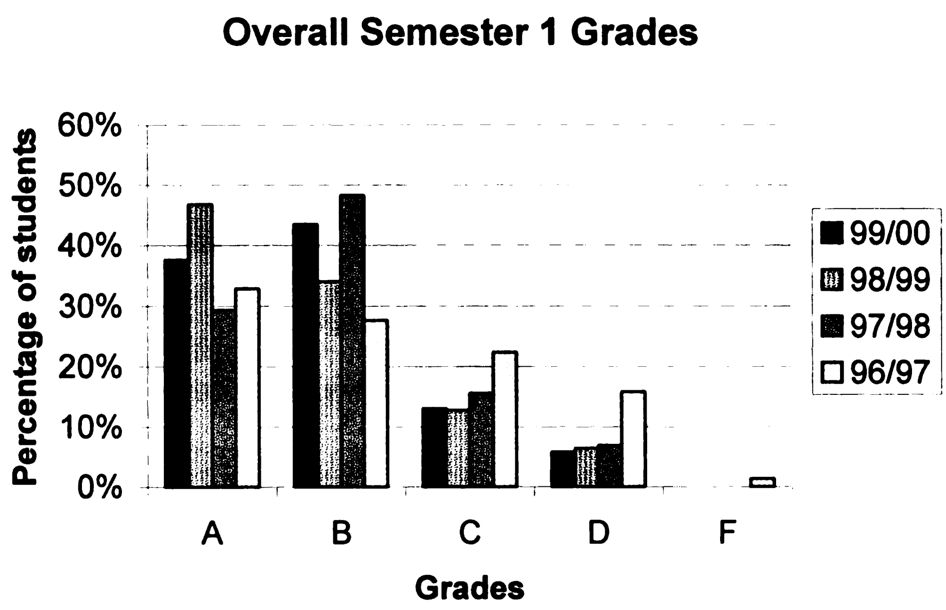


Figure 6: Grades for Semester 1 over the past four years.

Figures 6 and 7 show that during both semesters, the 1999-2000 year showed a reduction in the percentage of D and F grades earned by students over the past four years. In addition, the percentage of students scoring a B increased during first semester and the percentage of students scoring an A increased during the second semester of the 1999-2000 school year. Overall, there has been a greater percentage of students earning higher grades in the past four years since the implementation of more practical every day experiments.

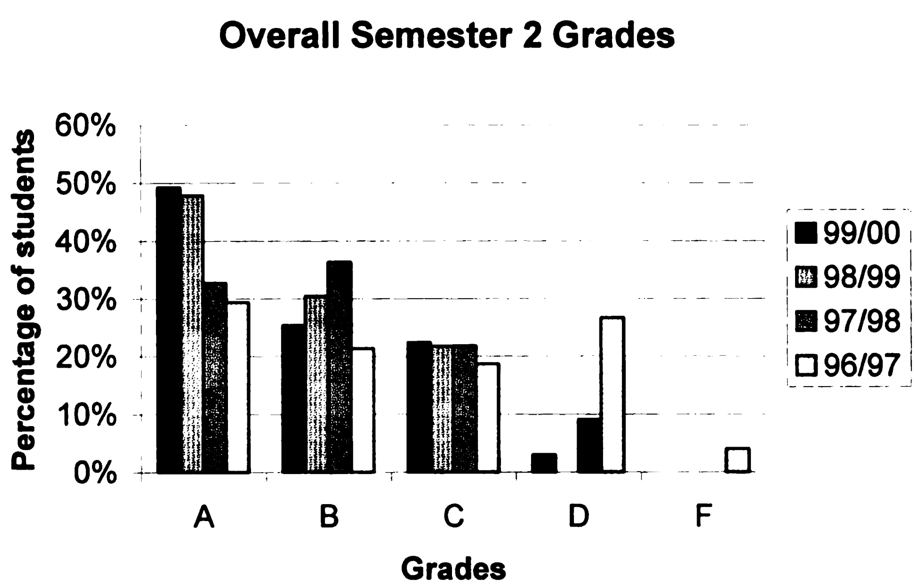


Figure 7: Grades for Semester 2 over the past four years.

IV. Student Retention and Association

Students were given a survey (Appendix D1) to determine if they remembered a chemistry concept as a result of using a common material in an experiment. The first survey was done at the beginning of second semester after the students had completed the fifteen experiments. The survey listed materials for each of the respective labs in the order that they were used during the year. The students were asked to write the chemistry concept they remembered next to the material. The survey was repeated at the end of the year.

The same survey, with the addition of a list of chemistry concepts (Appendix D2), was given to students to determine if they could match the common material used in lab with the related chemistry concept. The survey was also given at the beginning and end of second semester. The complete results of each survey can be found in Appendix G.

The first survey showed that, on average, students remembered nine of the fifteen chemistry concepts. When matching the list of concepts to the materials, the students also correctly associated nine of the fifteen. Please note that there is some error in the concept matching average for the first survey because one third of my students did not finish the survey because of an early dismissal. The results of the second survey showed that, on average, the students remembered six of the fifteen chemistry concepts and correctly associated nine of the fifteen.

V. Student Opinion Survey

The first page of the student opinion survey (Appendix D3) was a series of sixteen statements relating to experiments. The students were asked to circle a number corresponding to whether they agreed (1) or disagreed (5) with the remark. Even though the survey was given three times at three different points during the year, the average student response did not vary.

Table 3: Student Opinion Survey Results

Average Response for Survey

Question	Pre-	Mid-	Post-
#1	1.7	1.6	1.8
#2	1.7	1.6	1.6
#3	1.6	1.5	1.8
#4	1.9	2.0	2.0
#5	2.3	2.0	2.3
#6	2.1	1.7	1.8
#7	4.0	3.5	3.6
#8	2.2	2.0	2.1
#9	1.7	1.6	1.8
#10	2.4	2.0	2.1
#11	2.8	3.2	3.3
#12	3.8	3.2	3.3
#13	2.1	1.9	1.7
#14	2.9	2.9	2.8
#15	2.3	2.8	2.6
#16	1.9	1.7	1.8

Students agreed with most of the statements on the survey. The following are the statements from the survey with which the students agreed, representing a student average response of 1 to 2.9:

#1 Chemistry relates to every day materials.
#2 Chemistry could be understood better if it relates to every day materials.
#3 Chemistry courses should offer lab activities that relate to every day materials.
#4 Chemistry courses should offer more lab activities than they do.
#5 Lectures and labs in chemistry are connected.
#6 Chemistry labs have increased my understanding of how scientists work.
#8 Experiments have increased my interest in science.
#9 Experiments have taught me more about chemistry than lectures.
#10 Experiments have supplemented my understanding of lecture.
#13 The best experiments are very structured and already written out for me to follow.
#15 I am more focused on lab work if I know I will be tested over the experiment.
#16 I am able to remember chemistry concepts when I have performed an experiment on that concept.

Students disagreed with only a few statements on the survey. The following are the statements from the survey with which the students disagreed, representing a student average response of 3.1 to 5:

#7 Experiments are more work than they are worth.
#11 The best experiments are open-ended experiments that are of my own design.
#12 The best experiments are take-home experiments.
#14 Experimental work should be a part of unit tests.

The second page to the student opinion survey was five free response questions and is discussed further in the next section.

VI. Experiment Evaluation

Overall, on the fifteen lab reports students averaged a B. The students enjoyed the labs, especially the ones that incorporated food. The favorite experiment by most students was Lab 5: Ice Cream Depression. Other experiments that students chose as their favorites were Lab 7: Junk Food Energy, Lab 10: Percent of an Oreo®, and Lab 4: Separation of Iron, Sugar, and Sand. Some student comments included:

- My favorite experiment was the ice cream because I love to eat ice cream and it was good. It also helped me (to) get a good understanding of freezing point depression.
- My favorite experiment was that of the SISS (Separation of Iron, Sugar, and Sand) because I came up with the experiment alone.

The second portion of the student opinion survey asked students to rank the three lab styles we used this year, from most favorite to least favorite. They also had to explain why they responded this way. Overall, the students ranked the cookbook experiments the highest and open-ended experiments the lowest.

The students liked the cookbook style of experiments the most because they are quick, easy, and everything they have to do is explained. Other student comments:

- I like labs that are all written out because I know how to do the things if it is written out for me. It also gives me a better example to follow when I have to write a formal lab.
- I like cookbook experiments because we get to do them in-class with a friend and I learn more about the experiment.

Some students did not like cookbook experiments because they found them less interesting.

The students who did not like the open-ended lab style thought they were too much work and were too hard. Student comments included:

- I don't like open-ended labs because they take too long to do.
- ...I do not have anything to follow and I don't like typing my own report.
- ...I'm terrible at writing my own procedure.

A few students did appreciate the open-ended experiments. One student commented:

> I like the open-ended experiments the most because they make me think more about what I am doing and how I plan on doing it. It prepares me for the more complex experiments.

Another student wrote:

> I like open-ended experiments because I feel that I learn more using my own ideas and procedures. I understand the experiment better using my own work and try to get a very low percent of error to show that my procedure worked.

Even though take-home experiments were not ranked the worst experiment style, many students did not like them because they do not have time to do the lab at home and they can not ask questions. Other students enjoyed the take-home experiments because they were free to do the lab when they wanted and work at their own pace. One student wrote, "I like take-home labs because it gives me more time to think and less distractions." Another student responded, "I like take-home labs because my parents can help me."

Students listed a few reasons why they did not like labs. Most of the dislikes involved some type of work the student had to perform. A few of the reasons were having to do lab write-ups, having to wear goggles, and having to clean up at the end of lab. One student wrote the worst part about labs is "to do all of the writing, the data, the conclusion, and especially the analysis 'cause those are the hardest parts..." Yet, the same student finished the comment with "...but I learn from that."

Students listed many reasons why they liked labs including: working in-groups, getting to eat food, and doing hands-on activities. The following lists more specific student comments:

- The best part is being able to eat the food.
- They are more fun than taking notes and listening to lectures.
- The best part is the experiment itself. I think it is neat to see how different things react with others.
- The best part about labs is the hands-on contact. You get to do things on your own and see the experiments yourself.
- The best part about labs is that you get to see things first hand. By doing this it helps you to better understand the concept that you are trying to learn.
- The best part is when you turn in your write-up because it makes me feel as if I've accomplished something.
- The best part about labs is that through them you learn very easily. More labs = more learning.
- Being able to burn food and make food. The fun of playing with stuff and still learning chemistry.

DISCUSSION

I. Effectiveness

The use of household materials in experiments was effective in helping students learn chemistry. The experiments maintained student interest and the food at the end of an experiment provided an incentive for students to complete the lab on time. I feel that the experiments were a success and I plan on using all of these experiments again in future years.

By restructuring most of my semester one experiments, I had hoped there would be a carry over to make a difference in future experiments during the second semester. I did notice a change in student behavior during labs and in student lab reports during the second semester. There was a lot less chaos in lab this year compared to past years. Students seemed more focused and ready to figure things out on their own.

This was especially true during the more complicated second semester experiments. For example, during the longest lab of the year, students completed fourteen different chemical reactions and classified them as synthesis, decomposition, single replacement, double replacement, and combustion. In past years during this experiment, students had questions during every single reaction step while experimenting and more questions when they tried to write the correct formulas, observations, and products. This year students had fewer questions during the experiment and worked together to reason out what they saw happen during each reaction. This year I felt the students were less apprehensive about experimenting and in control of their own learning experience. I provided them with the starting information but then I merely became an observer.

Even though students did not like all of the various lab types, I plan on continuing to use all of them again in the future. Each type brought something different to the lab adventure. Students need to experience this variety when exploring science in a hands-on manner. Students liked the cookbook style of labs the best because they did not have to think about what procedure to use. Yet, students did not comment on the analysis portion of these labs, which required them to do more work than the other experimental types. Students ranked the open-ended experimental style the lowest, because they had to think about every part of the lab. Even though this style of lab was less involved experimentally, some students had difficulties with being in control of their own scientific exploration. The only problem I found with the take-home experiments was a few students deciding not to do the lab. Students must continually be encouraged to work on their own, whether at home or at school.

The biggest problem during the experiments was students who were absent. Students were given the opportunity to make up missed assignments, however most students do not do this in a timely fashion. This presents a problem when working with food. Doing a food lab is different than doing a traditional chemical-based lab. With a chemical-based lab students could easily make up a lab after school. However, with some of the food-based labs, the experiment is a one time shot. The main experiment for which this is true is the ice cream lab.

When analyzing the survey results, I question the effectiveness of the student opinion survey. The results seem to be a little more vague than I had anticipated. The survey that proved to be more interesting to me was the student retention and association survey. Unfortunately, some students did not make much effort to fill out the survey completely, while other students went into great detail about what we used to do each experiment. Over time student memory declined, but when given both the concept and the material students seemed to maintain their knowledge. Overall, I was very pleased with what they could remember.

II. Improvements

There are two areas of improvement with the experiments and with future experiments. A few minor improvements can be made to some of the experiments in the lab manual. These include: Lab 3: Density Dilemma, Unit 1 Take-Home Lab on Solutions, Lab 4: Separation, Lab 6: Powder Potential, and Lab 11: How thick is Aluminum Foil? Most of these changes were simple improvements and mentioned in the *Experimental Results and Discussion* section. The only experiment that needs major revision is Lab 9: Formulas for Smarties®. I feel that it can be more effective by choosing a candy that allows for empirical formulas to emerge.

In the future, I hope to integrate more household materials and food into experiments for second semester. At the end of the school year students could truly use some motivation in the classroom. I also plan to integrate more experiments that use all three lab styles.

III. Conclusion

Food based experiments have been a motivation for learning chemistry for my students. The application of chemistry to every day materials helps all levels of students understand the concepts better. Students could easily see the relationships between chemistry and consumer products. This year I did not get asked by students, "How does this relate to every day life?" Instead the question I heard was: "When are we going to do another food based lab?"

One student comment that really took me off guard was in response to the best part of labs. The student wrote, "The best part is working with things that we don't use every day, for example Bunsen burners." I was so focused on applying every concept to every day materials that I forgot students also enjoy new things related just to chemistry. Some of the experiments in my lab book do use common chemistry equipment, but I must remember experiments should have a balance of both traditional chemistry materials and household materials. Students benefit from experiencing both kinds of experiments.

Science is the basis for solving real world problems. One should not be surprised then by using real world materials to explore science. I believe that students had fun doing these experiments while learning science. Knowing that I was responsible for helping students enjoy learning is what makes teaching worthwhile. I hope that other teachers may also bring as much joy to their students by bringing science home and using materials that students can sink their teeth into.

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Potchen, James. (2000, May). Virtual imaging of living humans and performance evaluation in observers. Frontiers in science workshop, Michigan State University, East Lansing, MI.

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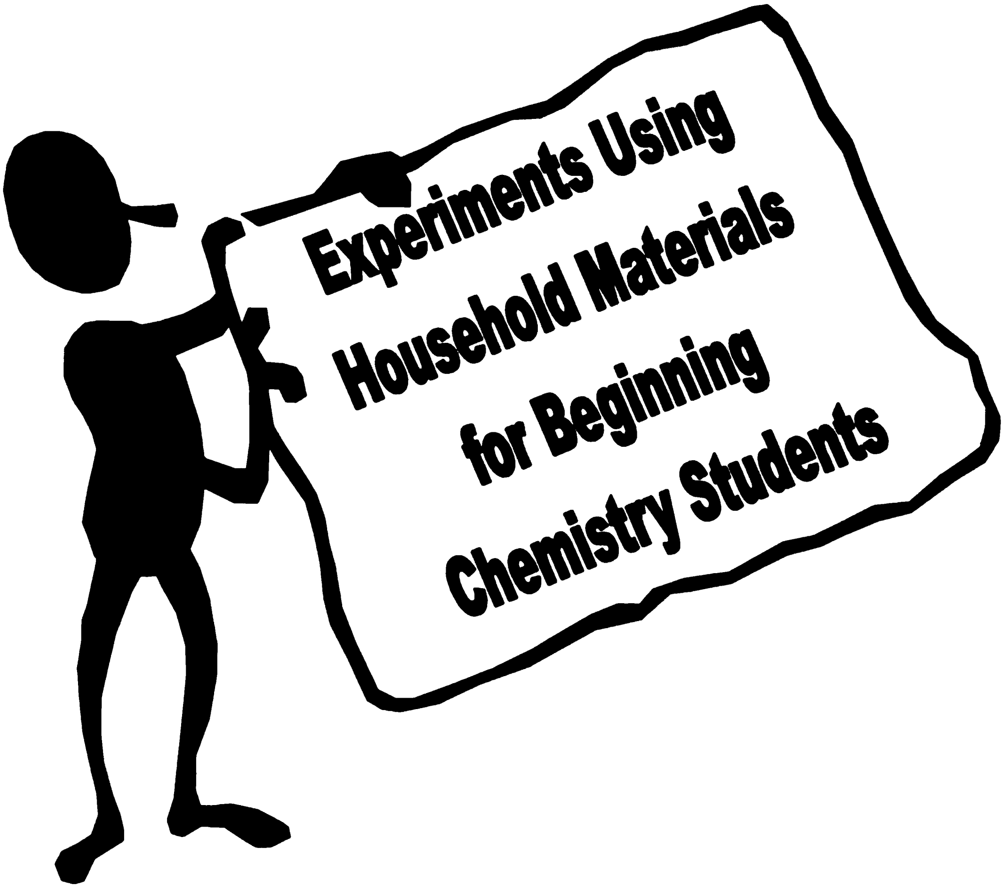
Sumrall, William J. & Brown, Fred W. (1991). Consumer chemistry in the classroom. The Science Teacher, 58(4), 29-31.

Telewski, Frank W. (1999, September). Botanical gardens and arboreta: The living museums. Frontiers in science workshop, Michigan State University, East Lansing, MI.

APPENDICES

APPENDIX A



Developed by
Deborah Pudell
Laker High School

APPENDIX A1

Lab 1: Observation Skills: Peanut Possibilities

Purpose
To introduce students to the detailed observation skills needed while doing an experiment and be able to classify observations as quantitative and qualitative.

Materials
Peanut (in the shell) String Ruler

Procedure/Data
Part 1: With your partner collect a peanut, string, and ruler. Make at least 15 observations regarding your peanut. Remember you have a string and ruler to aid in your analysis. You want to make enough distinctive observations that anyone could find your peanut. A few observation rules: do not mark or taste your peanut, do not give your peanut human descriptions (i.e. your peanut is not happy or sad). Classify your observations as quantitative or qualitative in the chart below. You have 15 minutes to make these observations.

Quantitative	Qualitative

Part 2: Place all of the peanuts in a pile on the front table. Trade your observation lab sheet with another pair of students and try to find their peanut from the pile. If you think you have found their peanut check with the group. You have 10 minutes to find the peanut.

Conclusion

1. Were you successful in discovering the other students' peanut? ______

2. If yes, why were you successful? If no, why were you unsuccessful?

3. Why do scientists need good observation skills?

Learn (What did you learn from this experiment?)

References:

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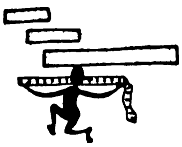
APPENDIX A2



Lab 2: Metric Measurement Madness

Purpose: To introduce students to metric measurements using the proper significant digits and becoming familiar with basic laboratory equipment.

Materials (List all materials you used in lab today. Hint: there are seven)

Procedure

Part I: Measuring Length

A. Compare centimeters to inches.

1. Using your 15 cm metric ruler draw a square that is 1 cm on a side, and draw a square that is 1 inch on a side in the space below.

"centimeter square" "inch square"

2. Measure the side of the "1 inch" square in centimeters. Record the number of centimeters on the line below. (Remember the precision of a metric ruler and units!)

____

B. Compare meters to centimeters.

1. With the help of your partner use the meter stick to find your height to the nearest centimeter.

____

2. Knowing that 100 centimeters equals 1 meter, calculate your height in meters. Watch your significant digits.

____

Part II: Measuring Mass

A. Examine the balance.

1. What is the smallest mass you can measure? __________
2. What is the largest mass you can measure? __________

B. Take a mass on the balance.

1. Determine the mass of one penny dated after 1982. _____
2. Determine the mass of one penny dated prior to 1982.

____

Part III: Measuring Volume

A. Determine the volume of a liquid.
   1. Examine the graduated cylinder. What is the smallest unit of volume you can measure with the cylinder? _________
   2. Carefully fill the graduated cylinder about half full with water. Accurately record the volume of the water. _________

B. Determine the volume of an irregular solid (Petoskey stone).
   1. Gently lower a small Petoskey stone into the graduated cylinder that is still half full of water. Record the new volume of the water. _________
   2. To calculate the volume of the stone, subtract the original volume of water from the volume of the water with the stone. (B1 - A2 = volume) _________

C. Determine the volume of a regular solid.
   1. Measure the dimensions of a Starburst® in the wrapper.
      Length = _______
      Width = _______
      Height = _______
   2. Since volume = length x width x height, what is the volume of your Starburst®? (Don't forget to multiply your units.)
   3. Knowing that $1\ cm^3 = 1\ ml$, calculate the volume of the candy in ml.

Data Evaluation
(Did you have any problems collecting your data? Why or why not?)

Conclusion
(Write a conclusion that summarizes what you did during the experiment.)

Learn (Tell me what you learned during the experiment.)

Questions:

Part I: Length

Which unit (m, dm, cm, mm) is closest to the following size:

a. The thickness of a fingernail? _______
b. the width of a finger? _____________
c. the width of a hand? ______________
d. the length of your leg? ____________

Part II. Mass

2. Was the mass of each penny the same? Explain.

Part III. Volume

3. What kind of error would result if you read the liquid volume at the top of the curve and not the bottom of the curve?

General

4. How is the metric system simpler to use than English units (like inches, feet, and yards)?

References:

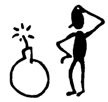
American Chemical Society. (1998). Isotopic Pennies. Chem Com: Chemistry in the community (pp.309-310). Dubuque, IA: Kendall/Hunt Publishing Company.

Measurement and the metric system (Rev 6/91). Unpublished experiment from Chemistry 101, Central Michigan University, Mt. Pleasant, MI.

Williams, Tammy K. (1995). Metric measurement. Science experiments: Chemistry and physics (pp.5-8, 23). USA: Mark Twain Media/Carson-Dellosa Publishing Company, Inc.

APPENDIX A3

Lab 3: Density Dilemma



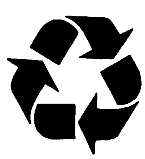
Introduction: Today many people recycle plastics. You may have noticed the recycle codes, numbers, and letters, stamped into various plastics. These codes stand for different plastic compounds with various densities.

Plastic	Abbreviation	Code Number	Density(g/mL)
polyethylene terephthalate	PETE	1	1.39
high density polyethylene	HDPE	2	0.95-0.97
polyvinyl chloride	PVC	3	varies
low density polyethylene	LDPE	4	0.92-0.94
polypropylene	PP	5	0.90-0.91
polystyrene	PS	6	1.05-1.07

When a plastic sample is missing a code, recycling becomes more difficult. How can you solve this missing code dilemma?

You will be given a small strip of unknown plastic to perform an experiment. However, before you enter the lab write your title, purpose, materials, and procedure. Make sure the teacher initials the bottom of your lab page. (Experimental hint: use skills and equipment from Lab #2 Metric Measurement Madness.)

When you have completed your experiment, you should compare your results with other students and determine the percent error as described in the analysis.



Title:

Purpose:

Materials:

Procedure:

Observations:

Data:

Teacher's initials

____

Density Dilemma Group Analysis

Group	Volume ( )	Mass ( )

Data Analysis:

1. Using graph paper, plot the mass of the plastic on the y-axis and the volume of the plastic on the x-axis. Draw a straight line that passes through as many points as possible. Points may fall on either side of the line due to experimental error. (Remember that graphs need a title and labels on both the x and y axis.)

2. Determine the x and y values of two points on the line. Calculate the slope, m, of the line. Remember that slope is the change in y over the change in x. The slope of the line is equal to the average density of the plastic.

3. Determine the density from your own experiment, using the density equation.

4. How does the density from your own trial compare with average density found from the slope of the plot?

5. Using the average density and the list of given plastic densities at the introduction of the experiment, determine the identity of the unknown plastic.

6. Calculate the percent error for the average trial and your own trial based on the actual density value from the chart.

$$\% \text{ error} = \left| \frac{\text{actual density - experimental density}}{\text{actual density}} \right| \times 100$$

7. Describe any sources of experimental error.

Conclusion:

Learn:

References:

Smoot, Robert C. & Smith, Richard G. (1995). A graphical determination of density. Chemistry (pp.799-780). Westerville, OH: Glencoe/McGraw-Hill.

Anderson, Guy E. (1996). A simpler small scale method for the identification of plastics. Journal of Chemical Education, 73(3): A173.

APPENDIX A4

Unit I: Take-Home lab: Density Bottle

You may work alone or as a group.

What you will need: empty 20 oz pop bottle with the label removed
Tape, baby oil or vegetable oil, water
food coloring (optional)

What you have to do:

- Carefully pour cooking oil or baby oil into a clean plastic 20 oz pop bottle until it is half full.
- Carefully add water to the bottle until it is completely full, but not overflowing. You may also add a few drops of food coloring of your choice.
- Screw the cap tightly onto the bottle and seal the cap using tape. Wipe off the outside of the bottle and check to make sure that it doesn't leak.
- Using the provided label stickers, write water on one label and oil on the other and place each one on the appropriate portion of the bottle.

How to get credit for your take-home lab:

1. You must bring the density bottle to school to show the teacher the outcome of your lab, or you may take a picture of yourself with your density bottle (pictures must be turned in with this form to get credit.)
2. List all chemistry students involved with lab and hour. (Ex. Joe Smith–1st)
3. List any other people involved with the lab, including anyone you told about the lab, i.e. parents.
4. How does this experiment relate to chemistry?
5. What did you learn?

Reference: Source unknown.

APPENDIX A5

Lab 4: Separation of Iron, Sugar, and Sand

To begin your experiment, you must first mix 2 grams of iron with 2 grams of sugar and 4 grams of sand. Record the exact mass of each substance in your data table. These values will be your actual masses.

Your goal is to use only the following list of materials to separate the three items. In the end you will have experimental values for each of the masses and be able to calculate the percent errors.

Materials: electronic balance, funnel, ring stand, clamp, filter paper, magnet, 2 beakers, stirring rod, hot plate, drying oven, 1 piece of paper, beaker tongs, water bottle, graduated cylinder, ceramic pad, water (as much as you need), flask

You and your partner must decide on a procedure for the separation and write it down. Before you begin the lab get it checked first by the teacher.

Remember your write-up should include a purpose, materials used, procedure, data analysis, conclusion, and learn section.

References:

Ehrenkranz, David & Mauch, John J. (1990). Micro-mixture separation. <u>Chemistry in microscale</u> (pp.35-36). Dubuque, IA: Kendall/Hunt Publishing Co.

Kotas, Ann. (1994). [Separation lab]. Unpublished experiment.

APPENDIX A6

Lab 5: Properties of Solutions: Ice Cream Depression

Purpose: To study the colloid properties of a mixture combined with freezing point depression.

Part I: Materials

- 1 quart size zip lock freezer bag
- 2 tablespoons of powdered coffee creamer
- ¼ cup granular sugar
- ½ teaspoon vanilla
- 1 cup of milk

Procedure

With your partner rotate through the stations and fill your zip lock bag with all of the ingredients. Securely close your zip lock bag and carefully mix the ingredients.

Part II: Materials

- 1 gallon size zip lock freezer bag
- 4 cups of ice
- ½ cup of salt

Procedure

Record the temperature of the pure ice in the cooler. Next, obtain a gallon size zip lock bag that is half full of ice and contains ½ cup of salt. Place your sealed smaller bag inside of the larger bag and seal. Carefully shake or flip the bag every minute for five minutes.

Carefully open the larger bag to measure the temperature of the ice and salt mixture (outer bag only) and record your reading. Again, make sure your larger bag is resealed and continue mixing and flipping the bag every 30 seconds for five more minutes. Once the ice cream is firm you may stop.

Take a final temperature reading of the ice salt solution and record. You may now remove your ice cream, reseal the large zip lock and return it to the cooler.

Grab a cup, spoon, and some chocolate syrup and share your experiment with your partner.

General Observations:

Data

	Temperature Results
Pure ice	______________
Ice & salt, 5 min	______________
Ice & salt, 10 min	______________

Data Analysis

1. Is it necessary to add salt to the ice to make ice cream? Why?

2. Why does the salt melt the ice?

3. Is ice cream homogeneous or heterogeneous? Explain.

4. What allows the milk solution/ice cream to change state?

Conclusion

Learn

References:

Mehas, Kay Y & Rodgers, Sharon L. (1997). Salt and homemade ice cream. Food science [supplemental experiments] (pp.116-117) Peoria, IL: Glencoe/McGraw-Hill.

Ebrahimi, Kathy. (1996). [Ziploc ice cream]. Unpublished experiment.

APPENDIX A7

Lab 6: Powder Potential: Chemical & Physical Changes

Purpose: To observe the interactions of common household powders with common household liquids and use the observations to identify the unknown components of other mixtures.

Materials
4 vials of pure powders (table salt, cane sugar, starch, baking soda)
3 bottles of liquids (deionized water, vinegar, iodine)
Unknown mixture powder, Pixy Stix®, powdered sugar, baking powder
2 well plates (4x3 wells), wooden splints, micro-spatulas, hand magnifier

Procedure/Data
Part I: Place your well plate so that you have three wells across and four wells down. In the first row (across), use a micro-spatula to place a BB size or smaller sample of table salt in each of the three wells. Do the same process for the second row with the cane sugar, the third row with the starch, and the fourth row with the baking soda.

Next add five drops of distilled water to each of the four wells in the first column (down). Observe and record your observations for each well in the data table. Use the same procedure for the second column with the vinegar and the third column with the iodine solution. Don't forget to record your observations as you go along.

Analysis: Classify each of your observations in the table by placing "C" for chemical change and "P" for physical change in the box provided.

Part I: **Known Tests**	Deionized Water	C or P	Vinegar	C or P	Iodine Water	C or P
Table Salt						
Cane Sugar						
Starch						
Baking Soda						

<u>Part II:</u> Place your second well plate so that you have three wells across and four wells down. In the first row, use a micro-spatula to place a BB size or smaller sample of Pixy Stix® powder, in each of the three wells. Do the same process for the second row with the powdered sugar, the third row with the baking powder, and the fourth row with the unknown. Also, write down the code letter of the unknown in your chart. This unknown mixture contains one or more of the following: table salt, cane sugar, starch, or baking soda.

Next add five drops of distilled water to each of the four wells in the first column. Observe and record your observations for each well in the data table. Use the same procedure for the second column with the vinegar and the third column with the iodine solution. Don't forget to record your observations as you go along.

Analysis: Classify each of your observations in the table by placing "C" for chemical change and "P" for physical change in the box provided.

<u>Part II:</u> **Unknown Tests**	Deionized Water	C or P	Vinegar	C or P	Iodine Water	C or P
Pixie Stick						
Powdered Sugar						
Baking Powder						
Unknown Mixture						

<u>Part III</u>: In the larger well on your well plate, place eight scoops of the Pixy Stix® and eight scoops of the baking soda. Mix the two powders with the wooden splint. Add 5-10 drops of deionized water. Record your results.

<u>Part III:</u> **Mix Test**	Pixy Stix® + Baking Soda + Deionized Water	Observations:	C or P	

Analysis for Part I

Based on your observations, what chemical change did you observe for the following powder? What liquid was required for this to happen? If a powder did not have a chemical change leave the spaces blank.

Table Salt ______________ with ________________

Cane Sugar ______________ with ________________

Baking Soda ______________ with ________________

Starch ______________ with ________________

Anaysis for Part II

A. What does each unknown powder mixture definitely contain? Circle one or more of the following for each unknown substance:

Pixy Stix®	table salt	cane sugar	baking soda	starch
Powdered sugar	table salt	cane sugar	baking soda	starch
Baking powder	table salt	cane sugar	baking soda	starch
Unknown mixture	table salt	cane sugar	baking soda	starch

B. Are there any powders which may or may not be present in the powder mixtures? Why were these powders hard to determine?

Analysis for Part III:

How do you explain what caused this reaction?

What other powder and liquid had a similar reaction?

Powder__________________ Liquid used __________________

Conclusion

Learn

■■■

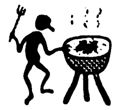
References:

Kitchen powders (Rev 11/92). Unpublished experiment from Chemistry 101, Central Michigan University, Mt. Pleasant, MI.

Hunter, Deb. (1997). [What's the matter with you]. Unpublished experiment.

APPENDIX A8

Lab 7: Junk Food Energy



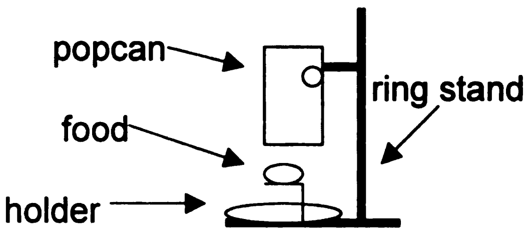
Purpose
To find out how much energy is in your favorite junk food.
Circle your food choice: potato chip, corn chip, or cheese cracker.

Materials: (List all materials you used in lab today)

Procedure
Obtain a sample of _________(food you selected) and a food holder (baby food lid with a paper clip glued to the inside). Record the initial mass of the holder and your food.

Record the weight of an empty pop can with a wooden rod. Measure about 100 ml of cool water in a graduated cylinder and pour the water into the pop can. Reweigh the pop can with the water and determine the exact mass of the water.

Set up the apparatus as shown. The can should be about 1 cm above the food.



Record the initial temperature of the water in the can with a thermometer to +/- 0.1 degree Celsius. Using a match light the food on fire. As soon as the food stops burning, carefully stir the water, and record the final temperature of the water. After the food is cool, measure the final mass of the food and holder.

If time permits repeat the procedure for a second trial.

General Observations during experiment:

Table 1: Collected Energy Data

	Trial 1	Trial 2
Initial mass of food and holder		
Final mass of food and holder		
(1) Mass of burned food		
Mass of can with 100mL water		
Mass of empty can		
(2) Mass of water in can		
Final temperature of water		
Initial temperature of water		
(3) Temperature change		
(4) Heat, q in kJ		
(5) Energy content in kJ/g		
(6) Energy content in Cal/g		
(7) Actual energy content in Cal/g		
(8) Percent Error		

<u>Data Evaluation</u>

The following steps are listed to aid you in your calculations. All calculations and results can be shown in the data table above.

1. Determine the mass of food sample burned.
2. Determine the mass of water heated in the can.
3. Calculate the temperature change in the water.

4. Calculate the heat absorbed by the water, using the equation $q = mTC_p$. Remember $C_p = 4.18$ J/(g·C), m= mass of water, and T = temperature change of the water. Convert your answer to kJ.
5. Calculate the energy content of your food sample. (Assume the energy absorbed by the water is equal to the energy your food released.) energy content = energy(4) /mass of food burned(1).
6. Remember food energy equals heat and is expressed in Calories. One Calorie equals 4.18 kJ. Calculate the Calories per gram sample of your food.
7. Determine the actual Calorie per gram value for your sample.

Table 2: Consumer Package Energy Values

	Energy(Calories)	Mass(grams)
Cheese Nips®	150	30.0
Fritos® Brand Corn Chips	200	35.4
Ruffles® Brand Potato Chips	160	28.3

8. Determine the percent error of your results.
9. Explain your error. Give two specific sources for error.

10. Could the apparatus used in this lab be used to test the energy content for all foods? Explain your answer.

Conclusion

Learn

References:

Holmquist, Dan D. & Volz, Donald L. (1994). Energy content of foods. Chemistry with computers, (pp.16-1 to 16-4) USA: Vernier Software.

American Chemical Society. (1998). Food energy in a peanut. Chem Com: Chemistry in the community (pp. 239-242). Dubuque, IA: Kendall/Hunt Publishing Company.

APPENDIX A9

Unit 2: Take-Home Lab: Solutions

You may work alone or as a group. You may choose **one** of the two lab options and answer the appropriate questions for credit for the take-home lab. Answer the questions as you do the experiment.

- <u>Option 1: Sweetened Tea</u>

  What you will need:

  tea bag (or instant tea), ice cubes, water, sugar, spoon, glass, cup that can be microwaved, microwave

  What you have to do:

1. Make a glass of iced tea and remove the ice (1 cup of liquid will do).
   Is this a homogeneous or heterogeneous mixture?____________
   Record observations:

2. Add a spoon of sugar and stir. Add sugar and stir until some undissolved sugar remains on the bottom of your glass.
   Is this a homogeneous or heterogeneous mixture? ___________
   What type of solution have you created? ______________________
   (supersaturated, saturated, or unsaturated)
   Record observations:

3. Transfer the mixture to a microwavable cup. Be sure to transfer the sugar on the bottom of the glass. Microwave the cup for 1 minute and stir.
   Is this a homogeneous or heterogeneous mixture? ___________
   What type of solution have you created? ______________________
   (supersaturated, saturated, or unsaturated)
   What happens to the solubility of the sugar as the temperature of the tea is increased?_________________________
   Record observations:

4. Be sure to clean up after you are done!

Additional questions...

A. List any other people involved with the lab, including anyone you told about the lab, i.e. parents, friends

B. How does this experiment relate to chemistry?

C. What did you learn?

➢ Option 2: Fudge Factor

What you will need: (or any other favorite fudge recipe)

2 cups sugar
¾ cup milk
2 one ounce squares of unsweetened chocolate
1 teaspoon corn syrup
2 tablespoons butter or margarine
1 teaspoon vanilla

What you have to do:

1. Butter sides of a 2-quart saucepan. In the pan, combine the sugar, milk, chocolate, and corn syrup. Heat and stir over medium heat, until the sugar dissolves and the mixture comes to a boil.
   Is this a homogeneous or heterogeneous mixture? ___________
   What type of solution have you created? ____________________
   (supersaturated, saturated, or unsaturated)
   Record observations:

2. Continue to cook until a "soft-ball" stage around 234 degrees F. Stir only if necessary.
   (Note: Milk is a solution in which water is the solvent.)
   When you add sugar to milk, the boiling point ___________.
   (increases, decrease, stays the same)
   This is known as boiling point ________________.

3. Remove from heat and add butter and cool to luke warm without stirring
   This cool time is to allow for crystallization or ________________.
   What type of solution have you created? ____________________
   (supersaturated, saturated, or unsaturated)
   Record observations:

4. Add vanilla and beat vigorously until the fudge becomes very thick and starts to loose its gloss. Quickly spread into a shallow dish.
5. Be sure to clean up after you are done!

Additional questions...

A. List any other people involved with the lab, including anyone you told about the lab, i.e. parents, friends

B. How does this experiment relate to chemistry?

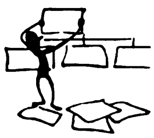
C. What did you learn?

References:

Mackenzie, Norma N. [Old-time fudge an at home lab]. Unpublished experiment.

Smoot, Robert C. & Smith, Richard G. (1995). Sweetened tea. Chemistry (pp. 52-53). Westerville, OH: Glencoe/McGraw-Hill.

APPENDIX A10



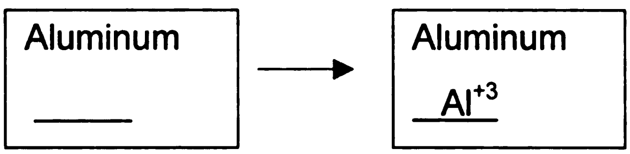
Lab 8: Chemical Formulas

Purpose: To combine various ions to create chemical formulas.

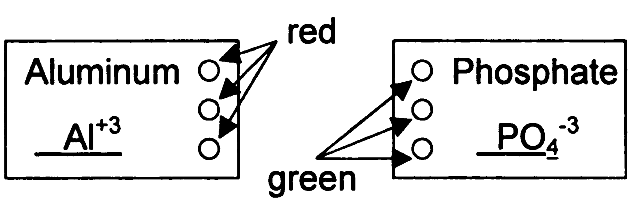
Materials: 2 Sheets of paper that contain various ions in a grid.
1 cup with red and green plain m&m's® candies.
(Do not eat any candy until you have completed the lab!)

Procedure

Find all of the ion cards that say aluminum. Write the symbol and charge for aluminum on the space below the card. Do the same for all other ion cards. Check your completed sheet with your partner's completed sheet.



Carefully cut out all of the ions from the gridded paper to create ion cards. Once the cards are complete you are ready to start creating formulas. Stack similar ion cards together. Each positive charge will be represented by a red m&m's® and each negative charge will be represented by a green m&m's®. For example, to make aluminum phosphate, you would need an aluminum ion card and a phosphate ion card. The aluminum ion card would have three red m&m's ®(+3 charge), and the phosphate ion card would have three green m&m's ®(-3 charge).



All formulas on this lab have a neutral charge. Therefore, every red candy must be matched with a green candy from the other card. Since aluminum phosphate has one card for each ion, the formula is $AlPO_4$.

If the candies are not equal, other cards of the same ion must be added until equal candies are obtained. The number of each card used becomes the subscript for that ion. Also, if a polyatomic ion has more than one card, place parenthesis around the ion before using a subscript.

Data:	Compound	Formula
Example:	aluminum phosphate	$AlPO_4$
1)	sodium chloride	______________
2)	ammonium hydroxide	______________
3)	calcium sulfate	______________
4)	magnesium nitrate	______________
5)	zinc bromide	______________
6)	mercury (II) oxide	______________
7)	aluminum sulfate	______________
8)	silver nitrate	______________
9)	barium hydroxide	______________
10)	potassium sulfide	______________
11)	iron (II) sulfate	______________
12)	copper (II) carbonate	______________
13)	calcium acetate	______________
14)	iron (III) sulfate	______________
15)	calcium phosphate	______________
16)	zinc sulfide	______________
17)	ammonium carbonate	______________
18)	potassium oxide	______________
19)	iron (III) chloride	______________
20)	aluminum oxide	______________

Data Analysis

Do you believe that using the m&m's® helped you to write the formulas for compounds? Explain.

Conclusion

Learn

References:

Smoot, Robert C. & Smith, Richard G. (1995). Formulas and oxidation numbers. Chemistry (pp. 806-807). Westerville, OH: Glencoe/McGraw-Hill.

Tzimopoulos, Nicholas D., Metcalfe, H. Clark, Williams, John E., & Castka, Joseph F. (1990). Worksheet VI: Quizzes on formula writing and ions and their charge(s). Modern chemistry teacher's resource binder (pp. TW14). Austin TX: Holt, Rinehart, and Winston, Inc.

Aluminum ______	Aluminum ______	Ammonium ______	Ammonium ______	Acetate ______
Acetate ______	Barium ______	Bromide ______	Bromide ______	Calcium ______
Calcium ______	Calcium ______	Carbonate ______	Chloride ______	Chloride ______
Chloride ______	Copper (II) ______	Hydroxide ______	Hydroxide ______	Hydroxide ______
Iron (II) ______	Iron (III) ______	Iron (III) ______	Magnesium ______	Mercury (II) ______
Nitrate ______	Nitrate ______	Oxide ______	Oxide ______	Oxide ______
Phosphate ______	Phosphate ______	Potassium ______	Potassium ______	Sulfide ______
Sulfide ______	Sulfate ______	Sulfate ______	Sulfate ______	Silver ______
Zinc ______	Sodium ______			

APPENDIX A11

Lab 9: Formulas for Smarties®

Purpose:
To determine all of the chemical formulas found in a package of Smarties.

Materials: 1 package of Smarties® per person

Procedure:
Get into a group of at least four people.
Each person will count the number of each color (atom of an element) and write a chemical formula for his or her Smartie compound. After everyone is complete, switch until you have all of the compounds in your group. Complete the chart below as data is collected.

Do NOT open any package until the activity is over.

Smarties element symbols:

White = W	Yellow = Y	Pink = P	Orange = O
Green = G	Lilac (light purple) = L		

Data:

Package Number	Number of Each Atom & Element	Chemical Formula (Molecular Formula)	Empirical Formula
Example	2 W, 1 Y, 1 P, 3 O	W_2YPO_3	W_2YPO_3
1.			
2.			
3.			
4.			

Data Analysis:

1. Did each person have the same compound? ______
2. How could you tell?

3. Did each compound have the same formula?

4. Did some compounds have the same elements in them?_______

5. Were the elements in the same ratio or different ratio?

____

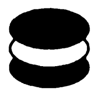
Conclusion:

Learn:

Reference:

Hensley, Lynn. (1998, March). Using Candy to Teach Chemistry. Annual Conference for Michigan Science Teachers Association.

APPENDIX A12

Lab 10: Percent of an Oreo®

Is there really extra cream in a double stuffed Oreo® cookie? Now is the time to put your percent composition skills to work and figure out how to solve this problem. Here are some materials you can use:

- 1 regular Oreo® cookie
- 1 double stuffed Oreo® cookie
- 1 balance (do <u>not</u> put cookies directly on the balance)
- 1 plastic spoon
- 1 piece of toweling

The procedure is up to you, just remember to be specific.

oooooooooooooooooooooooooooooooooooooooooooooooooooooo

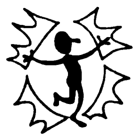
A formal lab write up is required.
Please include the following in your report:

- Title
- Purpose
- Materials
- Procedure & General Observations
- Data & Analysis: Collected masses from both cookies (cream, wafer and total cookie mass)
  - Calculations, include % composition of cream and % compostion of wafer for both cookies.
  - Include sources of error
- Conclusion: Be sure to answer the question:
  - Does a double stuffed Oreo have twice the cream of a regular Oreo®? Support your answer with your results.
- Learn

Reference:

Decker, Luann. (1998). Stoichiometry unit project. Unpublished master defense, Michigan State University, East Lansing, MI.

APPENDIX A13



Lab 11: How Thick is Aluminum Foil?

How many centimeters thick is the aluminum foil surrounding your miniature Reese's® peanut butter cup®? How many atoms thick is this? The small size of an atom may give you a clue as to the tremendous number of atoms that are actually in a sample of matter that we can measure.

Purpose

To relate the size of an atom to the thickness of a piece of aluminum foil surrounding a piece of candy.

Materials

- aluminum foil or candy wrapper
- string
- balance
- aluminum block or cylinder
- ruler
- water
- 10 mL graduated cylinder

Procedure

1. Mass the block or cylinder of aluminum metal. Record the mass in grams in the following data table.
2. Fill a 10 ml graduated cylinder with about 6-ml of water and record the exact volume to +/- 0.1 ml.
3. Tie a string to the aluminum block or cylinder and lower it into the water in the graduated cylinder until it is completely immersed. Record the new volume of water.
4. Compute and record the volume of the aluminum.
5. Find the mass of a piece of aluminum foil.
6. Measure and record the length and width of the foil to +/- 0.1 cm.

Table: Collected Aluminum Data

A. Mass of piece of aluminum	
B. Volume of water in cylinder	
C. Volume of water plus aluminum	
D. Volume of piece of aluminum	
E. Mass of aluminum foil	
F. Length of aluminum foil	
G. Width of aluminum foil	

Data & Analysis (show all work)

1. What was the purpose of the aluminum block or cylinder?

2. Determine the density of the aluminum block.
   Density = Mass / Volume

3. Find the volume of the aluminum foil in cubic centimeters.
   Volume = Mass/ Density

4. Find the height (thickness) of the foil in centimeters.
   Volume = l x w x h

5. One aluminum atom is 2.5×10^{-8} cm thick.
   Find the thickness of the foil in atoms.
   Number of atoms thick = height / 2.5×10^{-8} cm

6. Compute the number of moles in the TOTAL sample of aluminum foil.

7. Compute the number of atoms in the TOTAL sample of aluminum foil.

8. If the world had 5.6×10^{9} people, how many atoms of aluminum could you distribute to each person from your sample of aluminum foil?

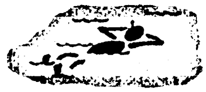
Conclusion

Learn

Reference:

Smoot, Robert C. & Smith, Richard G. (1995). Aluminum foil thickness. Chemistry (pp. 809-810). Westerville, OH: Glencoe/McGraw-Hill.

APPENDIX A14



Lab 12: Water of Crystallization

<u>Overview:</u> Many ionic compounds contain water in their crystal structure. The water occurs in a fixed ratio with ionic components of the crystal and is called the water of hydration. This water may be driven off with heat. Our goal is to determine the empirical formula of the hydrate magnesium sulfate. You may know this as Epsom Salt.

<u>Materials</u>

balance	evaporating dish	Bunsen burner	tongs
ring stand	spatula	iron ring	
Epsom Salt	clay triangle	ceramic pad	

<u>Procedure</u>

1. Make sure your lab equipment is clean.
2. Heat the evaporating dish on top of the clay triangle for about a minute, then move it to a ceramic pad to cool for about five minutes.
3. Once cool, weigh the evaporating dish and record the mass in a data table.
4. Place about 1-2 grams of Epsom Salt ($MgSO_4 \cdot nH_20$) into the evaporating dish and weigh the exact mass of the wet sample.
5. Heat the sample gently for about 5 minutes. Watch the sample carefully and record any qualitative observations. If you hear crackling lower your flame.
6. Heat the sample an additional 3-5 minutes on maximum heat.
7. Cool the dish on the ceramic pad for at least 5 minutes.
8. Once cool, weigh the dry sample and dish.
9. If time permits, heat the dish a second time for 2-5 minutes on maximum heat and repeat steps 7 and 8.
10. Dispose of the dry sample in a designated waste jar and clean up your station.

Note #1: You will be responsible for a full formal lab write-up in ink or typed. (Title, Purpose, Materials, Procedure, Data Analysis, Conclusion, and Learn)

Note #2 : You will need to design a data table to collect your experimental data. It must include: mass of evaporating dish, mass of dish & wet sample, mass of dish & dry sample. You may also want to include your general observations here. Don't forget a title to your table.

Note#3: The following questions should help you with your calculations to arrive at your conclusion. This information should be placed in the data analysis section of your write-up along with any errors made during the experiment. You may wish to summarize the calculated information in a second data table. Please attach this lab sheet to your final report.

<u>Calculations: (show all work)</u>

1. Calculate the mass of the anhydrous magnesium sulfate (dry sample).

2. Calculate the moles of anhydrous magnesium sulfate.

3. Calculate the mass of water driven off from the sulfate.
   (wet sample –dry sample)

4. Calculate the moles of water driven off from the sulfate.

5. The reaction for the experiment is

   $$MgSO_4 \cdot nH_20 \longrightarrow MgSO_4 \quad + \quad nH_20$$

   Find the value of "n" by taking the mole ratio of water to $MgSO_4$.

6. Determine the percent error of your results. You may find the actual value by looking at the Epsom Salt package.

7. What were your sources of error? How could you improve your results?

<u>Conclusion:</u>

<u>Learn:</u>

References:

Dougan, David. (1994). Percentage of hydration. 40 Low-waste, low-risk chemistry labs (p.53-54). J. Weston Walch Publisher.

Tzimopoulos, Nicholas D., Metcalfe, H. Clark, Williams, John E., & Castka, Joseph F. (1990). Water of crystallization and empirical formula of a hydrate. Modern chemistry laboratory experiments (pp.151-154). Austin TX: Holt, Rinehart, and Winston, Inc.

APPENDIX A15

Unit 3: Take-Home Lab: Molarity

Now that you are familiar with the mole concept and know how to calculate the concentrations of solutions, the time has come for you to examine your favorite beverages. You may work alone or as a group.

What you will need:

- a packet of Kool-Aid® (the flavor is up to you)
- water
- sugar
- container
- unit conversion chart
- can or bottle of pop

What you have to do:

- Carefully make yourself a pitcher of Kool-Aid® according to the directions on the packet. While you are drinking your beverage, perform the following calculations to determine the concentration of sugar in your solution.

Analysis of your Kool-Aid® :

1. Calculate the moles of sugar in your Kool-Aid® .
   (1 cup of sugar = 102 g sugar)
   (Use $C_{12}H_{22}0_{11}$ for the formula of table sugar)

2. Calculate the liters of Kool-Aid® .
   (Look up the conversion for _____quarts to ______ liters.)

3. Calculate the Molarity of sugar in your Kool-Aid® .

Analysis of your pop:

4. Look at the nutrition information on your container of pop. Find the number of grams of sugar per serving and then calculate the moles of sugar in your pop. (Assume that pop is made in the same manner as the Kool-Aid®.)

5. Calculate the liters of pop per serving of sugar.

6. Calculate the Molarity of sugar in your pop.

Comparing the two solutions:

7. What solution had the highest concentration of sugar? ________

8. Did this surprise you? Explain.

Additional questions:

A. List any other people involved with the lab, including anyone you told about the lab, i.e. parents.

B. How does this experiment relate to chemistry?

C. What did you learn?

References: Self designed idea.

APPENDIX B

Lab Write-up

Experimental write-ups should be organized in a logical order. Before you begin the experiment you must have a purpose prepared. Some experiments may also require a procedure to be written ahead of time. The general format of a write-up should be as follows:

Title: Each lab should be titled appropriately.

Purpose: Short sentence that gives the reason for doing the lab. Usually, starts with the preposition "To....."

Materials: List of all items and apparatus used during experiment.

Procedure: Summary of steps taken while experimenting. Data collected during the experiment should be in data tables. This must always be neat and clear. Use a ruler to make your data tables. Any general observations made can also be included in this section

Data Evaluation: Answer the question: Are the data you collected accurate and/or precise? If there was a problem obtaining the data explain it. Also, graphs and any calculations are included in this part.

Conclusion/Final Analysis: Answer the question: Did you achieve the purpose in this experiment? Why or why not? Explain why your data was good or bad. Include any calculation results and percent error.

Learn: Tell me what you learned during this experiment in a few sentences. Example: How did the experiment help you understand what we did in class?

APPENDIX C

Unit Tests

APPENDIX C1

Unit 1 Test: Chemistry and Measurement

I. Match the following terms to the correct definition. Put the appropriate letter of the definition in front of the term.

1. ______ accuracy	A.	mass per unit volume
2. ______ scientific notation	B.	logical solution to problems;order in nature
3. ______ precision	C.	whatever occupies space and has mass
4. ______ density	D.	plausible explanation of nature; why
5. ______ volume	E.	number in form A x 10^n
6. ______ weight	F.	amount of space and object occupies
7. ______ quantitative	G.	closeness to true value
8. ______ mass	H.	amount of matter in a material
9. ______ qualitative	I.	closeness of values to each other
10. ______ matter	J.	describes quality of an item
11. ______ experiment	K.	# of digits reported for value
12. ______ scientific method	L.	measure of force of gravity between objects
13. ______ theory	M.	describes quantity of an item; measurement
14. ______ significant figures	N.	controlled observation; repeatable

15. Define: chemistry and list three branches of chemistry*

* For an extra point list all of the <u>six</u> chemistry branches

II. Circle the appropriate classification to the following observation.

16. The candle is 4.5 cm tall.	quantitative	qualitative
17. The candle is white.	quantitative	qualitative
18. Smoke came from the candle.	quantitative	qualitative
19. The diameter of the candle is 2.5 cm.	quantitative	qualitative
20. The candle smelled like vanilla.	quantitative	qualitative

III. True or False.

21. Hold your nose directly over a solution and take a big whiff to smell a solution. __________

22. Report all accidents to Miss Pudell even the minor ones. __________

23. Always taste every chemical you use in the lab to make sure it is fresh. __________

24. Handle chemicals carefully. DO NOT touch chemicals. __________

25. Never return chemicals to the original containers. __________

26. Never wear your safety goggles in the laboratory. __________

27. If a chemical is spilled put a piece of paper on it and walk away. __________

28. DO NOT MESS AROUND IN THE LAB! __________

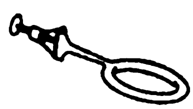
29. Always leave your work area as messy as possible and be sure to leave the gas on for the next class. __________

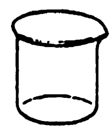
30. Know the location of all safety equipment. __________

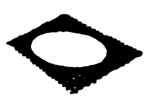
31. Handle chemicals carefully at all times. __________

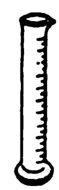
32. Always discard garbage and matches down the sink and not in the trash can. __________

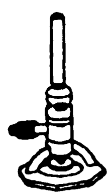
IV. Write the name for the following symbols and apparatus.

33. ______________ 

34. ______________ 

35. ______________ 

36. ______________ 

37. ______________ 

38. ______________ 

V. Short answer.

39. Name the two types of measurement systems used in the U.S.

40. Describe in detail how to find the density of an object.

41. List two safety equipment devices in the room. For each one describe: where it is located and how to use it.

Equipment	Where is it?	How do you use it?
1.		
2.		

VI. Problems (Show your work and use proper sig figs!)

42. Part A. A graduated cylinder weighed 45.1 g. Added to the cylinder was 23.0 g water and 1.63 g of sodium bromide. What was the total mass of the cylinder and the solution? Express the answer to the correct number of sig figs.

ANSWER: ___________

How many sig figs should be in your answer? ___________

Part B. Multiply your answer from A by 5.1 g and record the answer with the correct number of sig figs.

ANSWER: ___________

How many sig figs should be in your answer? ___________

43. Fill in the following equivalency statements and in the box behind the statement write if it is a length, mass,volume or density unit.

_____ km = _____ m [ ]　　_____ in = _____ cm [ ]

_____ mL = _____ L [ ]　　_____ cm^3 = _____ mL [ ]

44. Write the following in Scientific notation:

569,000,000 ______________ 0.0000603 ______________

45. The Star of India sapphire weighs 563 carats. A carat equals 200 mg. What is the weight of the gemstone in grams? Use dimensional analysis and show all work please.

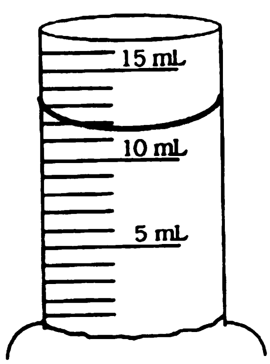
46. Convert: 144 ft to dm

47. The density of mercury is 13.5 g/mL. Write the density equation and answer the following questions.

(a) What is the mass of 14.20 mL of mercury?

(b) What is the volume of 28.0 g of mercury?

48. Measure the solution below to the greatest precision.



Answer:_________

APPENDIX C2

Unit 2 Test: Matter, Solutions, and Energy

I. Match the following terms to the correct definition. Put the appropriate letter of the definition in front of the term. (2 points each)

1. ______ matter	A. specific kind of matter
2. ______ solute	B. energy unit
3. ______ element	C. two or more kinds of material separated physically
4. ______ heterogeneous	D. a homogeneous mixture; two parts
5. ______ mixture	E. same kind of atom
6. ______ compound	F. does not depend on amount of matter, ex density
7. ______ exothermic	G. mixture composed of different parts
8. ______ heat	H. anything that occupies space & has mass
9. ______ extensive	I. same throughout; material contains similar materials
10. ______ homogeneous	J. material that does dissolving in solution, ex H_2O
11. ______ solution	K. dissolved material in a solution
12. ______ endothermic	L. transfer of energy as a result of ΔT; symbol q
13. ______ chemical symbol	M. letter(s) to represent an element
14. ______ material	N. absorbed energy in a reaction
15. ______ intensive	O. depends on amount of matter, ex. mass
16. ______ joule	P. released energy in a reaction
17. ______ solvent	Q. more that one different atom chemically combined
18. ______ precipitate	R. solid that separates from a solution

II. Answer the following short answer questions.

19. List and describe the three phases of matter. (3 points)

20. State the difference between a physical property/change and chemical property/change (4 points)

III. Answer the following . . .

21. Classify the following materials as homogeneous or heterogeneous. (6 pts)

a. sugar	homogeneous	heterogeneous
b. granite	homogeneous	heterogeneous
c. air	homogeneous	heterogeneous
d. a penny	homogeneous	heterogeneous
e. table salt	homogeneous	heterogeneous
f. chocolate chip cookie	homogeneous	heterogeneous

22. Circle whether the following is a chemical or physical change. (6 points)

a. dissolving salt in water	chemical	physical
b. alcohol evaporating	chemical	physical
c. rotting egg	chemical	physical
d. chopping wood	chemical	physical
e. melting ice cream	chemical	physical
f. burning gasoline	chemical	physical

23. Write whether the following are compounds, mixtures, solutions, or elements.(6 pts)

a. apple ______________________________

b. sulfur ______________________________

c. paint ______________________________

d. water ______________________________

e. sugar ______________________________

f. Fruitopia ______________________________

24. Write the following symbols (7 points)

a. mercury

b. potassium

c. sodium

d. silver

e. neon

f. fluorine

g. phosphorous

25. Write the following names (6 points)

a. B

b. S

c. Ca

d. Cu

e. N

f. O

IV. Problems

Convert between energy units: 1 calorie = 4.184 joules
1000 calories = 1 Calorie

26. A serving of Frosted Shredded Wheat Cereal contains 190 Calories. How many joules is this? (6 pts)

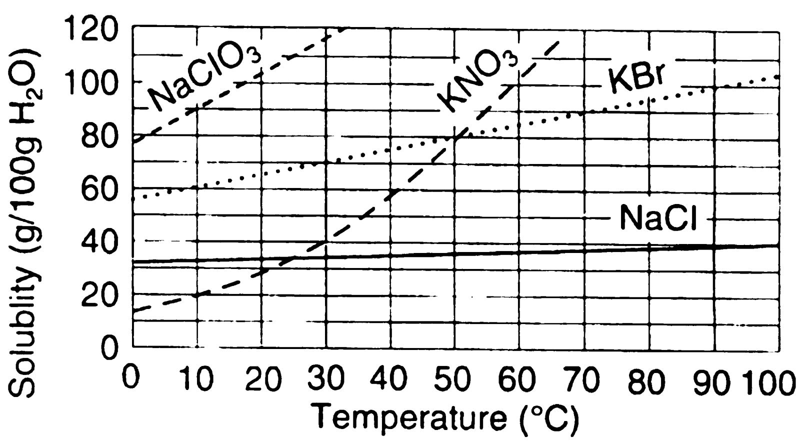
27. How much heat is required to raise the temperature of 235 g of H_2O from 10 °C to 75 °C? (5pt) Cp = 4.184 J/g°C

$q = m \Delta T\ Cp$

28. What is the mass PCl_3 required to produce 12,675 J of heat? The temperature rose from 55.2 °C to 80.2 °C and the specific heat is 0.874 J/g·°C (5 pt)

29. Describe what happens when salt is added to ice. What colligative property does this process represent? (5 pt)

Solubility graph: 5pt



Use the solubility curve above to answer the following questions:

30. Name the two salts that have the same solubility at 25°C.

____________________ ____________________

31. What salt has the least solubility at 0°C? ________________

32. How many grams of KBr are needed to saturate 100 g of water at 70°C?

____

33. At 20°C a solution of 80 g of $NaClO_3$ in 100 g of water is

(saturated, unsaturated, supersaturated).

APPENDIX C3

Unit 3 Test Part A: Chemical Formulas

I. Multiple Choice (2pts each)

______1. The charge on an individual atom is represented by the ________.
a. coefficient
b. subscript
c. formula unit
d. oxidation number

______2. A metal and a nonmetal are named using the ____________ compound rules.
a. ionic
b. molecular
c. polyatomic
d. molecular and ionic

______3. A nonmetal produces a ________ ion.
a. neutral
b. negative
c. positive
d. happy

______4. A metal produces a ________ ion.
a. neutral
b. negative
c. positive
d. happy

______5. For the formula of a compound to be correct, the algebraic addition of the charges on the atoms or ions in the compound must add up to _______.
a. zero
b. a sum one less than the number of elements present
c. a sum one greater than the number of elements present
d. a sum equal to the number of elements present

______6. A shorthand method used to represent one atom of an element is a _____.
a. chemical formula
b. coefficient
c. chemical symbol
d. subscript

______7. Which of the following represents the number of atoms of a given kind in a compound?
a. oxidation number
b. coefficient
c. subscript
d. formula unit

______8. Which of the following is an organic compound?

a. C_2H_2
b. H_2SO_4
c. MgO
d. KNO_3

______9. A compound having six carbon atoms linked in a chain would be named using which of the following prefixes?

a. eth-
b. prop-
c. hept-
d. hex-

______10. An atom that has an electric charge is called a(n) __________.

a. formula unit
b. isotope
c. ion
d. binary compound

______11. The oxidation number of the nitrate ion is ________.

a. +1
b. +2
c. -1
d. -2

______12. Which of the following elements occurs naturally as diatomic molecules?

a. phosphorus
b. sulfur
c. carbon
d. oxygen

______13. How many formula units are represented by $3K_2SO_3$?

a. four
b. three
c. two
d. one

______14. The oxidation number of the ammonium ion is ________.

a. -1
b. +1
c. +2
d. -2

______15. The empirical formula for benzene (C_6H_6) is ________.

a. C_6H_6
b. C_2H_2
c. C_3H_3
d. CH

______16. The simplest formula for a compound (having the smallest whole number ratio) is the

a. molecular formula.
b. empirical formula.
c. structural formula.
d. atomic formula.

II. Answer the following short answer questions.

17. Name the oxidation number of both elements in the following molecules: (1 pt each)

a. PO_2 P________ O__________

b. $MgCl_2$ Mg_______ Cl_________

18. How many atoms of each kind are in $Fe_2(CO_3)_3$? (2pt each)

Fe ____________ C _____________ O _____________

19. How many atoms of each kind are in $5MgCl_2$? (2pt each)

Mg ____________ Cl _____________

20. Name the following compounds: (4 points each)

a. Na_2O

b. AgBr

c. $Fe(NO_3)_3$

d. NH_4F

e. N_2Br_6

21. Write the symbols for the following compounds: (4 pts)

a. nickel(II) phosphate

b. sulfur trioxide

c. magnesium hydroxide

d. calcium oxide

e. tin(IV)chloride

III. Short Answer. (Please answer in complete sentences)

22. Why is the name sulfur aluminide incorrect for the compound Al_2S_3?

23. How do chemical symbols and formulas help scientists to communicate?

APPENDIX C4

Unit 3 Test Part B: The Mole Concept

You must show all work to get full credit. Don't forget units and proper sig figs!

1. How many moles of sulfur are contained in 25.0 g of sulfur? (6 pt)

2. Baking soda ($NaHCO_3$) is an active ingredient in the rising of baked goods. If a certain cake recipe calls for 2.55 g of baking soda, how many formula units does this represent?(Remember formula units are found the same way as molecules) (8 pt)

3. Determine the percent composition of each element in $C_6H_{12}O_6$. (6 pt)

4. What is the empirical formula of a substance composed of 3.05% carbon, 0.26% hydrogen and 96.69 % iodine? (8 pt)

5. What is the concentration(molarity) of a solution that contains 75.3 g of $MgSO_4$ in 5.02 L ? (6pt)

6. What is the molecular weight of $Al_2(SO_4)_3$? (4 pt)

7. Distinguish between molarity and molality as measures of concentration. (2 pt)

APPENDIX D

Surveys

APPENDIX D1

Student Retention Survey

Write the corresponding Chemistry Concept for the labs that contained the following common items:

Common Item	Chemistry Concept
Peanut	____________________
Starburst®, Water, Pennies	____________________
Plastics	____________________
Oil & Water	____________________
Sand, Sugar, Iron	____________________
Ice Cream	____________________
Baking Powder & Vinegar	
Starch & Iodine	____________________
Salt & water	
Cheese Nips®	____________________
Fudge or Tea	____________________
m&m's®	____________________
Smarties®	____________________
Oreo®	____________________
Aluminum Foil	____________________
Epsom Salt	____________________
Kool-Aid®	____________________

APPENDIX D2

Student Association Survey

Write the corresponding Chemistry Concept for the labs that contained the following common items. You may use the word bank down below.

Common Item	Chemistry Concept
Peanut	____________________
Starburst®, Water, Pennies	____________________
Plastics	____________________
Oil & Water	____________________
Sand, Sugar, Iron	____________________
Ice Cream	____________________
Baking Powder & Vinegar	
Starch & Iodine	____________________
Salt & water	
Cheese Nips®	____________________
Fudge or Tea	____________________
m&m's®	____________________
Smarties®	____________________
Oreo®	____________________
Aluminum Foil	____________________
Epsom Salt	____________________
Kool-Aid®	____________________

Observation Skills
Density & Percent Error
Matter Separation
Chemical & Physical Changes
Boiling Point Elevation
Molecular & Empirical Formulas
Avogadro's Number
Molarity
Measurement & Conversion
Density
Freezing Point Depression
Energy
Chemical Formulas & Naming
Percent Composition
Analysis of a Hydrate

APPENDIX D3

Student Opinion Survey

Please respond by circling the number that shows how much you agree with the following statements. Low numbers mean you agree with the statement and high numbers mean you disagree with the statement. Base your answers on this science course only.

1. Chemistry relates to every day materials.
   agree 1 2 3 4 5 disagree
2. Chemistry could be understood better if it relates to every day materials.
   agree 1 2 3 4 5 disagree
3. Chemistry courses should offer lab activities that relate to every day materials.
   agree 1 2 3 4 5 disagree
4. Chemistry courses should offer more lab activities than they do.
   agree 1 2 3 4 5 disagree
5. Lectures and labs in chemistry are connected.
   agree 1 2 3 4 5 disagree
6. Chemistry labs have increased my understanding of how scientists work.
   agree 1 2 3 4 5 disagree
7. Experiments are more work than they are worth.
   agree 1 2 3 4 5 disagree
8. Experiments have increased my interest in science.
   agree 1 2 3 4 5 disagree
9. Experiments have taught me more about chemistry than lectures.
   agree 1 2 3 4 5 disagree
10. Experiments have supplemented my understanding of lecture.
    agree 1 2 3 4 5 disagree
11. The best experiments are open-ended experiments that are of my own design.
    agree 1 2 3 4 5 disagree
12. The best experiments are take-home experiments.
    agree 1 2 3 4 5 disagree
13. The best experiments are very structured and already written out for me to follow.
    agree 1 2 3 4 5 disagree
14. Experimental work should be a part of unit tests.
    agree 1 2 3 4 5 disagree
15. I am more focused on lab work if I know I will be tested over the experiment.
    agree 1 2 3 4 5 disagree
16. I am able to remember chemistry concepts when I have performed an experiment on that concept.
    agree 1 2 3 4 5 disagree

(Mid- and Post-Survey Only)

17. Rank the following from favorite to least favorite (1 most to 3 least)

    Open-ended experiments ______

    Take-home experiments ______

    Cookbook experiments ______

18. Explain your reasons for selecting your favorite and least favorite experimental type.

19. What is the best part about labs?

20. What is the worst part about labs?

21. What was your favorite experiment this semester? Why?

APPENDIX E

Lab Results

APPENDIX E1

Lab 1 Results

(20 points total)

Table 4: Grades for Lab 1: Observation Skills: Peanut Possibilities

3rd Hr.			5th Hr.			6th Hr.		
Student	Score	%	Student	Score	%	Student	Score	%
# 1	18	90 A	#24	19	95 A	#47	20	100 A
# 2	15	75 C	#25	20	100 A	#48	18	90 A
# 3	19	95 A	#26	20	100 A	#49	19	95 A
# 4	19	95 A	#27	18	90 A	#50	20	100 A
# 5	18	90 A	#28	19	95 A	#51	18	90 A
# 6	19	95 A	#29	20	100 A	#52	20	100 A
# 7	20	100 A	#30	20	100 A	#53	18	90 A
# 8	15	75 C	#31	19	95 A	#54	20	100 A
# 9	20	100 A	#32	17	85 B	#55	18	90 A
#10	20	100 A	#33	19	95 A	#56	20	100 A
#11	14	70 C	#34	20	100 A	#57	15	75 C
#12	20	100 A	#35	20	100 A	#58	18	90 A
#13	20	100 A	#35	19	95 A	#59	15	75 C
#14	19	95 A	#37	20	100 A	#60	20	100 A
#15	20	100 A	#38	19	95 A	#61	20	100 A
#16	20	100 A	#39	19	95 A	#62	19	95 A
#17	19	95 A	#40	19	95 A	#63	18	90 A
#18	20	100 A	#41	19	95 A	#64	19	95 A
#19	15	75 C	#42	19	95 A	#65	19	95 A
#20	19	95 A	#43	19	95 A	#66	20	100 A
#21	19	95 A	#44	19	95 A	#67	15	75 C
#22	17	85 B	#45	18	90 A	#68	15	75 C
#23	17	85 B	#46	20	100 A	#69	20	100 A
Ave.	18	92 A	Ave.	19	96 A	Ave.	18	92 A

Grade	3rd Hr.	5th Hr.	6th Hr.
A	17	22	19
B	2	1	0
C	4	0	4
D	0	0	0
F	0	0	0
	23	23	23

	TOTAL	%
A	58	84%
B	3	4%
C	8	12%
D	0	0%
F	0	0%
	69	100%

APPENDIX E2

Lab 2 Results
(40 points total)

Table 5: Grades for Lab 2: Metric Measurement Madness

3rd Hr.			5th Hr.			6th Hr.		
Student	Score	%	Student	Score	%	Student	Score	%
# 1	33	83 B	#24	36	90 A	#47	38	95 A
# 2	32	80 B	#25	35	88 B	#48	33	83 B
# 3	29	73 C	#26	40	100 A	#49	37	93 A
# 4	24	60 D	#27	32	80 B	#50	38	95 A
# 5	35	88 B	#28	36	90 A	#51	35	88 B
# 6	37	93 A	#29	38	95 A	#52	39	98 A
# 7	36	90 A	#30	37	93 A	#53	35	88 B
# 8	33	83 B	#31	35	88 B	#54	35	88 B
# 9	29	73 C	#32	35	88 B	#55	31	78 C
#10	23	58 F	#33	38	95 A	#56	35	88 B
#11	29	73 C	#34	38	95 A	#57	36	90 A
#12	30	75 C	#35	35	88 B	#58	33	83 B
#13	28	70 C	#35	34	85 B	#59	31	78 C
#14	34	85 B	#37	36	90 A	#60	35	88 B
#15	35	88 B	#38	28	70 C	#61	31	78 C
#16	32	80 B	#39	35	88 B	#62	32	80 B
#17	35	88 B	#40	35	88 B	#63	32	80 B
#18	34	85 B	#41	35	88 B	#64	36	90 A
#19	32	80 B	#42	40	100 A	#65	38	95 A
#20	35	88 B	#43	39	98 A	#66	40	100 A
#21	34	85 B	#44	39	98 A	#67	34	85 B
#22	30	75 C	#45	28	70 C	#68	34	85 B
#23	33	83 B	#46	35	88 B	#69	34	85 B
Ave.	32	80 B	Ave.	36	89 A	Ave.	35	87 B

	3rd Hr.	5th Hr.	6th Hr.
A	2	11	8
B	13	10	12
C	6	2	3
D	1	0	0
F	1	0	0
	23	23	23

	TOTAL	%
A	21	30%
B	35	51%
C	11	16%
D	1	1%
F	1	1%
	69	100%

APPENDIX E3

Lab 3 Results

(40 points total)

Table 6: Grades for Lab 3: Density Dilemma

3rd Hr.			5th Hr.			6th Hr.		
Student	Score	%	Student	Score	%	Student	Score	%
# 1	33	83 B	#24	36	90 A	#47	29	73 C
# 2	32	80 B	#25	37	93 A	#48	37	93 A
# 3	34	85 B	#26	36	90 A	#49	32	80 B
# 4	33	83 B	#27	27	68 D	#50	37	93 A
# 5	26	65 D	#28	37	93 A	#51	34	85 B
# 6	35	88 B	#29	33	83 B	#52	38	95 A
# 7	28	70 C	#30	34	85 B	#53	30	75 C
# 8	35	88 B	#31	34	85 B	#54	37	93 A
# 9	34	85 B	#32	0	0 F	#55	34	85 B
#10	32	80 B	#33	36	90 A	#56	37	93 A
#11	28	70 C	#34	33	83 B	#57	34	85 B
#12	35	88 B	#35	31	78 C	#58	35	88 B
#13	30	75 C	#35	33	83 B	#59	36	90 A
#14	34	85 B	#37	35	88 B	#60	35	88 B
#15	29	73 C	#38	33	83 B	#61	36	90 A
#16	32	80 B	#39	0	0 F	#62	30	75 C
#17	31	78 C	#40	35	88 B	#63	36	90 A
#18	34	85 B	#41	34	85 B	#64	35	88 B
#19	34	85 B	#42	36	90 A	#65	32	80 B
#20	28	70 C	#43	35	88 B	#66	38	95 A
#21	31	78 C	#44	36	90 A	#67	34	85 B
#22	34	85 B	#45	29	73 C	#68	36	90 A
#23	35	88 B	#46	34	85 B	#69	36	90 A
Ave.	32	80 B	Ave.	31	78 C	Ave.	35	87 B

Grade	3rd Hr.	5th Hr.	6th Hr.
A	0	7	11
B	15	11	9
C	7	2	3
D	1	1	0
F	0	2	0
	23	23	23

TOTAL		%
A	18	26%
B	35	51%
C	12	17%
D	2	3%
F	2	3%
	69	100%

APPENDIX E4

Unit 1 Take-Home Lab Results

(15 points total)

Table 7: Grades for Unit 1 Take-Home Lab: Density Bottle

3rd Hr. Student	Score	%	5th Hr. Student	Score	%	6th Hr. Student	Score	%
# 1	15	100 A	#24	15	100 A	#47	15	100 A
# 2	15	100 A	#25	15	100 A	#48	15	100 A
# 3	13	87 B	#26	15	100 A	#49	11	73 C
# 4	13	87 B	#27	15	100 A	#50	15	100 A
# 5	15	100 A	#28	0	0 F	#51	13	87 B
# 6	15	100 A	#29	15	100 A	#52	15	100 A
# 7	15	100 A	#30	15	100 A	#53	15	100 A
# 8	13	87 B	#31	15	100 A	#54	13	87 B
# 9	15	100 A	#32	0	0 F	#55	13	87 B
#10	13	87 B	#33	15	100 A	#56	15	100 A
#11	15	100 A	#34	15	100 A	#57	15	100 A
#12	15	100 A	#35	15	100 A	#58	15	100 A
#13	15	100 A	#35	15	100 A	#59	15	100 A
#14	15	100 A	#37	15	100 A	#60	15	100 A
#15	13	87 B	#38	15	100 A	#61	15	100 A
#16	15	100 A	#39	0	0 F	#62	13	87 B
#17	0	0 F	#40	15	100 A	#63	15	100 A
#18	13	87 B	#41	15	100 A	#64	15	100 A
#19	15	100 A	#42	15	100 A	#65	15	100 A
#20	15	100 A	#43	15	100 A	#66	13	87 B
#21	13	87 B	#44	15	100 A	#67	13	87 B
#22	15	100 A	#45	15	100 A	#68	13	87 B
#23	9	60 D	#46	0	0 F	#69	13	87 B
Ave.	13	90 A	Ave.	12	83 B	Ave.	14	94 A

Grade	3rd Hr.	5th Hr.	6th Hr.
A	14	19	14
B	7	0	8
C	0	0	1
D	1	0	0
F	1	4	0
	23	23	23

	TOTAL	%
A	47	68%
B	15	22%
C	1	1%
D	1	1%
F	5	7%
	69	100%

APPENDIX E5

Lab 4 Results

(50 points total)

Table 8: Grades for Lab 4: Separation of Iron, Sugar, and Sand

3rd Hr.			5th Hr.			6th Hr.		
Student	Score	%	Student	Score	%	Student	Score	%
# 1	38	76 C	#24	40	80 B	#47	43	86 B
# 2	38	76 C	#25	45	90 A	#48	25	50 F
# 3	44	88 B	#26	48	96 A	#49	46	92 A
# 4	44	88 B	#27	39	78 C	#50	41	82 B
# 5	38	76 C	#28	43	86 B	#51	0	0 F
# 6	39	78 C	#29	41	82 B	#52	46	92 A
# 7	34	68 D	#30	41	82 B	#53	41	82 B
# 8	43	86 B	#31	44	88 B	#54	43	86 B
# 9	40	80 B	#32	46	92 A	#55	35	70 C
#10	36	72 C	#33	48	96 A	#56	46	92 A
#11	41	82 B	#34	46	92 A	#57	37	74 C
#12	45	90 A	#35	43	86 B	#58	46	92 A
#13	39	78 C	#35	44	88 B	#59	40	80 B
#14	39	78 C	#37	46	92 A	#60	42	84 B
#15	35	70 C	#38	48	96 A	#61	42	84 B
#16	39	78 C	#39	39	78 C	#62	45	90 A
#17	41	82 B	#40	36	72 C	#63	41	82 B
#18	45	90 A	#41	37	74 C	#64	41	82 B
#19	45	90 A	#42	41	82 B	#65	36	72 C
#20	38	76 C	#43	47	94 A	#66	46	92 A
#21	43	86 B	#44	48	96 A	#67	40	80 B
#22	42	84 B	#45	41	82 B	#68	40	80 B
#23	45	90 A	#46	39	78 C	#69	43	86 B
Ave.	40	81 B	Ave.	43	86 B	Ave.	39	79 C

3rd Hr.		5th Hr.		6th Hr.	
A	4	A	9	A	6
B	8	B	9	B	12
C	10	C	5	C	3
D	1	D	0	D	0
F	0	F	0	F	2
	23		23		23

	TOTAL	%
A	19	28%
B	29	42%
C	18	26%
D	1	1%
F	2	3%
	69	100%

APPENDIX E6

Lab 5 Results
(20 points total)

Table 9: Grades for Lab 5: Properties of Solutions: Ice Cream Depression

3rd Hr.			5th Hr.			6th Hr.		
Student	Score	%	Student	Score	%	Student	Score	%
# 1	18	90 A	#24	17	85 B	#47	17	85 B
# 2	18	90 A	#25	17	85 B	#48	17	85 B
# 3	18	90 A	#26	18	90 A	#49	15	75 C
# 4	18	90 A	#27	15	75 C	#50	14	70 C
# 5	18	90 A	#28	17	85 B	#51	13	65 D
# 6	18	90 A	#29	18	90 A	#52	16	80 B
# 7	18	90 A	#30	15	75 C	#53	14	70 C
# 8	18	90 A	#31	17	85 B	#54	17	85 B
# 9	18	90 A	#32	18	90 A	#55	18	90 A
#10	18	90 A	#33	18	90 A	#56	16	80 B
#11	17	85 B	#34	18	90 A	#57	15	75 C
#12	18	90 A	#35	18	90 A	#58	18	90 A
#13	18	90 A	#35	15	75 C	#59	17	85 B
#14	19	95 A	#37	18	90 A	#60	18	90 A
#15	18	90 A	#38	20	100 A	#61	18	90 A
#16	16	80 B	#39	16	80 B	#62	18	90 A
#17	16	80 B	#40	16	80 B	#63	15	75 C
#18	16	80 B	#41	15	75 C	#64	16	80 B
#19	18	90 A	#42	18	90 A	#65	16	80 B
#20	16	80 B	#43	18	90 A	#66	16	80 B
#21	18	90 A	#44	20	100 A	#67	18	90 A
#22	17	85 B	#45	19	95 A	#68	15	75 C
#23	17	85 B	#46	16	80 B	#69	18	90 A
Ave.	18	88 B	Ave.	17	86 B	Ave.	16	82 B

	3rd Hr.	5th Hr.	6th Hr.
A	16	12	7
B	7	7	9
C	0	4	6
D	0	0	1
F	0	0	0
	23	23	23

	TOTAL	%
A	35	51%
B	23	33%
C	10	14%
D	1	1%
F	0	0%
	69	100%

APPENDIX E7

Lab 6 Results

(50 points total)

Table 10: Grades for Lab 6: Powder Potential: Chemical & Physical Changes

3rd Hr.			5th Hr.			6th Hr.		
Student	Score	%	Student	Score	%	Student	Score	%
# 1	42	84 B	#24	47	94 A	#47	44	88 B
# 2	38	76 C	#25	47	94 A	#48	42	84 B
# 3	42	84 B	#26	41	82 B	#49	46	92 A
# 4	43	86 B	#27	47	94 A	#50	35	70 C
# 5	42	84 B	#28	38	76 C	#51	36	72 C
# 6	41	82 B	#29	45	90 A	#52	48	96 A
# 7	42	84 B	#30	46	92 A	#53	38	76 C
# 8	44	88 B	#31	41	82 B	#54	48	96 A
# 9	40	80 B	#32	26	52 F	#55	45	90 A
#10	36	72 C	#33	44	88 B	#56	35	70 C
#11	36	72 C	#34	44	88 B	#57	49	98 A
#12	43	86 B	#35	43	86 B	#58	48	96 A
#13	42	84 B	#35	41	82 B	#59	41	82 B
#14	43	86 B	#37	46	92 A	#60	41	82 B
#15	45	90 A	#38	44	88 B	#61	43	86 B
#16	41	82 B	#39	41	82 B	#62	45	90 A
#17	43	86 B	#40	41	82 B	#63	47	94 A
#18	43	86 B	#41	42	84 B	#64	48	96 A
#19	40	80 B	#42	43	86 B	#65	48	96 A
#20	43	86 B	#43	44	88 B	#66	49	98 A
#21	43	86 B	#44	45	90 A	#67	37	74 C
#22	49	98 A	#45	46	92 A	#68	41	82 B
#23	49	98 A	#46	42	84 B	#69	41	82 B
Ave.	42	84 B	Ave.	43	86 B	Ave.	43	87 B

3rd Hr.		5th Hr.		6th Hr.	
A	3	A	8	A	11
B	17	B	13	B	7
C	3	C	1	C	5
D	0	D	0	D	0
F	0	F	1	F	0
	23		23		23

TOTAL		%
A	22	32%
B	37	54%
C	9	13%
D	0	0%
F	1	1%
	69	100%

APPENDIX E8

Lab 7 Results
(40 points total)

Table 11: Grades for Lab 7: Junk Food Energy

3rd Hr.			5th Hr.			6th Hr.		
Student	Score	%	Student	Score	%	Student	Score	%
# 1	33	83 B	#24	32	80 B	#47	35	88 B
# 2	37	93 A	#25	33	83 B	#48	33	83 B
# 3	33	83 B	#26	38	95 A	#49	35	88 B
# 4	37	93 A	#27	0	0 F	#50	34	85 B
# 5	34	85 B	#28	34	85 B	#51	13	33 F
# 6	40	100 A	#29	29	73 C	#52	39	98 A
# 7	36	90 A	#30	30	75 C	#53	39	98 A
# 8	31	78 C	#31	34	85 B	#54	38	95 A
# 9	36	90 A	#32	24	60 D	#55	36	90 A
#10	27	68 D	#33	37	93 A	#56	36	90 A
#11	29	73 C	#34	38	95 A	#57	36	90 A
#12	39	98 A	#35	39	98 A	#58	35	88 B
#13	32	80 B	#35	39	98 A	#59	39	98 A
#14	32	80 B	#37	40	100 A	#60	37	93 A
#15	30	75 C	#38	40	100 A	#61	38	95 A
#16	34	85 B	#39	35	88 B	#62	33	83 B
#17	31	78 C	#40	36	90 A	#63	34	85 B
#18	33	83 B	#41	37	93 A	#64	37	93 A
#19	16	40 F	#42	37	93 A	#65	36	90 A
#20	27	68 D	#43	39	98 A	#66	38	95 A
#21	37	93 A	#44	40	100 A	#67	38	95 A
#22	35	88 B	#45	37	93 A	#68	37	93 A
#23	36	90 A	#46	33	83 B	#69	38	95 A
Ave.	33	82 B	Ave.	34	85 B	Ave.	35	88 B

	3rd Hr.	5th Hr.	6th Hr.
A	8	13	15
B	8	6	7
C	4	2	0
D	2	1	0
F	1	1	1
	23	23	23

	TOTAL	%
A	36	52%
B	21	30%
C	6	9%
D	3	4%
F	3	4%
	69	100%

APPENDIX E9

Unit 2 Take-Home Lab Results

(15 points total)

Table 12: Grades for Unit 2 Take-Home Lab: Solutions

3rd Hr.				5th Hr.				6th Hr.			
Student	Score	%		Student	Score	%		Student	Score	%	
# 1	13	87	B	#24	12	80	B	#47	14	93	A
# 2	12	80	B	#25	15	100	A	#48	14	93	A
# 3	12	80	B	#26	13	87	B	#49	12	80	B
# 4	13	87	B	#27	0	0	F	#50	13	87	B
# 5	14	93	A	#28	0	0	F	#51	12	80	B
# 6	12	80	B	#29	14	93	A	#52	14	93	A
# 7	9	60	D	#30	12	80	B	#53	5	33	F
# 8	12	80	B	#31	14	93	A	#54	11	73	C
# 9	14	93	A	#32	0	0	F	#55	13	87	B
#10	12	80	B	#33	14	93	A	#56	14	93	A
#11	0	0	F	#34	13	87	B	#57	8	53	F
#12	14	93	A	#35	14	93	A	#58	13	87	B
#13	9	60	D	#35	11	73	C	#59	8	53	F
#14	14	93	A	#37	15	100	A	#60	13	87	B
#15	13	87	B	#38	13	87	B	#61	15	100	A
#16	14	93	A	#39	10	67	D	#62	14	93	A
#17	0	0	F	#40	13	87	B	#63	14	93	A
#18	14	93	A	#41	9	60	D	#64	11	73	C
#19	15	100	A	#42	15	100	A	#65	13	87	B
#20	0	0	F	#43	14	93	A	#66	14	93	A
#21	13	87	B	#44	12	80	B	#67	15	100	A
#22	15	100	A	#45	11	73	C	#68	11	73	C
#23	15	100	A	#46	10	67	D	#69	11	73	C
Ave.	11	75	C	Ave.	11	74	C	Ave.	12	82	B

	3rd Hr.	5th Hr.	6th Hr.
A	9	8	9
B	9	7	7
C	0	2	4
D	2	3	0
F	3	3	3
	23	23	23

	TOTAL	%
A	26	38%
B	23	33%
C	6	9%
D	5	7%
F	9	13%
	69	100%

APPENDIX E10

Lab 8 Results

(30 points total)

Table 13: Grades for Lab 8: Chemical Formulas

3rd Hr. Student	Score	%	5th Hr. Student	Score	%	6th Hr. Student	Score	%
# 1	28	93 A	#24	24	80 B	#47	27	90 A
# 2	26	87 B	#25	30	100 A	#48	29	97 A
# 3	22	73 C	#26	30	100 A	#49	30	100 A
# 4	24	80 B	#27	27	90 A	#50	26	87 B
# 5	23	77 C	#28	30	100 A	#51	29	97 A
# 6	30	100 A	#29	28	93 A	#52	29	97 A
# 7	22	73 C	#30	29	97 A	#53	27	90 A
# 8	29	97 A	#31	28	93 A	#54	30	100 A
# 9	20	67 D	#32	30	100 A	#55	27	90 A
#10	24	80 B	#33	30	100 A	#56	25	83 B
#11	30	100 A	#34	25	83 B	#57	25	83 B
#12	22	73 C	#35	25	83 B	#58	24	80 B
#13	24	80 B	#35	25	83 B	#59	27	90 A
#14	26	87 B	#37	27	90 A	#60	27	90 A
#15	24	80 B	#38	28	93 A	#61	27	90 A
#16	25	83 B	#39	29	97 A	#62	30	100 A
#17	27	90 A	#40	27	90 A	#63	22	73 C
#18	28	93 A	#41	29	97 A	#64	25	83 B
#19	29	97 A	#42	27	90 A	#65	27	90 A
#20	27	90 A	#43	30	100 A	#66	27	90 A
#21	27	90 A	#44	29	97 A	#67	28	93 A
#22	29	97 A	#45	28	93 A	#68	22	73 C
#23	29	97 A	#46	27	90 A	#69	30	100 A
Ave.	26	86 B	Ave.	28	93 A	Ave.	27	90 A

Grade	3rd Hr.	5th Hr.	6th Hr.
A	11	19	16
B	7	4	5
C	4	0	2
D	1	0	0
F	0	0	0
	23	23	23

	TOTAL	%
A	46	67%
B	16	23%
C	6	9%
D	1	1%
F	0	0%
	69	100%

APPENDIX E11

Lab 9 Results

(20 points total)

Table 14: Grades for Lab 9: Formulas for Smarties®

3rd Hr.			5th Hr.			6th Hr.		
Student	Score	%	Student	Score	%	Student	Score	%
# 1	19	95 A	#24	19	95 A	#47	20	100 A
# 2	20	100 A	#25	20	100 A	#48	20	100 A
# 3	17	85 B	#26	20	100 A	#49	20	100 A
# 4	18	90 A	#27	20	100 A	#50	20	100 A
# 5	20	100 A	#28	20	100 A	#51	17	85 B
# 6	20	100 A	#29	20	100 A	#52	20	100 A
# 7	19	95 A	#30	20	100 A	#53	20	100 A
# 8	19	95 A	#31	20	100 A	#54	20	100 A
# 9	20	100 A	#32	20	100 A	#55	20	100 A
#10	20	100 A	#33	19	95 A	#56	20	100 A
#11	19	95 A	#34	20	100 A	#57	20	100 A
#12	18	90 A	#35	20	100 A	#58	20	100 A
#13	19	95 A	#35	20	100 A	#59	20	100 A
#14	19	95 A	#37	20	100 A	#60	20	100 A
#15	20	100 A	#38	20	100 A	#61	19	95 A
#16	20	100 A	#39	18	90 A	#62	20	100 A
#17	19	95 A	#40	20	100 A	#63	20	100 A
#18	20	100 A	#41	19	95 A	#64	20	100 A
#19	20	100 A	#42	19	95 A	#65	19	95 A
#20	20	100 A	#43	20	100 A	#66	20	100 A
#21	20	100 A	#44	20	100 A	#67	20	100 A
#22	20	100 A	#45	20	100 A	#68	20	100 A
#23	20	100 A	#46	19	95 A	#69	20	100 A
Ave.	19	97 A	Ave.	20	98 A	Ave.	20	99 A

	3rd Hr.	5th Hr.	6th Hr.
A	22	23	22
B	1	0	1
C	0	0	0
D	0	0	0
F	0	0	0
	23	23	23

	TOTAL	%
A	67	97%
B	2	3%
C	0	0%
D	0	0%
F	0	0%
	69	100%

APPENDIX E12

Lab 10 Results

(20 points total)

Table 15: Grades for Lab 10: Percent of an Oreo®

3rd Hr.			5th Hr.			6th Hr.		
Student	Score	%	Student	Score	%	Student	Score	%
# 1	16	80 B	#24	19	95 A	#47	18	90 A
# 2	15	75 C	#25	19	95 A	#48	15	75 C
# 3	16	80 B	#26	19	95 A	#49	19	95 A
# 4	15	75 C	#27	17	85 B	#50	18	90 A
# 5	19	95 A	#28	18	90 A	#51	17	85 B
# 6	19	95 A	#29	19	95 A	#52	18	90 A
# 7	15	75 C	#30	18	90 A	#53	18	90 A
# 8	17	85 B	#31	19	95 A	#54	16	80 B
# 9	20	100 A	#32	17	85 B	#55	15	75 C
#10	15	75 C	#33	19	95 A	#56	17	85 B
#11	18	90 A	#34	19	95 A	#57	13	65 D
#12	19	95 A	#35	19	95 A	#58	18	90 A
#13	16	80 B	#35	19	95 A	#59	18	90 A
#14	18	90 A	#37	19	95 A	#60	15	75 C
#15	17	85 B	#38	20	100 A	#61	15	75 C
#16	18	90 A	#39	18	90 A	#62	17	85 B
#17	17	85 B	#40	16	80 B	#63	16	80 B
#18	16	80 B	#41	18	90 A	#64	18	90 A
#19	16	80 B	#42	20	100 A	#65	15	75 C
#20	16	80 B	#43	19	95 A	#66	17	85 B
#21	18	90 A	#44	19	95 A	#67	18	90 A
#22	17	85 B	#45	18	90 A	#68	17	85 B
#23	17	85 B	#46	14	70 C	#69	17	85 B
Ave.	17	85 B	Ave.	18	92 A	Ave.	17	84 B

Grade	3rd Hr.	5th Hr.	6th Hr.
A	8	19	9
B	11	3	8
C	4	1	5
D	0	0	1
F	0	0	0
	23	23	23

	TOTAL	%
A	36	52%
B	22	32%
C	10	14%
D	1	1%
F	0	0%
	69	100%

Lab 11 Results

(20 points total)

Table 16: Grades for Lab 11: How Thick is Aluminum Foil?

3rd Hr.			5th Hr.			6th Hr.		
Student	Score	%	Student	Score	%	Student	Score	%
# 1	18	90 A	#24	17	85 B	#47	18	90 A
# 2	17	85 B	#25	17	85 B	#48	18	90 A
# 3	15	75 C	#26	20	100 A	#49	16	80 B
# 4	13	65 D	#27	15	75 C	#50	18	90 A
# 5	11	55 F	#28	17	85 B	#51	20	100 A
# 6	18	90 A	#29	14	70 C	#52	19	95 A
# 7	9	45 F	#30	16	80 B	#53	18	90 A
# 8	16	80 B	#31	11	55 F	#54	16	80 B
# 9	12	60 D	#32	15	75 C	#55	15	75 C
#10	16	80 B	#33	19	95 A	#56	16	80 B
#11	8	40 F	#34	17	85 B	#57	11	55 F
#12	14	70 C	#35	19	95 A	#58	18	90 A
#13	5	25 F	#35	19	95 A	#59	12	60 D
#14	15	75 C	#37	17	85 B	#60	14	70 C
#15	6	30 F	#38	12	60 D	#61	12	60 D
#16	17	85 B	#39	18	90 A	#62	20	100 A
#17	15	75 C	#40	15	75 C	#63	0	0 F
#18	17	85 B	#41	10	50 F	#64	16	80 B
#19	15	75 C	#42	17	85 B	#65	18	90 A
#20	7	35 F	#43	18	90 A	#66	19	95 A
#21	15	75 C	#44	15	75 C	#67	20	100 A
#22	19	95 A	#45	14	70 C	#68	16	80 B
#23	20	100 A	#46	18	90 A	#69	15	75 C
Ave.	14	69 C	Ave.	16	80 B	Ave.	16	79 B

Grade	3rd Hr.	5th Hr.	6th Hr.
A	4	7	11
B	5	7	5
C	6	6	3
D	2	1	2
F	6	2	2
	23	23	23

	TOTAL	%
A	22	32%
B	17	25%
C	15	22%
D	5	7%
F	10	14%
	69	100%

APPENDIX E14

Lab 12 Results

(40 points total)

Table 17: Grades for Lab 12: Water of Crystallization

3rd Hr.			5th Hr.			6th Hr.		
Student	Score	%	Student	Score	%	Student	Score	%
# 1	34	85 B	#24	35	88 B	#47	40	100 A
# 2	31	78 C	#25	33	83 B	#48	30	75 C
# 3	35	88 B	#26	33	83 B	#49	38	95 A
# 4	33	83 B	#27	38	95 A	#50	40	100 A
# 5	34	85 B	#28	34	85 B	#51	31	78 C
# 6	40	100 A	#29	35	88 B	#52	40	100 A
# 7	33	83 B	#30	30	75 C	#53	33	83 B
# 8	36	90 A	#31	36	90 A	#54	37	93 A
# 9	37	93 A	#32	31	78 C	#55	36	90 A
#10	37	93 A	#33	40	100 A	#56	35	88 B
#11	31	78 C	#34	33	83 B	#57	35	88 B
#12	37	93 A	#35	38	95 A	#58	36	90 A
#13	33	83 B	#35	38	95 A	#59	38	95 A
#14	37	93 A	#37	38	95 A	#60	36	90 A
#15	28	70 C	#38	36	90 A	#61	36	90 A
#16	37	93 A	#39	38	95 A	#62	32	80 B
#17	30	75 C	#40	34	85 B	#63	40	100 A
#18	39	98 A	#41	0	0 F	#64	40	100 A
#19	0	0 F	#42	40	100 A	#65	37	93 A
#20	30	75 C	#43	33	83 B	#66	40	100 A
#21	37	93 A	#44	38	95 A	#67	34	85 B
#22	35	88 B	#45	30	75 C	#68	35	88 B
#23	38	95 A	#46	36	90 A	#69	35	88 B
Ave.	33	83 B	Ave.	34	84 B	Ave.	36	91 A

	3rd Hr.	5th Hr.	6th Hr.
A	10	11	14
B	7	8	7
C	5	3	2
D	0	0	0
F	1	1	0
	23	23	23

	TOTAL	%
A	35	51%
B	22	32%
C	10	14%
D	0	0%
F	2	3%
	69	100%

APPENDIX E15

Unit 3 Take-Home Lab Results

(20 points total)

Table 18: Grades for Unit 3 Take-Home Lab: Molarity

3rd Hr. Student	Score	%		5th Hr. Student	Score	%		6th Hr. Student	Score	%	
# 1	20	100	A	#24	20	100	A	#47	20	100	A
# 2	18	90	A	#25	19	95	A	#48	18	90	A
# 3	18	90	A	#26	20	100	A	#49	18	90	A
# 4	18	90	A	#27	20	100	A	#50	20	100	A
# 5	20	100	A	#28	0	0	F	#51	0	0	F
# 6	20	100	A	#29	20	100	A	#52	20	100	A
# 7	18	90	A	#30	19	95	A	#53	0	0	F
# 8	20	100	A	#31	20	100	A	#54	18	90	A
# 9	20	100	A	#32	18	90	A	#55	20	100	A
#10	18	90	A	#33	19	95	A	#56	20	100	A
#11	20	100	A	#34	18	90	A	#57	20	100	A
#12	20	100	A	#35	20	100	A	#58	20	100	A
#13	15	75	C	#35	20	100	A	#59	20	100	A
#14	20	100	A	#37	19	95	A	#60	20	100	A
#15	20	100	A	#38	20	100	A	#61	20	100	A
#16	18	90	A	#39	0	0	F	#62	18	90	A
#17	0	0	F	#40	20	100	A	#63	18	90	A
#18	20	100	A	#41	20	100	A	#64	20	100	A
#19	20	100	A	#42	20	100	A	#65	19	95	A
#20	0	0	F	#43	20	100	A	#66	20	100	A
#21	20	100	A	#44	20	100	A	#67	18	90	A
#22	20	100	A	#45	20	100	A	#68	18	90	A
#23	20	100	A	#46	20	100	A	#69	18	90	A
Ave.	18	88	B	Ave.	18	90	A	Ave.	18	88	B

Grade	3rd Hr.	5th Hr.	6th Hr.
A	20	21	21
B	0	0	0
C	1	0	0
D	0	0	0
F	2	2	2
	23	23	23

	TOTAL	%
A	62	90%
B	0	0%
C	1	1%
D	0	0%
F	6	9%
	69	100%

APPENDIX F

Student Write-up Check Sheet

Whose lab are you checking? ______________________

1. Is there a title on the experiment? Yes No
2. Is the purpose clear and does it describe what was to be done? Yes No
3. Does the conclusion answer the purpose? Yes No
4. Are all of the correct materials listed? Yes No
5. Could you perform the experiment from the procedure? Yes No
6. Did the person present a clear data table of the collected information? Yes No
7. Does the data table have a title? Yes No
8. Does the data have units? Yes No
9. Are the correct calculations shown? Yes No
10. Did the person comment on accuracy of the results?(percent error) Yes No
11. Overall, this lab report was: excellent -- great -- good --- ok --needs work
12. Suggest one improvement:

Checked by________________________

APPENDIX G

Survey Results

APPENDIX G1

Student Retention Results

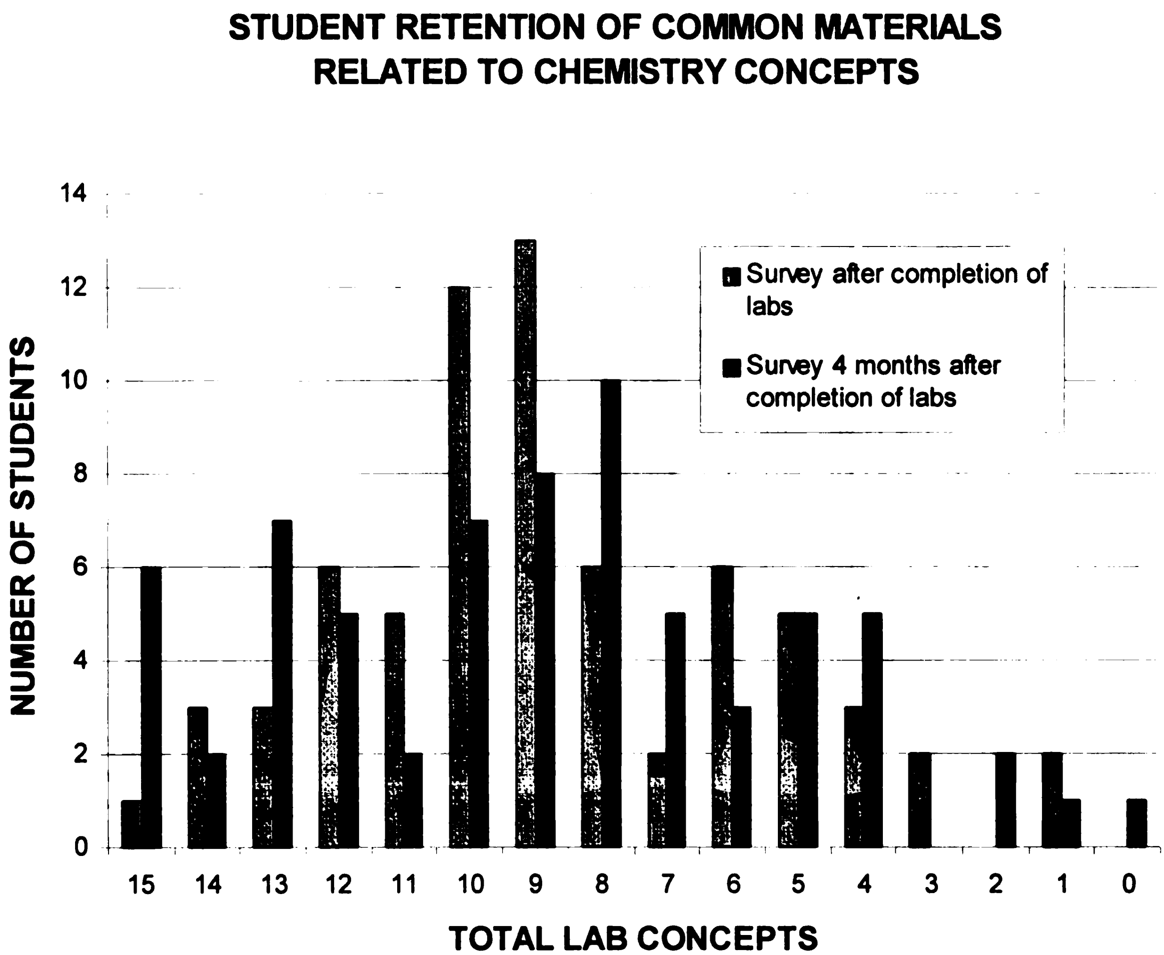


Figure 8: Graph for Survey of Chemistry Concept Retention with Labs

APPENDIX G2

Student Association Results

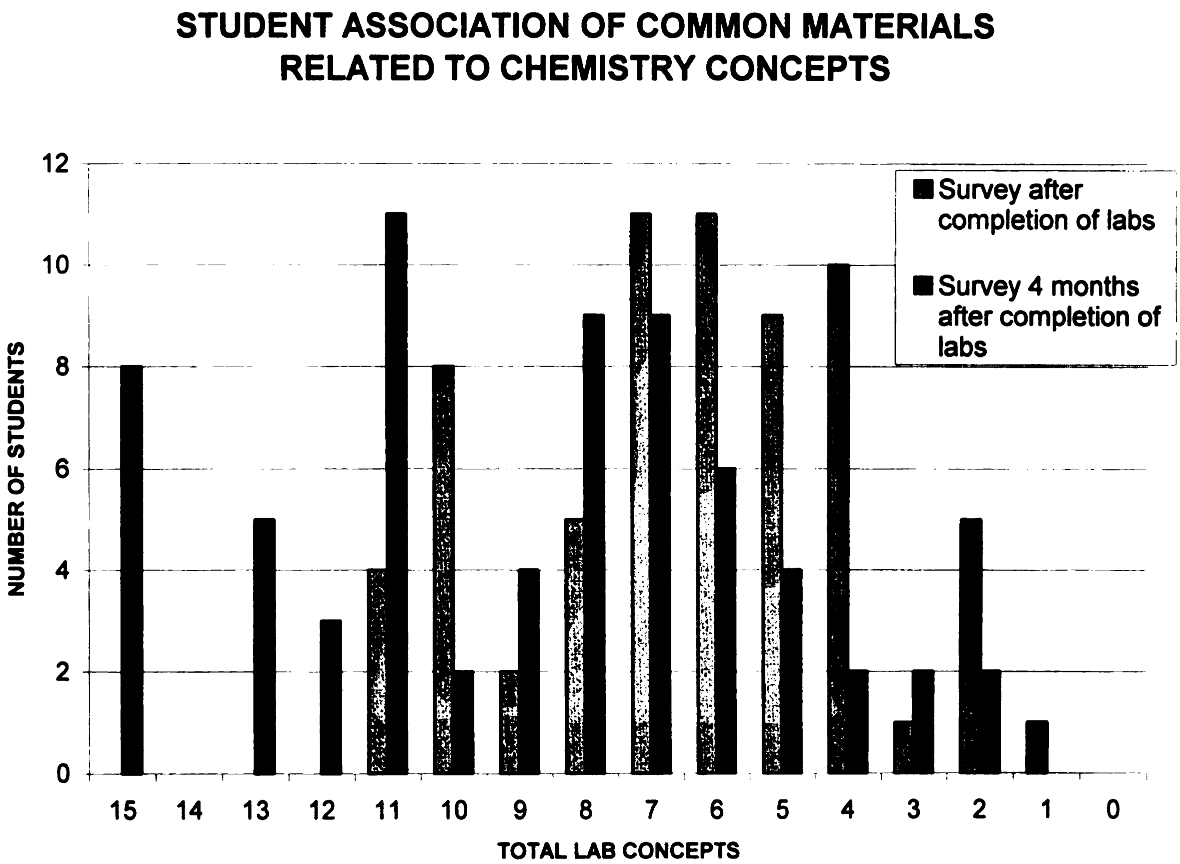


Figure 9: Graph for Survey of Chemistry Concept Association with Labs