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To The Study Of Matter

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A CONSTRUCTIVIST APPROACH TO THE STUDY OF MATTER

By

Susan Hankins Fritzell

A THESIS

Submitted to
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ABSTRACT

A CONSTRUCTIVIST APPROACH TO THE STUDY OF MATTER

By

Susan Hankins Fritzell

Ninth grade physical science students in a suburban school district were not gaining adequate understanding of the basic concepts of matter during their lab-oriented chemistry unit. This unit was therefore rewritten to follow a constructivist approach of teaching. The unit includes activities to introduce the particle theory. These were followed by lab activities on mixtures and physical changes and compounds and chemical changes. This revised unit was adapted to a new situation, in which small groups of ninth grade talented and gifted students participated, but were not graded. Short writings and discussion accompanied all labs and activities. There was no lecture, text, or homework. Class room observations and follow-up surveys indicate that most students enjoyed learning by the constructivist approach. Comparison of pre-test and post-test scores indicate that students gained a significant amount of knowledge during the unit.

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INTRODUCTION

I. Statement of Problem and Rationale for Study

Although I had taught Biology and Chemistry for twelve years, I finished my first year teaching Physical Science to ninth graders in frustration. This course included basic chemistry, astronomy, and earth science. The two main purposes of the first semester were to introduce basic chemical principles and to teach proper lab skills. The course worked well in teaching lab skills. Students were exposed to almost three laboratory activities each week and wrote most of them up in proper laboratory format. Students were taught how to properly use lab equipment and were exposed to many chemistry lab techniques, such as fractional distillation and crystallization. What I found they did not gain from this course, however, was a good understanding of basic chemistry concepts. On an informal survey administered three months after we completed our chemistry unit, forty-seven percent of my students could not provide an adequate explanation of the differences between elements, mixtures, and compounds, and many could not define a chemical or physical change.

The course was based on the text, Introductory Physical Science, 4th ed., (1982) by Haber-Schaim, Abegg, Dodge, and Walter. The main concepts covered in the chemistry unit of this text include mixtures, compounds, elements, conservation of mass, density, and solubility. This text is unusual in that it teaches concepts through laboratory investigations. A concept such as defining a compound is not just given to a student. Students first complete a series of experiments from which their conclusions are supposed to bring them to the correct understanding of compounds. The text does not actually define compounds until students have completed all the experiments.

Although in theory this is a great way to teach science, it was not effective in my classes for several reasons. First of all, many of these labs were very technical and the students became so involved with the mechanics of the labs that they failed to take time to think about the reasons certain phenomena were occurring. For example, they may have spent hours writing out the procedure and creating a histogram of class results from a lab measuring densities, but never wrote an adequate conclusion explaining density itself.

Secondly, the text was very difficult to use. Students and their parents complained about its style. The language was difficult to understand, the objectives were not outlined, and the vocabulary words were not bold-faced. Also, the chapter review questions often did not address the main concepts that the labs were designed to teach. I found that many of my students could not answer these questions because they were too difficult to understand or because they didn't address what we had done in class. I therefore assigned few of them as homework.

Finally, my students had difficulty with this course because I was ill prepared to teach it the way it was designed. The course was designed so students would learn from their text, labs, and class discussion as a package. The text intentionally did not give students all the information that they needed to be successful. Instead, the course relied on the teacher to engage students in a lengthy discussion after each lab. This was often difficult because I did not fully understand the course design and also because the students were generally not interested in the subject.

I realized that there were several ways I could improve student understanding of the basic concepts this course was designed to teach. I needed to increase student interest, rewrite and alter the labs and follow-up questions so that they focused on the concepts they were intended to teach, and most importantly, alter the teaching style from a hands-on approach to a constructivist approach. In both of these styles students actively participate in laboratory experiments. But as explained in the following paragraphs, the constructivist approach differs from the hands-on approach because it focuses on students constructing their own meaning from the experiments.

My method of teaching this course had been a hands-on approach. I would hand out and discuss the procedure to a lab, have students do the lab, and then conclude the lab by having students read the text, answer questions from the text, and engage in post-lab discussion. However, students had difficulty in understanding the lab protocol or the reading, and coming to their own conclusions. Because of this I often found myself reverting to a lecture format and just telling students what they should conclude from the lab. Students rarely came to an appropriate conclusion themselves. I found what was occurring in my class was what many other teachers have found in their own:

> "A small group of learners do benefit from the traditional approach of being presented the product of scientists' work and imagination in the form of rules, laws, and generalizations. Such an approach is not helpful to the majority of students, however. It creates in them a feeling of helplessness, forces them to merely memorize the definitions, rules, laws, and formulas, and makes them grateful that it will all "go away" as soon as the exams are over."(Stepans, 1994)

I now realize that although I thought my method of teaching by using labs was effective and engaging, I was using the wrong approach for this group of students. By giving students step-by-step lab activities and telling them the "proper" conclusions, I was basically relying on the traditional transmission model of "writing on students' blank minds" (Bisard, 1994). This has been "notoriously ineffective" as evidenced by low scores of American high school students on international science and math tests (Fisher, 2000). To be effective, I needed to alter my style of teaching to a constructivist approach in which I "take into account students' past learning and preconceptions about a concept . . . and refine them into more useful and correct constructs" (Bisard, 1994).

The constructivist approach follows basic steps in which students come to a scientifically acceptable understanding of concepts. Before a lab begins, students must think and make predictions about the activity. This allows them to become aware of their existing ideas. Then their idea is tested through an experiment. Student discussion following the experiment should resolve conflicts between their original understandings and their new observations. Students then are asked to extend their new understanding of this concept to explain other situations in their daily lives, and hopefully use the concept to predict and explore more problems. (Stepans, 1994, Posner, et al., 1982).

There were many aspects of the constructivist model that I was missing in my method of instruction. First, I rarely had students discuss their ideas or make predictions at the beginning of an activity. Because their earlier understandings were not discussed, a conflict between what the learner expected to happen and what actually happened was not brought out into the open. It is "the desire or need to resolve this conflict [that] creates in the learner a motivation to learn"(Stepans, 1994). I hoped that I could draw more student interest into my class by discussing different ideas, including misconceptions, before an experiment began.

The main misconception of my students seemed to be their understanding of the particulate nature of matter. I falsely assumed that my students had a good understanding of the particle theory because the middle school curriculum covered atoms and molecules. The textbook did not cover the particle theory and so I did not include this concept in my chemistry unit. I believe this led to the difficulty my students had in explaining such concepts as the differences between mixtures and compounds.

The particle nature of matter has been found to be very difficult for students to comprehend. Novick and Nussbaum (1978) found that students don't internalize the ideas of space existing between particles, the intrinsic motion of particles, or the interactions between particles. Morris (1998) found his students thought of molecules in solids as hard, in liquids as soft and slushy, and in gases as transparent. Griffiths (1992) reported that many of his twelth grade students believe that molecules of the same substance may vary considerably in size, shape and weight during phase changes, and forty percent believe water molecules contain components other than oxygen and hydrogen.

Studies of college chemistry students have shown that a firm understanding of the particle nature of matter is a necessary foundation for the study of chemistry. Gabel (1993) found students who were first taught the particle model were more successful in introductory chemistry than those who were not. Nakhleh and Mitchell (1993) found over half of their students could predict the chemical structure of sulfur trioxide algorithmically but could not use conceptual skills to recognize that one sulfur combines with three oxygens based on the formula SO_3. Similarly, Pickering (1990) found students could solve stoichiometry and gas law problems numerically but could not solve similar problems when written in diagram form. Information from these studies, as well as my own observations, led me to believe that I must revise my chemistry unit by first being sure students understood the particle nature of matter.

The second basic step of the constructivist model is for students to test their preconceptions through activities and labs. I had been actively engaging my students in hand-on activities, but too often they followed “cookbook” style lab directions rather than active problem solving. A study by Worrel (1992) of a Florida State University chemistry class showed that student understanding and retention of the law of conservation of mass was much better when taught through lab activities and problem solving rather than by lecture. Lamba’s (1994) studies showed the efficacy of changing the role of the lab from one that verifies concepts and principles to one that makes the lab “the centerpiece of the students’ learning experience”. To truly follow the constructivist approach, I needed to restructure my labs so they were truly investigative. As Lamba (1994) stated, “students should learn chemistry in the same way that we, as practicing scientists, continually learn chemistry”. Using the constructivist approach would help students recognize that science is an “ongoing project in which alternative models continue to be constructed and examined in a critical manner” (Mintzes, et al., 1997).

The third basic step of the constuctivist model is for students to propose explanations for laboratory findings in order to resolve conflicts between their preconceptions or misconceptions and their recent observations. Plenty of time should be allowed for this process in which the teacher should take the role of facilitator of the discussion, but be careful not to give the students his or her own explanation. The constructivist theory now recognizes “the social aspects of learning, like the classroom environment and interactions” (Foley, 2000). Learning is a complex process, and for most of us “it requires activity, discussion, and establishing relationships among various components” (Stepans , 1994). Laboratory experiences are only meaningful if students are given time and resources to think about their experiences (Tobin, 1990). The emphasis of lab follow-up activities needs to turn from teacher instruction and worksheets to discussion of ideas (Gunstone and Champagne, 1990).

Finally, students learning in the constructivist model need to extend their findings to situations in their everyday lives. As Zulaf (1999) writes about teaching matter, once students understand the model of the particle theory, they can use this "model as a tool – to solve real world problems – [and] the model becomes relevant and valuable." Teachers can create an atmosphere in which students are motivated to learn more if "we put our emphasis on creating meaningful changes in learners and help them look at the world differently" (Stepans, 1994). One way to do this is to model a concept in a simple, understandable means and then extend this to more difficult examples. For example, Stavy (1991) found that students can apply the ideas from the conservation of mass in a closed test tube with acetone evaporating more easily when they first observe it with iodine evaporating. One of my goals in revising my chemistry unit was to develop a progression of simple labs to more difficult labs, so that the labs which are intuitively easy to understand could serve as "a springboard to better understanding of a difficult concept" (Stavy, 1991).

II. Demographics

After developing this unit for my ninth grade Physical Science class, I discovered I would be moving out of state during the summer and would not return to my previous teaching position. Fortunately, I was able to find a new teaching job, but it was not teaching science. Instead I was hired to run the gifted and talented program in an urban school district of 5,000 students with a minority population of approximately twenty percent. I currently teach at a high school of 1600 students. The majority of my students have been selected for the talented and gifted (TAG) program because they have scored in the ninety-fifth percentile on the Iowa Test of Basic Skills and they have been nominated by their teachers because of their high achievement potential. Students come to my classroom for fifty-five minutes either every day or on alternate days for supplemental instruction. The number of students in my room during an hour ranges from two to eleven and their grade levels range from ninth through eleventh. There is no set curriculum but students set goals and sign a contract to complete independent or group study based on their individual interests. While working in my room, students engage in class discussion, work on independent projects, or do homework for their other classes.

My basic charge as a teacher of the gifted and talented is to enrich my students in ways they can not be enriched in the regular classroom. I saw this as a perfect opportunity to try out my newly revised science unit. Students entering ninth grade in my school district have a weak science background. There is no science class in the eighth grade and one of the two middle schools in the district does not even have a certified science teacher. In the ninth grade, most students take Earth Science, which begins with a strong emphasis on teaching basic lab skills and includes basic chemistry taught for approximately twelve class days. Many of the concepts taught in this class were ones I had written into my newly developed chemistry unit. However, these concepts were not being taught to the same depth or with the same methods as I planned to teach.

Twenty-four ninth graders chose to work on this science unit with me. This was counted as their independent study project for the quarter and students received a pass/fail grade with no credit for their efforts. I worked with individual groups ranging from two to eight students during two fifty-five minute classes each week for nine weeks. We usually used my classroom for discussions but had to move to a chemistry lab for our experiments. Thirteen of my students were male and eleven were female. Twenty-three were Caucasian and one was Indian.

III. Scientific Background

The basis to understanding matter and the changes it undergoes is understanding the particle theory. It has long been believed that all matter is composed of extremely small particles (atoms) that take up space and have mass. Atoms may exist independently or bond to other atoms to form molecules. These particles are in constant motion. As a material is heated, the particles gain energy and move faster. Particles in a solid are vibrating in a set position. When a solid melts into a liquid, the particles gain enough energy to break out of their set position. Attractive forces between the particles are strong enough, however, to keep the particles close together. Liquids turn to gases when the particles gain enough energy to overcome the attractive forces between them. Particles in gases are widespread and fast moving. The changing of particles between solids, liquids, and gases are phase changes. Phase changes are physical changes because the particles in the matter have not changed identity. For example, ice melting is a physical change because the particles in all three phases are the molecule composed of two hydrogens and one oxygen.

Another type of physical change is mixing, in which the particles in the mixture retain their individual properties. For this reason, mixtures can be separated by physical methods. The formation of compounds, on the other hand, requires a chemical change.

Chemical changes generally can be characterized by reactions that give off heat or light, absorb heat, release a gas, or form a precipitate.

Compounds differ from mixtures in several ways. First of all, unlike mixtures, a compound has different properties than its original components because chemical bonds have been broken and formed. Secondly, compounds differ from mixtures in that their atoms must join in set ratios. The components of mixtures do not need to occur in set ratios because they are not chemically bonded. This leads to a third difference, that mixtures can be separated easily through physical methods, while only chemical methods can separate compounds into component parts. During physical and chemical changes, matter is neither created nor destroyed. Therefore, mass is always conserved. A complete list of resources I used in gathering this scientific information and in designing the activities can be found in Appendix A.

IMPLEMENTATION OF UNIT

I. Introduction

I developed this unit on matter at Michigan State University during the summer of 1999 by significantly revising the original unit I had taught which was based on Introduction to Physical Science (1982). The new unit is written in three basic parts. I developed Part I, a series of demonstrations and labs on the particle theory (Appendix B), as an introduction to matter. I restructured Part II and Part III, mixtures and physical changes (Appendix C) and compounds and chemical changes (Appendix D), from the earlier course.

A major modification of this new unit is that it is based around the constructivist model. For example, when teaching the unit most labs were introduced using group discussion in which students tried to explain a simple demonstration or were asked to predict what would occur during a laboratory experiment. After this initial discussion, students tested their predictions by following lab instructions. Following the lab students answered more questions, which were designed to trigger discussion and lead students to a re-evaluation of their original ideas or misconceptions.

Each lab did not stand alone, nor did I expect students to come to a complete understanding of difficult concepts such as the differences between compounds and mixtures by the completion of one lab. Instead each part of the unit includes many labs, each designed to reinforce and add to what the previous lab teaches. After students had completed all the labs of Part I, II, or III, they were asked to answer discussion and application questions that were designed to guide students toward a complete understanding of the concepts addressed in the previous labs.

When designing this unit, I was unsure of whom I would be teaching and how much time I would have for the unit. After pre-testing (Appendix E) my students at the beginning of the unit, I found they had a good understanding of certain concepts such as phase changes and position of particles in solids, liquids, and gases. Because I was afraid of boring my students, I decided to modify my original plan by discussing rather than carrying out Lab 1 (Appendix B-VI), Lab 2 (Appendix C-I) and Lab 3 (Appendix C-III). Because I had only ten weeks to teach this unit, I ran out of time to use all the labs I had developed. The Take Home Labs (Appendix D-VIII), Labs 11A and 11B (Appendix D-VIII and D-IX), and the Demonstration of Phase Changes activity (Appendix B-VII) were not used.

I was fortunate to teach this unit to eight small groups of students, ranging in numbers from two to six for a total of twenty-four students. The small size of the groups meant we were able to engage in good discussions that I could easily record. I found that one student's perceptions often influenced the others in his group. It was difficult for me to track the progress of one individual student. Therefore, in my descriptive accounts I will not follow a few certain students, but will often give accounts of different students as their predictions or conclusions prove especially interesting. Final evaluation of the unit was made by comparing my students' scores between a pre-test and post-test (Appendix E), analyzing their responses on a follow-up survey (Appendix G), and by comparing my students' results on a follow-up test (Appendix F) to the results of other students who were not enrolled in my class.

II. The Particle Nature of Matter

Demonstrations (Appendix B-II)

I introduced my students to the particle nature of matter by engaging them in several demonstrations (Appendix B-II). Students were asked to write down their observations, and, after sharing their observations, make a statement about what their observations mean about matter.

Many students had definite misconceptions about matter. I asked students what happened to the drop of alcohol that disappeared after I placed it on their arm. Five said it absorbed into the skin, and only one used the term "evaporate" in his explanation. He and his classmates knew this "because you can smell it and it cools you off". They could not however, explain why the evaporating alcohol makes the skin feel cool.

The demonstration of iodine evaporating in a flask and recrystallizing on a watch glass above it also led to interesting conversation. I asked students to explain in writing how the crystals got onto the watch glass. Six students wrote good explanations involving phase changes, such as " the iodine changes into gas and crystallizes". Others did not grasp the concept of phase change correctly. One student wrote "The crystals came from the solid, the gas carried the sparkles up to the top". Another wrote, "Water vapor carried them up". Students did not understand that the gas was iodine that had sublimated and later crystallized. One student described the newly formed iodine crystals as "those hair things which are the dust particles in the air caught on the side of the flask".

As students watched the potassium permanganate dissolve in water, I found they weren't sure how to define the term "mixing". I had them use X's and O's in drawings to show what was occurring. Some showed the two combining and other groups left them separated. I asked several groups how they could prove that the X's and O's didn't combine, and had one good answer of " evaporate off the X's [water] and see if the O's [potassium permanganate] are still there".

The demonstration using the sealed syringe showed me that students understood that all matter, including gas, was made of small particles. Most attributed the fact that they couldn't compress the sealed syringe all the way to "air pressure". They could explain that air pressure is air molecules pushing back against the syringe.

I concluded these demonstrations using a molecular model demonstrator kit. This really helped students visualize on the particle level what they had just been observing in the demonstrations. There were a lot of "ah-hah's" when we used the kit to model what happened when alcohol evaporated from their arm and the iodine crystallized. Students now, with some guidance and hints from me, were able to come up with the basic tenets of the particle theory.

<u>Discovery Stations</u> (Appendix B-III)

A few days later I took students to our chemistry lab where I had set up "Discovery Stations"(Appendix B-III) which build on what students had learned about the particle theory in the previous demonstrations. Students were to rotate through these nine stations with a partner, perform the simple experiment as instructed, and answer questions which basically asked them to explain their observations. My expectation was that students would apply what they had learned about the particle theory to this activity. I found that in the beginning I had to work with students to remind them to "think in particle terms". After they got in the right mind-set they worked fairly independently.

Students enjoyed moving from station to station and performing the experiments, but complained about having to write out answers to all the questions. Students had no problem explaining the stations (such as "Candy in Water") which dealt with the motion of particles in relation to temperature. Students were most challenged by "Stop the Leak", "Balloon in a Bottle", and "Ruler Flip"(Appendix B-III). These stations all required the students to think of air pressure in terms of particles. This led to good discussion by the students, which are summarized in the following paragraphs.

At the "Stop the Leak" station, students were presented with a two liter pop bottle filled with water and capped. A hole was punched in the side of the bottle, about 2 inches above the base. Students discovered that water would only flow out of this hole when the cap of the bottle was loosened. Most of my students explained this by saying that the water can't flow out when the lid is tightened because "you need more air to fill up the space when the water leaves". When I asked students why this was so, they could not explain. So I squeezed on the top of the bottle with the lid still on tight. This forced water out of the bottle and students now realized that in order for water to move out "air must be pressing down on the water".

Another station which intrigued students was "Balloon in the Bottle". Students were presented with a balloon that was inside an Erlenmeyer flask. I had earlier accomplished this by first heating water in the flask while the balloon was covering the opening and then quickly cooling the flask in ice water. I asked students to come up with an idea of how the balloon could have entered the flask. None of the students could explain this well, and many used the terms "suck" and "vacuum" in their explanation, though they could not define either term. A few groups noticed the water in the bottom of the Erlenmeyer flask and the hot plate which had been used. One of the most interesting discussions that ensued follows:

> Student: " It was heated and the air particles moved apart. It was then cooled off and they got closer together and the balloon was sucked in to fill up the extra space."
>
> Teacher: "Explain how the balloon was sucked in. Did the air particles pull it in?"

Students were now stumped. They understood that molecules move slower and are closer together when cool, but none understood that the balloon was forced into the flask because of the differences in air pressure between the outside and inside of the balloon. I chose not to explain this to the students, but hoped they could come to their own understanding the next day after more demonstrations and discussion.

The "Ruler Flip" also challenged students. In this activity, students let half of a meter stick hang over a table. They then covered the end on the table with a sheet of newspaper. Students gave the overhanging end of the meter stick a good wack, and found the meter stick did not fall to the floor. Most students explained this by saying the weight of the newspaper caused the meter stick to stay on the table. Only a few groups thought in terms of air particles, as shown by one student's drawing (Figure 1) and his comment that "air pushes down with more force than you". Another wrote, "The paper adds weight and the surface area is greater, so it is harder to push the air particles out of the way."

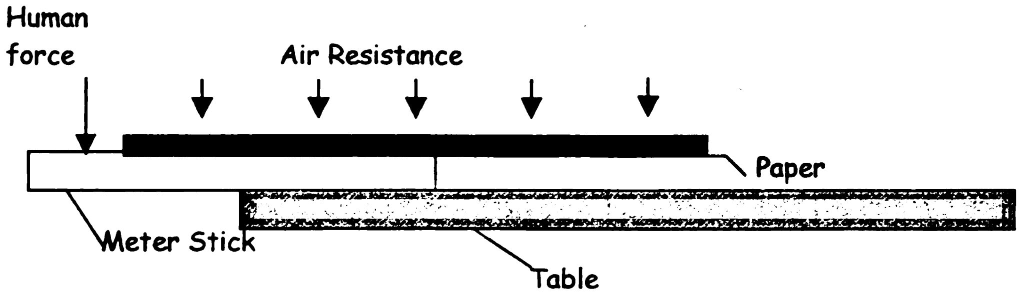


Figure 1. A student's drawing of the forces involved in "Ruler Flip"

On the following day we discussed what was demonstrated in the Discovery Stations in more depth. To help students understand "Ruler Flip", "Balloon in a Bottle" and "Stop the Leak", I had them sketch out each case using X's for air particles. I tried to stay true to the constructivist approach and not give them an explanation but only guide them in their thinking. The sketches helped students visualize and explain what had occurred on the previous day.

Demonstrations and Discussions of Particle Nature (Appendix B-IV)

I followed this discussion with three demonstrations (Appendix B-IV) that could be explained by the particle theory and changes in air pressure. I hoped by now students would be able to use the thinking techniques they were exposed to in the previous demonstrations and discovery stations to explain each of the phenomena that they observed. I found they were moving closer to my goal, but I still needed to coach them to think in terms of particles and at times suggest they draw out what was occurring.

Nearly all the groups gave good explanations of how a suction cup worked. I had now trained them to avoid using the terms "suck" and "vacuum" and they were therefore forced to explain suction in terms of numbers of particles and corresponding differences in air pressure.

Students then were shown a modification of "The Balloon in the Bottle" discovery station. In this demonstration, I placed a slightly inflated balloon over the mouth of an Erlenmeyer flask which contained a small amount of boiling water. I then quickly placed the flask in ice water, and the balloon moved into the flask. I was disappointed here when about one-third of my students initially explained this by writing something like: "air molecules slow down and suck in the balloon". However I was pleased that, in all but one group, these students were corrected by their peers who explained that the "pressure outside pushing in" caused the balloon's entry into the flask.

The imploding can demonstration challenged and excited students more than the previous two demonstrations. A few groups explained what was occurring very well with little prodding from me, as shown in the diagrams that they drew (Figure 2). I still had two groups who initially offered inadequate explanations:

> "The particles were hot, moving really fast. When the can was put in cold water the particles condensed and BAM, they sucked it all in".

I asked this group if there was another force causing the can to implode and to relate what they just witnessed to the balloon entering the bottle. They still didn't understand. Finally, I had students draw the can and the gas particles. At first they only placed the particles inside the can. I asked if there were any particles anywhere else. Then the students finally realized what was occurring.

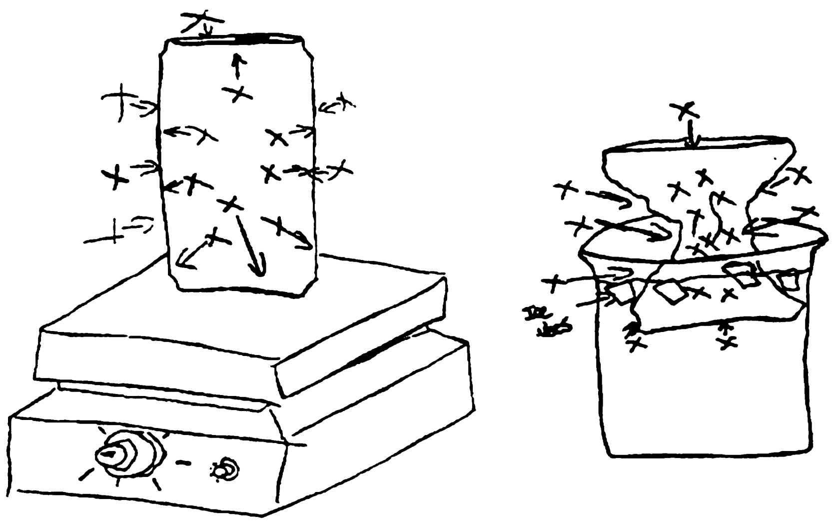


Figure 2: A student's representation of what occurred during the "Imploding Can" demonstration

These three demonstrations were excellent because they excited students and triggered their thinking. A few groups actually extended themselves by figuring out a way to get the balloon out of the bottle – by reheating it. I left this demonstration set up in my room for several days and students had a lot of fun trying to get the balloon to enter and exit the flask. More importantly, I could tell by their discussions that they were applying the principles of the particle theory.

<u>Application Questions of the Particle Theory</u> (Appendix B-V)

To wrap up our introduction to the particle theory, I gave students analysis questions (Appendix B-V) These questions were designed as a final "test" to see if students could independently apply the concepts from the particle theory to every day situations. My students rebelled, however, at having to write out any more answers, so I found it much more effective to discuss these as a group. I was pleased that most groups came up with good explanations for most of the questions. I found I had to help several groups with question 2, which asked why a lid on a jar opens better when hot water runs over it. They understood that particles move faster when heated, but thought the heating of the particles inside the jar – rather than those in the lid itself – caused the lid to loosen. Students had the most problem with question 7, which asked how water moves up a straw when somebody sucks on it. Many offered vague explanations using terms such as vacuum or suction. I again encouraged students to draw the glass of water, the straw, and the air particles. This led to a much better understanding that the air molecules pressing down on the liquid in the glass cause the liquid to move up the straw.

I had originally written two more activities, Lab 1 "Ice to Water" (Appendix B-VI) and "Demonstration of Phase Changes" (Appendix B-VII) to be included in the particle nature section of the unit. Students had shown me, however, that they had a good understanding of the change of position of particles during phase changes, so I chose to skip these activities. I did discuss the "Ice to Water" lab with students. They all accurately classified the melting of ice as a phase change, most saying this was so because the chemical make-up of the water did not change. They also understood the mass of the water does not change as it melts, and I used this opportunity to state the Law of Conservation of Mass.

III. Mixtures and Physical Changes (Appendix C)

Now that students were showing understanding of the particle nature of matter, I wanted them to apply this understanding to the changes matter undergoes. The next five activities of the unit (Appendices C-I through C-VI) dealt with the Law of Conservation of Mass and more importantly, the creation or separation of mixtures through physical changes. During these activities I never defined physical change or mixture for the students, but hoped that in our final discussion students could accurately come up with their own definitions.

Due to lack of time and lab space, I modified Lab 2a: Salt and Water (Appendix C-I) and Lab 3: Salt and Sulfur (Appendix C-III), into a demonstration and discussion. I assumed at the start of this activity that students had a fairly good grasp of physical changes and mixtures. They had just completed a lab exercise in their Earth Science classes in which they had to compare the physical characteristics of different solids. This involved adding water to salt and sulfur and later filtering each mixture. I found during student discussion, however, that many students retained misconceptions about physical changes.

Lab 2: Salt and Water (Appendices C-I and C-II)

The Salt and Water demonstration (Lab 2b, Appendix C-II) simply involved massing salt and water before and after they were mixed. All but two of the students predicted that their mass would not change. These two believed the mass would become less because the salt disappeared. This led to a good discussion after the lab on why the mass did not change. I had students diagram, using X's for salt and O's for water, what occurred, and the rearrangement of particles during dissolving became clear to them. Questions 2 and 5 of the conclusion led to a heated discussion in several groups. These questions asked students to classify dissolving and evaporating as a physical or a chemical change. I found that most students could easily give a definition of physical change, but they could not always recognize one. In one group a student said that dissolving is a physical change because "you can still separate the salt". Then another student drew a diagram of what he believed was occurring during the dissolving process – the sodium, chlorine, and water all combine. He convinced the entire group that a chemical change had occurred because something new was created. The same group later decided evaporation was both a physical and a chemical change. It was a chemical change because the water molecules must split from the salt molecules, but physical because they knew water boiling is a phase change, and phase changes are physical. As I listened to this discussion it was very difficult for me not to intercede and tell students what was occurring. I had difficulty thinking of ways to lead the discussion so that students would realize what was going on at the molecular level inside the glass of water. I therefore let them keep their inaccurate conclusions, expecting that the future labs would straighten out their understanding.

<u>Lab 3: Salt and Sulfur</u> (Appendix C-III)

In lab 3 (Appendix C-III), salt and sulfur were mixed, water was added, then the mixture was separated by filtration. Again, this lab led to good discussion in several groups because students were unsure of how to recognize a physical change. As the following example shows, many could give a good definition of a physical change, but intuitively believed that a physical change is a phase change.

> Student 1: "Mixing salt and sulfur is neither a physical or chemical change."
> Teacher: "What's a physical change?"
> Student 1: "A phase change."
> Student 2: "No, a phase change is only a type of physical change."
> Student 1: "A phase change is when the appearance, shape, or smell changes. When a physical property changes."
> Teacher: "Did this happen?"
> Student 1: "No."

Apparently simply mixing two solids together did not appear to be a significant enough change for Student 1, so he believed no change had occurred. Interestingly, all groups (except for student 1 described above) believed that adding sulfur to water was a physical change, but many still classified mixing salt and water as a chemical change. Again, this showed me that students can recognize a physical change when it is obvious, but not when it is less evident.

Lab 4: Mixture Separation (Appendix C-IV)

In this lab students were given a mixture of five substances and asked to devise a method to separate them. I hoped that students would be challenged and excited to develop their own lab methods, and also that in doing this they would discover that mixtures can be separated by physical methods. Most groups had little difficulty thinking of ways to separate their mixtures and initially worked enthusiastically to separate them. It became apparent during the lab that many had at some point learned the techniques from a text- book or teacher, but never actually done them. For example, a few students were astonished to find salt in their evaporating dish after boiling off the water. These were the same students who earlier believed that salt and water chemically combine. Possibly, this lab brought them closer to believing that evaporation is a physical change. In general, the conclusions to this lab showed me that students understood that substances in mixtures retain their own properties, and these physical properties can be used to separate them.

Lab 5: Chromatography Whodunit (Appendix C-V)

I was at first hesitant to do a chromatography lab with my students because I had assumed they had used the technique earlier. This was new to them, however, and they were very excited to observe the pigment separation of their water soluble markers and to determine the identity of the bank robber. Students had a difficult time understanding Rf values, however, and they struggled when writing a conclusion paragraph explaining chromatography. They had difficulty understanding that different pigments have varying affinities for the chromatography paper.

The main reason I used this lab in my unit was to show students that ink is truly a mixture and to introduce them to another way to separate mixtures. The bright colors that resulted from the chromatography convinced students that ink is in fact a mixture. Most students classified chromatography as a physical change, because "it is still ink" and "you can put the pigments back together". One group, however, was sure that chromatography was a chemical change because "the composition of the ink broke down into several pigments" and "you can not bring these colors back together or get them off the paper". To convince this group I really needed to demonstrate some type of reverse chromatography process. I couldn't do this, but I modeled the chromatography process using different colored marbles on the next day. The three colors of marbles represented different colored pigments. When mixed together they appear black. After chromatography, when certain colors (marbles) only move a set distance up the paper, the colors appear. This model helped students understand the chromatography process, but I am not sure it convinced all students that the pigments weren't originally chemically combined in the ink.

<u>Lab 6: Fractional Distillation</u> (Appendix C-VI)

I originally planned for students to fractionally distill a mixture of water and ethanol over three days, but because of lack of time and lab space this lab was modified into a one-day demonstration. Students observed the different properties of alcohol and water before and after they were mixed. They tested for appearance, smell, solubility and flammability. We then separated the mixture through distillation and tested the products. Although this exercise might have been more beneficial and interesting if students had actually been able to perform the lab themselves, they seemed convinced at the conclusion that water and alcohol retained their own properties when mixed and could be separated by a physical mechanism.

<u>Mixtures and Physical Changes – Conclusion Questions</u> (Appendix C-VII)

The previous five labs were all designed to lead up to this final discussion in which students define mixtures and physical change. I was pleased that none of my students now defined physical change as simply a phase change, as they had on the pre-test and in earlier discussions. Seven students, however, went to the opposite extreme and defined physical change as "when two or more substances are mixed together and can be separated". During group discussion these students modified their answers to include phrases such as "a change that occurs to a substance that does not change its properties". I was especially pleased to notice here that one student who earlier was convinced that dissolving salt into water was a chemical change now used it as an example of a physical change.

In defining mixtures most students initially wrote something along the lines of "a combination of two or more things that can be separated". I was disappointed that most did not mention that substances in mixtures retain their own properties or can be separated by physical mechanism. These came to mind only when I probed students to remember their conclusions from the fractional distillation and mixture separation labs.

In answering question three, "when a mixture is created does the total mass change?", students drew good diagrams using X's and O's to represent particles mixing (Figure 3). This showed me that they were remembering what they learned from our studies of the particle nature of matter and that they had a good grasp of the conservation of mass.

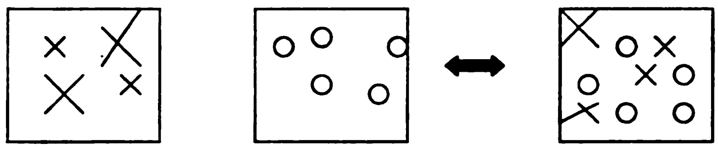


Figure 3. A typical student response to the question, 'When a mixture is created or separated does the total mass change? Explain using the particle theory and sketches."

IV. Compounds and Chemical Changes (Appendix D)

The next phase of this unit was to introduce students to chemical changes and compounds. As when working with physical changes, I was careful not to define either term directly for the students, but lead them to a proper understanding through a series of labs and activities. The basic purpose of the first three labs was to show students that the products of a chemical change have different properties than the reactants. I also wanted them to recognize the different signs of chemical change and understand that the Law of Conservation of Mass applies to chemical changes.

<u>Lab 7: Iron and Sulfur</u> (Appendix D-I)

In this lab students mixed iron and sulfur and recorded the properties of the mixture. They then heated the mixture in a test tube, broke the glowing hot test tube in a beaker of cold water, and observed the iron sulfide that was produced. Students were really impressed by the red-hot glowing iron sulfide during the heating of the tube, the smoke given off when the tube entered the water, and the breaking of the tube. Some were really surprised when they discovered that the product was not magnetic. A few groups used several magnets to be sure theirs was really working. This was a dramatic, simple lab that really hit home with the students. It also came at a good time, because we had just finished defining physical changes so students realized a chemical change had occurred when they saw that when bonded to sulfur, the properties of iron changed.

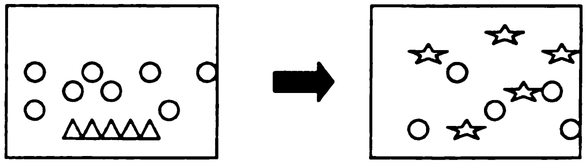
<u>Lab 8: Mixing Two Solutions</u> (Appendix D-II)

Mixing Two Solutions (Appendix D-II) illustrated a different type of chemical change. Students mixed four sets of transparent liquids and in each case a colored precipitate formed by a double-displacement reaction. Students were very impressed and surprised by the sudden color changes. When asked to explain the color change, many students simply responded that it was due to a chemical reaction. When encouraged to be more specific and look at their products more closely, students could see that the color change was actually due to a solid that had been produced. When diagramming the reaction using X's and O's, several students drew their product with the X's and O's unattached, just as they had diagrammed the mixture of water and alcohol. When I pointed this out and asked students "Where did this colored solid come from?", most realized that a new substance must have formed and then adjusted their sketches to attach their X's and O's.

<u>Lab 9: Mass of a Gas</u> (Appendix D-III)

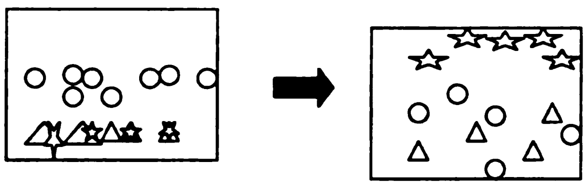
Mass of a Gas was another simple lab in which students dropped an antacid tablet into water and compared the mass of the closed system before and after the reaction. This lab led to more discussion than I had anticipated. Two students predicted the system would gain mass because “you created a gas”, and one predicted mass would be lost because “gas is lighter than solid”. Unfortunately our containers weren’t airtight and the electronic balance was malfunctioning, so students had to take my word for it that the mass did not change. When asked to identify what occurred as a chemical or physical change, several groups classified it as physical because they believed that the bubbles produced represented a phase change as a solid dissolved and turned into a gas. One student claimed it must be a physical change because he was “absolutely positive” he could get the antacid tablet back. Once I told students that the gas being released was carbon dioxide, which is not an ingredient of the antacid tablet, students quickly agreed that the fizzing must be a chemical change.

Another problem arose for many students when they tried to sketch what was occurring during the reaction. Their sketches show that they do not understand that the carbon dioxide was formed from the same atoms that originally were in the antacid tablet. As shown in Figure 4a, one student initially represented the gas given off with stars, though there are no stars shown in the antacid tablet. When I reminded him that the overall mass of the system did not change – which means no new components were added to the system – he realized his error and drew a more accurate representation of the system (Figure 4b).



Key ○ = water △ = antacid tablet ☆ = gas

Figure 4a. Student's original response when asked to sketch the system of an antacid tablet dissolving in water during lab 9, question 5.



Key ○ = water ⛤ = antacid tablet ☆ = gas △ = dissolved solid of antacid tablet

Figure 4b. Student's modified response after discussing question 5 of lab 9.

<u>Questions – Compounds and Chemical Changes</u> (Appendix D-IV)

In order to see if students could accurately define and illustrate chemical changes and compounds, I asked them a set of formal questions at the completion of the labs 7-9 (Appendices D-I, D-II, D-III). I was pleased by their responses to the first question in which they were asked to use X's and O's to represent the change sulfur and iron undergo when heated. All but three of the students clearly showed the X's and O's combining after heating. Students had more difficulty relating this change in particle arrangement to their definition of chemical change. Over half of the students said a chemical change occurs when a substance changes its chemical properties, but only ten out of twenty-four also said this occurs because a new substance has been formed. Students also had vague definitions of compounds, as shown by some sample definitions that follow. A compound is . . .

> "two chemicals that are together."
> "a product made from two substances and can't be separated."
> "two or more elements. Mixtures are two or more compounds."

In comparing compounds to mixtures, nearly all the students somehow mentioned that compounds are formed by chemical changes or by new chemical bonds. But only four students also wrote that in the creation of the compound the product has new properties, whereas in a mixture the components keep their own properties. I was disappointed that students had not picked up more from the three previous labs. Their answers seemed hasty, and they seemed to be relying on their previous knowledge rather than applying what they had just observed during the last three labs.

<u>Lab 10: Decomposition of Water</u> (Appendix D-V)

When discussing compounds and chemical changes, several students had stated that compounds can not be broken apart and chemical changes are irreversible. This was a misconception I hoped to reverse by using electrolysis to separate water into oxygen and hydrogen. I also used this lab to illustrate that the elements in water always combine in a set ratio with one another. Because of lack of equipment, this lab was actually done as a demonstration. Students enjoyed this simple demonstration for several reasons. First of all, they witnessed something that they predicted could not be done. Secondly, by igniting the gases produced, they could clearly see that a chemical change occurred because the products were so different from the reactant. Finally, students could see that hydrogen gas was being produced more rapidly than oxygen, and they could easily measure the volumes of the gases to see that a 2:1 ratio of hydrogen to oxygen was produced.

Questions – Synthesis of Water (Appendix D-VI)

I had hoped to demonstrate the reverse reaction of electrolysis by igniting a 2:1 ratio of hydrogen to oxygen, but only was able to collect enough gas to successfully demonstrate this for one group of students. This is a very exciting (and loud) demonstration that I hoped would have made my students more enthusiastic about answering the synthesis of water questions that I put together. The purpose of these questions is to illustrate to students that hydrogen and oxygen always combine in a 2:1 ratio when water is synthesized, which is the same ratio they observed during the previous lab (Appendix D-V) when water decomposes. Students needed help understanding the experiment and interpreting the photograph on the worksheet. Once they understood this, they easily answered the questions.

Take-home Lab – Physical or Chemical Change? (Appendix D-VII)

Because activities in class had most recently focused on chemical changes, I planned to have students perform a series of simple take-home labs as a way to review the differences between chemical and physical changes. I never assigned this lab, however, because at the time it seemed too elementary for my students. They seemed to have a good understanding of the two types of changes and since students are not offered credit or a letter grade for my class, I doubted that many would have taken it seriously.

Labs 11a & 11b – Synthesis of Zinc Chloride and Modeling a Synthesis Reaction (Appendices D-VIII and D-IX)

Because the semester was drawing to a close, I also did not complete these two labs. In retrospect, I wish I had fit them in because they required good lab skills and also illustrated to students that components of all compounds, not just water, combine in a set ratio. The post-test of this unit demonstrated that students did not fully grasp this concept and one more lab may have settled the idea deeper into their minds.

Demonstrations (Appendix D-X)

As a grand finale to our chemistry unit, students were treated to a series of demonstrations. Students really enjoyed these dramatic reactions, especially those involving combustion. They were asked to classify what they observed as a chemical or physical change. At the end of the hour we used those which were chemical changes to summarize the different signs of a chemical reaction. I also introduced students to chemical formulas and equations on this day. We wrote out the simple reactions on the board, such as magnesium burning and sodium reacting with water. We balanced these together, with students using symbols (such as circles and squares) to diagram these reactions. This led to a good discussion of the meaning of coefficients and subscripts. These concepts were obviously new to my students and they enjoyed thinking through the problems and correcting each other's mistakes.

EVALUATION

Four big questions were considered in order to evaluate the success of this unit. First, did students gain knowledge during the unit? Second, was the knowledge students gained due to their experiences in my class or from their Earth Science class that they were taking concurrently? Third, which activities of the unit were the most successful and worth repeating? Fourth, was the constructivist approach to teaching the particulate properties of matter successful?

To answer the question of whether students gained significant knowledge during the unit, pre-test and post-test (Appendix E) scores were compared using the Wilcoxon matched-pairs signed-ranks test. This statistical measurement was chosen for three reasons. First, because the sample size was so small, it was important to choose a nonparametric test which makes no assumptions about a normal distribution. Second, this test is used when the two sets of scores (pre-test vs. post-test results) are related. Third, this test is preferable to other nonparametric tests such as the Sign test because it accounts for the actual magnitude of the difference between rankings of the individual's pre-test and post-test scores, rather than simply finding a mean negative or positive difference between scores.

Analysis of the pre-test and post-test scores shows a significant improvement with a mean increase of 38.29% (Table 1). I was disappointed that the average on the post-test was only 81.08%, but it is important to note that my students had not studied or reviewed at all before the test because this is a non-graded class. Therefore, these scores are a reflection of what students learned through ten weeks of activities and discussions, rather than what they could have memorized from notes or a textbook.

Table 1: Comparison of pre-test and post-test scores.

Test	n	Mean Score
Pre-test	24	42.79%
Post-test	24	81.08%
Wilcoxon Signed Ranks Test $Z = -4.288$, $p<0.000$		

My next concern was that students might have shown improvement between the pre-test and post-test because of their Earth Science class, not because of my class. The two Earth Science teachers at my school told me that approximately three weeks had been devoted to basic chemistry in the first semester of Earth Science, during the same time-span that my students were working on my matter unit. They had covered all the same concepts of my unit except separation of compounds and writing chemical reactions. Though the two Earth Science teachers had different styles, both taught these concepts in less time than I did, with more lecture and less lab. One teacher devoted approximately 10% of class time to lecture, 80% to lab work or group activities, and 10% to videos or homework. The other teacher devoted 25% of class time to lecture, 45% to lab work or group activities, and 30% to videos or homework.

I used two methods to assess if student improvement on their pre-/post- test was due to their Earth Science class. One was to include two questions about the overlap between my class and Earth Science class in a follow-up student survey (Appendix F). Responses to these questions varied greatly (Table 2 and Table 3), with some students feeling there was a great overlap between the courses, and others feeling there was little overlap.

Table 2. Response to survey question "How much of this unit was also covered in your Earth Science class?"

Response	n	Percent %
None	0	0
A little	7	36.8
Some	8	42.1
Most	4	21.1
All	0	0
Did not respond	1	0
Totals	20	100

Table 3. Response to survey question "How much did your experiences in this unit help you in your performance in Earth Science class?"

Response	n	Percent %
It helped not at all	3	15.8
It helped me a little	7	36.8
It helped me some	5	26.3
It helped me most of the time	4	21.1
It helped me a great deal	0	0
Did not respond	1	0
Totals	20	100

Because student surveys did not give conclusive evidence on whether Earth Science aided students in my unit, I chose to give students a follow-up test (Appendix F) approximately five weeks after the completion of the unit. This test covered the same topics as the post-/pre-test, but was slightly shorter than the original test. The follow-up test was administered to nineteen of my students who were in both my class and Earth Science, and to thirteen other students who were not in my class but in Earth Science. In order to find students with similar abilities to my own students', I selected thirteen students who were either identified as exceptional by their Earth Science teacher and/or as talented and gifted at some point in their education. Students in my class and Earth

Science had a mean score of 77% correct and those just in Earth Science had a mean score of 38% correct (Table 4).

Table 4: Comparison of follow-up test scores between talented and gifted students enrolled in study of matter class and selected students not enrolled in study of matter class.

TAG Participation	n	Mean	Mean Rank	Sum of Ranks
Not In Class	13	38	7.23	94.00
In Class	19	77	22.84	434.00
Mann-Whitney U = 3.000, Z = -4.64, P < 0.000				

These results indicate that students learned in my class, but in which areas were their gains the greatest and which activities were the most effective? To answer this question I analyzed responses to specific questions on the pre-/post- test (Appendix E) and considered responses to the follow-up survey (Appendix G).

Two questions on the pre/post test were designed to test student understanding of and ability to apply the particle theory. Question 1 asked students to observe and explain a demonstration in which a balloon enters a jar of steaming water after the jar is cooled. The improvement in scores on this question was significant (Table 5). Most students left this question blank on the pre-test, but after seeing many similar demonstrations during our unit most got some credit on their post-test answer. I was very disappointed that only eight of my twenty-four students received full-credit on their answers and correctly used the concept of differing air pressures in their explanation. Most understood that air particles slow down when cooled, but many still had the misconception that this slowing down of particles somehow "sucked" the balloon into the flask.

Question 2 asked students to draw particle arrangements after the material was heated and after it was cooled. Improvement on this question was not significant (Table 5). I believe this occurred because most students answered the question correctly on the pre-test. I therefore spent little time specifically discussing phase changes during the teaching of the unit. My only concern is that on the post-test two students changed the size of their particles when heated and cooled. I was unaware of this misconception and need to watch for it in the future.

Table 5. Comparison of pre-test to post-test responses to individual questions on the particle theory.

Question	Points Possible	Mean Item Score (s.d.)	Wilcoxon Signed Ranks Test Asymp. Sig
Pre-test 1a	4	.79 (.93)	Z =-3.394, p= 0.001
Post-test 1a	4	2.38 (1.31)	
Pre-test 1b	2	.88 (.99)	Z =-3.556, p < 0.000
Post-test 1b	2	2.00 (.20)	
Pre-test 2	3	2.67 (.64)	Z =-1.730, p = 0.084
Post-test 2	3	2.92 (.28)	

Student attitudes toward the activities dealing with the particle theory were generally positive (items 1-3, Table 6). Students complained that the discovery stations required too much writing and that some of the stations were repetitive in demonstrating the same concepts. Students were most enthusiastic about the demonstrations.

Table 6. Student responses to follow-up survey question 8 in which they are asked to rank the unit's activities in terms of personal benefit.

Question 8 – Rank each activity using 1 = no benefit 2 = little benefit 3 = some benefit 4 = mostly beneficial 5 = very beneficial 0 = not sure						
	1	2	3	4	5	0
1. Discovery Stations	5%	10%	35%	35%	5%	10%
2. Balloon Entering Flask	5%	5%	30%	40%	20%	0%
3. Imploding Pop Can	5%	5%	5%	45%	40%	0%
4. Discussion – Salt/water, Ice/water .	5%	25%	30%	25%	5%	10%
5. Lab – Mixture Separation	5%	15%	30%	30%	20%	0%
6. Lab - Chromatography	10%	10%	20%	35%	10%	15%
7. Demo – Fractional Distillation	10%	15%	30%	35%	5%	5%
8. Lab – Heating Iron and Sulfur	10%	5%	15%	25%	45%	0%
9. Lab – Mixing Two Solutions	5%	10%	40%	15%	25%	5%
10. Lab – Mass of a Gas	15%	0%	25%	50%	0%	10%
11. Lab – Decomposition of Water	10%	15%	15%	25%	30%	5%
12. Demonstration – Synthesis of Water	5%	10%	15%	45%	10%	15%
13. Final Demonstrations	10%	10%	10%	40%	25%	5%

Students had mixed responses to the labs concerning mixtures and physical changes (items 4-7, Table 6). Only 50% or fewer of the students rated the labs as mostly or very beneficial. In general, many found the labs too basic or somehow repetitive of what they had previously learned in earlier classes. Although the labs themselves are not very dynamic for the students, most triggered good discussion. For example, the salt/water and salt/sulfur labs were so basic that I demonstrated them, but our following discussion was very beneficial. In the mixture separation lab students were generally excited to develop a method to separate their mixture, but actually doing so became tedious. On the other hand, the students enjoyed watching the ink separate during the chromatography lab, but didn't want to put effort into understanding and calculating Rf values. Finally, students were interested by the distillation demonstrations, but may have become more excited and involved if they could have done all three labs as originally planned.

Most students rated the labs related to compounds and chemical changes as more beneficial than the mixture labs (items 8-13, Table 6). These labs took less time, required less work of the students, and they were more exciting than the mixture labs. These labs and demonstrations also were definitely new material for the students, as I observed by their surprised responses.

The most telling evidence on the effectiveness of these labs, was whether or not students had mastered the major objectives of the unit as indicated by results on their post-test (Appendix E). Could students now accurately describe the differences between mixtures and compounds? Only four students responded with what I considered a complete response on this short answer question. Students improved, however, on this question when comparing their pre-test and post-test scores (Table 7, question 4). Most understood that compounds are formed by chemical changes and mixtures are formed by physical changes. Many did not write that compounds have different properties than their reactants, and most missed the concept of compounds and not mixtures forming in set ratios.

Other test questions also provided information about students' understanding of mixtures and compounds (Table 7). Question 5 asked students to classify items as elements, compounds, or mixtures. Students scored fairly well on question 5 on the pre-test (mean score 4.5 out of 6) and their improvement here was insignificant. Question 10 required that students apply the concepts of chemical change and formation of a compound to a real situation. Improvement here was significant. Many students could not answer this question on the pre-test but all gave partially correct answers on the post-test. Question 12 asked students to use symbols to diagram the particle arrangement in mixtures and compounds. Most students could diagram mixtures well on the pre-test, so their improvement on question 12a was insignificant. Students did not understand the particle arrangement of compounds, however, and so they made significant gains on this post-test question (12b) by showing representations of bonding between particles.

Table 7. Comparison of pre-test and post-test responses to individual questions concerning compounds and mixtures.

Question	Points Possible	Mean Item Score (s.d.)	Wilcoxin Signed Ranks Test Asymp. Sig.
Pre-test 4	4	.92 (.83)	Z = -3.993,
Post-test 4	4	2.33 (.87)	P < 0.000
Pre-test 5	6	4.5 (1.67)	Z = -1.512,
Post-test 5	6	5.52 (1.45)	p = .131
Pre-test 10	3	1.04 (.86)	Z = -3.045,
Post-test 10	3	2.42 (1.06)	p = 0.002
Pre-test 12a	1	.75 (.44)	Z = -1.633,
Post-test 12a	1	.92 (.28)	p = 0.005
Pre-test 12b	1	.63 (.49)	Z = -2.828,
Post-test 12b	1	.96 (.20)	p = 0.005

Another major objective of this unit was that students would be able to identify the difference between a physical and a chemical change. Three test questions dealt with this concept and student improvement on all three questions was significant (Table 8). In questions 7 and 8 students had to show how particles would rearrange during a physical change and during a chemical change. On the pre-test most students left this question blank or drew a simple rearrangement of particles in both physical and chemical changes. However, on the post-test most students showed that during the chemical change the particles actually bonded. Question 11 asked students to classify changes as either physical or chemical and explain their answer. Most students gave guesses with little explanation on the pre-test, but on the post-test their reasons for classification were more clear.

Table 8. Comparison of pre-test and post-test responses to individual questions concerning physical and chemical change.

Question	Points Possible	Mean Item Score (s.d.)	Wilcoxon Signed Ranks Test
Pre-test 7	2	.42 (.83)	Z = -3.384, p = 0.001
Post-test 7	2	1.54 (.83)	
Pre-test 8	2	.33 (.76)	Z = -3.661, p < 0.000
Post-test 8	2	1.63 (77)	
Pre-test 11	5	2.67 (1.66)	Z = -3.386, p = 0.001
Post-test 11	5	4.38 (.92)	

The third major objective of this unit was to teach the Law of Conservation of Mass. Only one test question dealt specifically with this concept, and students showed significant improvement on this concept between the pre-test and the post-test (Table 9). Many of the labs of the unit had follow-up questions dealing with conservation of mass, asking students if the mass should change, etc. Students seemed to get tired of these questions and automatically "knew" the correct answer. It was interesting, however, that when this concept was applied in Lab 9: Mass of a Gas (Appendix D-III), not all students were so sure that mass was conserved when carbon dioxide was changed into a gas.

Table 9. Comparison of pre-test and post-test responses to individual questions on conservation of mass.

Question	Points Possible	Mean ItemScore (s.d.)	Wilcoxon Signed Ranks Test
Pre-test 9	2	.50 (.83)	Z = -3.500, p<0.000
Post-test 9	2	1.54 (.83)	

The fourth goal in evaluating this unit is to consider how effective the constructivist approach was as a teaching method. In the follow-up survey (Appendix G) seventy percent of the respondents rated the constructivist teaching style as mostly or very effective (Table 10).

Table 10. Student response to the follow-up survey question, "This unit was based on experiments followed by discussion with no text book or assignments. How effective is this teaching style for you?"

Response	n	Percent Response (%)
Not at all effective	2	10
Slightly effective	0	0
Somewhat effective	4	20
Mostly effective	9	45
Very effective	5	25
Total	20	100

Most of the written comments on the survey (Appendix H) mentioned that they enjoyed the way the unit was taught. For example, one student wrote,

> "I liked the way it was taught. Hands-on activities and actually talking about them made it easier to understand. We covered things more in depth in here then we ever did in science – that was good."

Another interesting student comment mentioned that she enjoyed the hands-on part of the unit, but did not appreciate the self-discovery aspect. She wrote:

> "I liked doing the experiments where something happened. Sometimes I think you could have explained things better because I didn't always get it without a little extra help."

I understood this student's frustrations as I taught the unit. I was determined to use the constructivist approach by having students experience phenomena and come to their own understanding of it. However, I found that this worked better teaching some concepts than others.

In the follow-up survey (Appendix G) none of the students reported that they greatly enjoyed this unit and one reported that he did not enjoy the unit at all (Table 11). None of the students reported disliking the unit because of the constructivist approach (Appendix H). Their negative comments were more general, such as "It got repetitive, [need] more blowing up stuff, etc." and "I liked the experiments, but didn't like all the writing".

Table 11. Student responses to the follow-up survey question, "How much did you enjoy this unit"?

Response	n	Percent Response (%)
Did not enjoy at all	1	5
Disliked	3	15
Indifferent	7	35
Enjoyed	9	45
Greatly enjoyed	0	0
Total	20	100

DISCUSSION/CONCLUSION

My main objective when embarking on the Change in Matter unit was to improve the curriculum for a group of ninth grade Physical Science students. It is unfortunate that I was not able to teach this unit as intended. Comparison of student groups who were taught by the old approach and by the new approach would have been the best test of effectiveness of this unit. By switching to a new school in a very different situation, I had to change some of my goals for the unit and adapt many of the planned activities. Despite this, I found I had many successes with the unit and also noted several areas for improvement.

The most significant changes I had made in this unit were to teach it using the constructivist approach and to introduce the unit with an introduction to the particle theory. These changes were moderately effective, as shown by student responses on the follow-up survey (Appendix G and H) as well as student improvement between the pre-test and post-test (Appendix F). Most of the students really enjoyed learning by doing, and I enjoyed teaching this way. Because this class focused on carrying out activities and discussing the results, I believe my students were more involved in their work and were more actively engaged in thinking than they would have been in a traditional lecture style class. Many did not, however, come away with an exceptionally good set of facts about matter. I think this was due to the lack of reading, homework, and lecture in my non-credit class. If I were to teach this unit to a traditional science class, I would definitely try to maintain the constructivist approach, but follow it up with some good reading and meaningful homework assignments.

Not all students learn well by the constructivist approach and not all topics are appropriate for the constructivist approach. I felt the constructivist approach worked well in teaching the particle theory because there were many ways to demonstrate related concepts such as air pressure and these demonstrations led to lots of discussion. It was more difficult to use the constructivist approach when helping students to identify types of change. For example, students had difficulty deciding if salt dissolving in water was a chemical or physical change because they could not actually see if the salt molecules were bonding with the water molecules. Later experiments, such as that showing evaporation, led most students to the conclusion that dissolving was a physical change. But some students were still not convinced because they could not actually see what was going on at the particle level. I eventually used symbols to diagram the salt dissolving for these students. If I had left them to completely discover what dissolving is without my intervention, I don't think they would have had a complete understanding of the process. I believe that my student's post-test scores would have been higher if their lab work and discussion had been reinforced by the traditional means of learning.

I also found that the success of the constructivist approach depends on the dynamics of the group of students. I had one group of three students who learned a lot because they were enthusiastic and enjoyed discussion. Another group of two did not learn very much because one student was very negative and apathetic and the other followed suit. I also found that some students did what the constructivist approach intended – they processed information well and followed laboratory observations with their own explanations. Other students, however, did not seem to do very much of their own thinking, basically taking their conclusions from their more thoughtful peers.

I also believe that using the constructivist approach would be much more difficult with a classroom of many students. Having a facilitator who is able to monitor individual student thinking and lead discussions in the proper direction is crucial to the constructivist approach. I was successful because I dealt with no more than six students at a time. Once a class gets too large, individual monitoring would be difficult.

Another effective addition to the unit was to begin with extensive work on the particle theory. Learning to visualize particles and their motion helped students to understand the differences between mixtures and compounds. By the end of the unit students readily diagrammed many of their problems using concepts based on the particle theory. I think this is because they had been thinking in terms of particles since the first days of the unit. I now can't imagine trying to teach any type of chemistry without first introducing students to the particle theory. This is the foundation to a conceptual understanding of chemistry.

There are several aspects of this unit that could be improved. As mentioned earlier, more homework and readings could be developed as reinforcement to the labs. Some of the labs need to be modified. One common complaint of students was that they felt that the same concept was constantly being readdressed. They got tired of being asked whether an experiment demonstrated a physical or chemical change and if it involved a compound or a mixture. However, results comparing the students in my unit verses those just in Earth Science (Table 4) indicate that reinforcement of concepts does aid understanding. The trick is to reinforce the same concept in different ways, while still maintaining a fun learning environment. Perhaps if I move at a faster pace by emphasizing more discussion and less writing students will remain enthusiastic. Moving faster would also provide more time to study chemical reactions, writing formulas, and writing equations, which the students found challenging and enjoyable.

Students least enjoyed the labs dealing with mixtures and physical change. Lab 4, Mixture Separation (Appendix C-IV), dragged into three days and should be simplified to be completed in one day. Several other labs were changed to demonstrations due to time constraints. I think this section would have been more enjoyable to students if I had done a better job preassessing the students' knowledge, and then cutting out some of the more elementary activities like Lab 1, Ice to Water (Appendix B-V). This would allow time to complete the more challenging labs such as Lab 6, "Fractional Distillation" (Appendix C-VI)

Students really enjoyed the early demonstrations dealing with air pressure (Appendix B-IV) but six weeks later many could not adequately explain a similar situation on the post-test. To remedy this problem, I should spread out some of these demonstrations, as well as the Discovery Station activities (Appendix B-III), throughout the unit. If I use them as warm-up activities, students will be periodically reminded of the particle theory and possibly better internalize and apply its concepts.

One unfortunate modification of my unit from the previous year was that I dropped the emphasis on learning how to write a formal lab report. Because mine was a non-credit class, I had to concentrate on keeping students excited and involved. Requiring formal written lab reports of already busy students would not have been successful. I do believe this is a very important skill, however, and I will incorporate it into my plans when I teach a for-credit science class in the future.

I also did not place as much emphasis on lab technique as I had during the previous year. Students learned measurement techniques in their Earth Science classes, and still learned some separation skills such as chromatography, distillation, and evaporation during my unit. I found that by teaching some of these basic skills (and skipping others such as fractional crystallization), my students finished the unit with a good mastery of both lab skills and basic concepts of matter. This is preferable to the end result of my previous year, when the curriculum focused so much on lab skills that students never mastered the concepts the labs were designed to teach.

The development and teaching of this unit has made me a better teacher. Studying and using the constructivist approach has taught me that the process by which students learn is just as important as the final product. I've learned that good teaching requires good understanding of students' knowledge and beliefs. Some manner of pre-testing at the beginning of a unit should always be used so the teacher can appropriately challenge students by avoiding already understood concepts. After students begin a lab or witness a demonstration, constant monitoring by questioning and discussion is necessary to keep students focused and to help the teacher steer the students' thoughts in the proper direction. Final discussion of concepts with peers further brings out active thinking and hopefully clarifies concepts for all in the class. Follow-up independent reading and homework assignments should be used to reinforce these concepts and help a student process their ideas. In this method of teaching students aren't bored and aren't required to memorize many facts that will soon be forgotten. They are motivated to understand and actively problem solve.

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APPENDIX A

RESOURCES-Developing Content

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APPENDIX B-I

Part I: Particle Nature of Matter

The following activities are designed to introduce students to the particle theory. After participating in the activities students will hopefully understand the following concepts:

1. All matter is made of particles that take up space and have mass.
2. The molecules in matter are always moving.
3. As a material is heated, its particles move faster and faster. When it is cooled, the particles move more slowly.
4. Matter usually exists in one of three phases: solid, liquid, or gas. The phases differ in mobility and relative position of molecules.
5. Materials change phase at temperatures where the speed of the molecules affects the arrangement of the molecules.

<u>Outline of Activities</u>

Day 1: Demonstrations
Student observations
Discussion

Day 2/3: "Discovery Stations"

Day 4: Discussion
Demonstrations
Student assessment questions

APPENDIX B-II

Particle Nature of Matter Demonstrations

Students will observe the following demonstrations. They will keep track of their observations in the first two columns of a three column table, with the headings:

Demonstration Observations __________________.

After completion of the demonstrations I will ask them to fill out the third column, which they will label What This Means About Matter. We will then discuss the third column and hopefully this will illicite a list of the basic objectives listed above. The molecular model demonstrator kit will be used to help visualize these concepts.

Demonstrations: Fill balloon with vanilla and pass around the room.

Place a drop of alcohol on each student's hand.

Place iodine in an Erlenmeyer Flask, heat briefly over a Bunsen burner. Remove from heat and place a watch glass over the flask.

Pass a sealed syringe around the room. Compare to an opened syringe.

Open a bottle of perfume or almond extract at one end of the room.

Drop a few crystals of potassium permanganate in a large graduated cylinder. Wait several days. (Students add this to their observation chart later.)

APPENDIX B-III

Discovery Stations

Students will spend approximately ten minutes at each station. They will perform each activity in groups, discuss the accompanying questions with their group members, and then write out individual answers which they will turn in. The activities will be discussed as a class at the conclusion of the activity.

Station 1: EMPTY BEAKERS

MATERIALS: Beaker, Tub of Water, Paper

PROCEDURE:
1. Wad a piece of paper and place into the bottom of the beaker.
2. Invert the beaker above the water.
3. Press the beaker down on the water.
4. Lift the beaker straight up and examine the paper.

QUESTIONS:
1. When the beaker is pushed straight down into the water, what is keeping the water from entering the beaker? Sketch or explain what is happening on the particle level.
2. How could you get water to enter the beaker once it is in the water? Try this and then explain on the particle level why your method works.
3. What do we mean by an "empty" container? Could devise a way to truly empty a container?

Station 2: FOOD COLORING IN WATER

MATERIALS: beaker, food coloring, two colored pencils

PROCEDURE:
1. Fill the beaker 3/4 full of water.
2. Drop three drops of food coloring into the beaker.
3. Observe without moving the beaker.

QUESTIONS:
1. Write down your observations.

2. Suppose you had on "Magic Glasses" which allow you to see inside the beaker at a level so magnified you can make out individual particles. Use two colored pencils to draw the particles of food coloring and water at the time you first put in the coloring, after 5 minutes, and after the beaker is completed colored.

3. How would this experiment differ if the temperature of the water was near boiling? near freezing?

Station 3: CANDY IN WATER

MATERIALS: two peppermint candies, two beakers, hot water, cold water, three colored pencils

PROCEDURE:
1. Fill one beaker 3/4 full of hot water, the other 3/4 full of cold water.
2. Simultaneously drop the candies into each beaker.
3. Observe for about 10 minutes.

QUESTIONS:
1. Suppose you had on "Magic Glasses" which allow you to see inside the beaker at a level so magnified that you can make out individual particles. Sketch the candy molecules in each beaker of water at the start of the experiment, after 3 minutes, and at ten minutes.

2. Explain why the candy in one beaker dissolves faster than the candy in the other beaker.

3. Notice the peppermint smell in the air above the beakers. Explain how this smell gets into the air.

4. Sally repeats this experiment at home, but puts one candy in 200 ml of cold water and the other in 50 ml of hot water. Will her results differ from your experiment? Explain.

Station 4: DUST IN THE AIR

MATERIALS: Overhead projector, two chalkboard erasers

PROCEDURE:
1. Stand in front of the overhead projector and clap two dirty erasers together.
2. Turn on the overhead projector.

QUESTIONS:
1. Why don't the dust particles fall to the ground?
2. Some cities have "smog alerts" in which they caution people to stay indoors on days when the pollution is high. What is air pollution and why is it damaging to people?

Station 5: DANCING DIME

MATERIALS: empty small mouth bottle stored in freezer, dime

PROCEDURE:
1. Obtain the empty bottle from the freezer.
2. Wet the rim of the bottle.
3. Place a dime over the mouth of the bottle.
4. Hold the bottle in both of your hands. Be sure the dime stays completely over the opening of the bottle.

QUESTIONS:
1. Describe what happens.
2. Was the bottle really empty? Explain.
3. Use the particle model to explain why the dime danced.

Station 6: MOVING MOTHFLAKES

MATERIALS: Moth flakes, hotplate, Erlenmeyer flask, watch glass

PROCEDURE:
1. Place a small spoonful of moth flakes in the bottom of the flask
2. Heat gently on the hotplate. Observe.
3. After the flakes have melted, place the watch glass over the flask and turn off the heat. Observe.

QUESTIONS:
1. Moth flakes have a very strong odor. How does the odor leave the flakes and get to your nose?
2. Why does the odor of the moth flakes increase with heating?
3. Sketch the particles of the moth flakes . . .
   a) in the flask when they are a solid
   b) after they have melted
   c) in the air
   d) on the watch glass
   indicate relative position and movement of the particles in your answer.

Station 7: BALLOON IN A BOTTLE

PROCEDURE:
1. Carefully observe the balloon in the bottle.

QUESTIONS:
1. How did the balloon get into the bottle?
2. Ask your teacher and try to make it happen!

Station 8: RULER FLIP

MATERIALS: Ruler, large sheet of paper, table top

PROCEDURE:
1. Place the ruler on the edge of the table so one end is overhanging.
2. Hit the overhanging end of the ruler.
3. Place the ruler on the edge of the table as in step 1 and then cover the ruler & table with the sheet of newspaper.
4. Hit the overhanging end of the ruler.

QUESTIONS:

1. Record your observations.

2. Explain the differences between what happened in steps 2 and 4.

Station 9: STOP THE LEAK!

MATERIALS: 2 Liter pop bottle with hole cut near bottom.
water
sink

PROCEDURE: *Do all of the following over the sink!*

1. Hold your finger over the bottle's hole and fill the bottle 2/3 with water. Observe for a few seconds.

2. Screw the top of the bottle on tightly. Observe

QUESTIONS:

1. What happened when you screwed the top onto the bottle? <u>Why</u> did this occur?

2. Sally had a large can of juice for her children. She poked one hole in the lid of the can and tried to pour out juice, but only a trickle left the can. But when she poked a second hole opposite the first hole, the juice easily poured out. Explain.

APPENDIX B-IV

Demonstrations and Discussion of Particle Nature

Discussion of the "Discovery Station" activities

Demonstration: Coat the rim of an Erlenmeyer flask with petroleum jelly. Heat a small amount of water in the flask. Place a balloon over the top of the flask and place the flask in cold water. Observe.

Questions for students:

1. Why did the balloon enter the flask?
2. What happens to the air particles in the flask as the flask is heated? cooled? Do the particles outside the flask change?
3. Draw the flask, balloon and the particles before the flask is heated, during heating and after the flask is placed in the ice water. Show the relative motion and position of the particles.

Demonstration: Heat a small amount of water in an empty pop can. Remove the can from the water, invert it, and quickly place the can in a beaker of ice water. The can will implode.

Questions for students:

1. Why did the can implode?
2. What happens to the air particles in the can as the can is heated? cooled? Do the particles outside the can change?
3. Draw the can and the particles before the can is heated, during heating, and after the can is placed in the ice water. Show the relative motion and position of the particles.

Demonstration: Stick a suction cup to the wall, or stick two suction cups together.

Questions for students:

1. What force is holding the suction cups together?

Demonstration: Observe the graduated cylinder with potassium permanganate from day 1.

Questions for students:

1. Why has the cylinder turned purple?
2. Why do you think the movement of these particles take so long as compared to those in the candy lab?

APPENDIX B-V

Application Questions of the Particle Theory

1. We celebrated my daughter's January birthday last year with a party and gave helium balloons to each of the guests as they left the house. One little girl walked outside with her balloon and stated crying because her balloon wouldn't float. When she walked back into her house to get a new balloon hers became inflated again and we thought everything was fine. But after she left the house, the balloon seemed to lose air. Did it lose air? Explain what occurred.

2. Recall the demonstration of the metal ball and ring from the first day of demonstrations. Three students came up with different ideas as to why the ball got bigger with heating. Which one do you think is correct? Support your answer.

> Bill: "The ball gets bigger because the particles in the ball expand when heated."
>
> Bonnie: "The ball gets bigger because you are adding heat molecules to the ball."
>
> Barbara: " The ball gets bigger because the particles in the ball move farther apart when heated"

3. I couldn't open the metal lid on my glass jar of pickles. My grandmother told me to run hot water over the lid and then try to open it. I did and it worked! How can you explain this?

4. Bridges which cross large bodies of water are not paved all the way across, but usually have metal grating in the middle. Why do engineers design the bridges this way?

5. In the summer as I drive down the expressway I notice many blown out tire carcasses from trucks. I never see so many in the winter. How can you explain this?

6. The air pressure on each square inch of your body is 15 pounds. If there is so much air pushing down on you, why don't you collapse to the ground?

7. I dissolved some sugar in water. My little brother said "The sugar disappeared". My little sister said "No, the sugar melted". Is either of them correct? How can you explain this to them so that they will understand?

8. Explain why water moves up a straw when somebody sucks on it.

APPENDIX B-VI

LAB 1: **ICE TO WATER**

Introduction: As ice melts the particles contract and the volume changes. The purpose of this lab is to determine if the mass also changes.

Procedure:

1. Mass a small container with its cover (or a ziploc bag). Record data.
2. Add ice and mass again. Record data.
3. Melt the ice.
4. Mass the bag and water. Record data
5. Calculate the change in mass between the melted water and the ice.(#4 - #2)

Conclusion

1. What can you conclude about the change in mass as ice melts?
2. How would condensation on the outside of your container effect your results? What should you do about it? How did the condensation occur?
3. How does this activity show that ice and water are really the same?
4. *After doing the class activity,* draw two sketches -- one of the ice and one of the water. Show position and movement of the particles in your answer.

APPENDIX B-VII

ACTIVITY: **DEMONSTRATION OF PHASE CHANGES**

This activity is designed to accompany lab #1, Ice to Water. Students will act as molecules in order to demonstrate how the position and motion of the particles change as water changes states.

Give students the following instructions: *You are each a particle of water. You will change from being a solid, to a liquid, and finally a gas. When I say the following states, be sure you are doing the following:*

solid: *You must be touching the same two people at once, but you must be moving.*

liquid: *You must be touching two people at all times, but you must find a new person to touch every second.*

gas: *You must be constantly moving in a straight line. If you touch someone or* ***something you must move away in the opposite direction.***

APPENDIX C-I

LAB 2a: **SALT AND WATER**

Introduction: In this lab you will dissolve salt in water and observe the mass change. Then you will try to recover the salt from the water.

Part I: Dissolving Salt

Procedure:

1. Fill a small plastic container with cap 2/3 with water.
2. Mass the container, cap, and water. Record.
3. Your teacher will tell you how much salt to mass out. Do this and record.
4. Mass the container with water, cap, and salt before they are mixed. Record.
5. Add the salt to the water, cap the container, and shake until all is dissolved.
6. Mass the container with the salt. Record.
7. Calculate the change in mass between the container and ingredients before they are mixed and after they are mixed.

Save your salt water and container for Part II

Conclusion:

1. Compare the change in mass you calculated in #7 with the other groups in your class. Explain why there may be different values.
2. What do you conclude about the mass of salt and water as it dissolves?
3. Was this a physical or chemical change? Explain.
4. Evaluate the following statements students have made when observing this lab:
   a. "The salt vanished into nothing"
   b. "The salt melted"
5. Explain with words and/or sketches what occured in this lab.

Extension (optional) People claim that when salt dissolves in water the combined volume of the salt and water after the experiment is less than the total volume of the two before they are mixed.

1. Design and carry out an experiment to test this hypothesis.
2. Explain your results.

Part II: Recovery of Salt

Introduction: Is the salt from Part I gone forever, or can we get it back out of the water? In this lab you will attempt to recover all the salt that you had started with yesterday. This is very difficult to do. You need to read the procedure carefully and practice good lab technique! Record your data in a data table.

Procedure:

1. Mass an empty evaporating dish and watch glass.
2. Pour the salt water from Part I into the dish.
3. Partially cover the dish with the watch glass and heat *gently* over a Bunsen burner until the dish appears to be dry. Do not heat too quickly or splattering could occur.
4. Allow the dish to cool, then mass dish and watch glass again.
5. Calculate the change in mass (#4 - #1)

Conclusion:

1. What happened to the water as you heated the solution? Was this change physical or chemical? Explain.
2. Compare the amount of salt you recovered to the amount you started with.
3. Each group started with a different amount of salt in Part I. Did adding more or less salt change what happened in this experiment? Explain.
4. What does this experiment show you about what happens to salt when it is added to water?
5. One source of salt is seawater. Propose a practical method to remove salt from seawater.

APPENDIX C-II

LAB 2b: **SALT AND WATER – conclusion questions following demonstration.**

1. What can you conclude about the mass of salt and water as it dissolves?

2. Was this a physical or chemical change? Explain.

3. Evaluate the following statements students have made when observing this lab:

    a. "The salt vanished into nothing"

    b. "The salt melted"

4. Explain what happened in this lab using words and sketches.

5. Design an experiment in which you could recover the salt that was added to the water. Would this involve a chemical or physical change?

6. Does the amount of salt added to the water effect what happens in this experiment?

7. People claim that when salt dissolves in water the combined volume of the salt and Water after the experiment is <u>less</u> than the total volume of the two before the Experiment. Design an experiment to test this hypothesis.

APPENDIX C-III

LAB 3: **SALT AND SULFUR**

1. Add about 1/2 teaspoon salt to 1/2 teaspoon sulfur in a petri dish. Mix.

2. Use a hand-lens or microscope to observe the salt and sulfur.
   a. Sketch what you see.

   b. Have the salt and sulfur joined or are they separated?________________

3. Was this a physical or chemical change? Explain. ______________________

   ____

4. Add about 30 ml of water to the salt and sulfur. Stir for several minutes.

   a. Which substance is soluble? Insoluble?______________________

   b. Was this a physical or chemical change? Explain.____________________

   ____

5. Fold filter paper into a cone and place into a funnel as shown to you by your teacher. Place the funnel over an Erlenmeyer flask and pour the liquid through the funnel.

   a. What solid is left on the filter paper. Explain your answer. _________

   ____

   b. What do you think happened to the salt? How could it be recovered?

   ____

6. Would using different amounts of salt and sulfur in this lab affect your results? Explain.____

7. When salt is mined from the Earth it is mixed with many solid impurities. Propose a method to refine salt from these impurities.

   ____

<u>Extension</u>: Propose a method to separate a mixture of salt, sulfur, sand and water.

APPENDIX C-IV

LAB 4: **MIXTURE SEPARATION**

You will receive a mixture containing the following components:

Sodium chloride (salt)
Sulfur or sawdust
Iron Filings
Sand
Potassium Nitrate (insoluble in cold water, soluble in hot water)

Procedure

1. Each of the items listed above is on display in the lab. Examine each and make a chart comparing the properties of each.

2. Examine your mixture. Are the properties of each component still evident in the mixture?

3. Devise a method to separate the mixture into the five components. The following materials are available for your use: four test tubes, filter paper, small funnels, distilled water, Bunsen burners or hot plates, magnets.

4. Give evidence to show that the identity of each of the separated components is the same as the components placed in the original mixture.

Analysis:

Your lab book should contain the following components by the completion of this lab.

1. A chart describing the properties of all substances in the mixture.

2. Answer to #2 above.

3. A flow chart diagramming your procedure with a sample of each of the mixture's components in a baggy and affixed to the chart in the proper location.

4. Evidence that each of the separated components is the same as the original components in the mixture.

5. A discussion of the following statement: "Separation techniques depend upon one or more specified physical properties of the components being separated". Include in your answer at least five concrete examples from this lab.

APPENDIX C-V

LAB 5: **CHROMATOGRAPHY WHODUNIT?**

Introduction

Baylorville Bank has just been robbed of $120,000. The teller who dealt with the robber says the person was masked, about 5'8". He walked in, pulled out a black pen and wrote "I have a gun. Give me $ - or else" on a piece of white paper. After the teller emptied the cash drawers and handed over the money, he left on foot leaving the note behind. Police were notified only minutes after the robber left the bank. They quickly apprehended five suspicious looking people, all about 5'8''. Each carried a black pen. Now the police are coming to you, a team of forensic scientists. You must analyze the ink in each of the pens to determine which matches the ink from the robbery note.

Background

Black ink is actually a mixture of many different pigments. These pigments can be separated using a technique called paper chromatography. A spot of ink is placed near the end of filter paper. Then the tip of the paper is placed in a solvent which is usually water or alcohol. The ink will dissolve in the solvent as the solvent moves up the paper. The pigments in the ink have different solubilities and different affinities for the paper. Therefore they will absorb to the paper at different rates. When the chromatography is complete, the distance in which the pigment traveled is described using the Rf value. The Rf value is calculated by dividing the distance which the pigment traveled by the distance which the solvent traveled.

Materials

water
300 ml Erlenmeyer flasks
chromatography paper cut into 2 cm x 20 cm strips
black markers from each of the suspects
original ink sample from robber

Procedure

1. Set up your chromatography apparatus as demonstrated by your instructor.
2. You must separate each of the inks from the suspects and the robber using paper chromatography. Decide as a group how you will most efficiently do this.
3. Calculate the Rf values of the ink.

Results

Person	Sketch of basic color bands *(use colored pencils)* + Rf val.
Robber	______________________________
Suspect #1	______________________________
Suspect #2	______________________________
Suspect #3	______________________________
Suspect #4	______________________________
Suspect #5	______________________________

Conclusion

Write a paragraph which will be presented in the trial of the robber. State who you think the robber is and then support yourself using the evidence you just created. In order to be convincing your statement must also explain the technique of paper chromatography and show that it is a valid, reliable method to separate mixtures.

General Question

1. Is the separation of ink a physical or chemical change? Explain.

2. Ink is a mixture of pigments. You have shown this by separation. Could you put these pigments back together to create ink? If yes, propose a method.

Extension

1. Are purple, green, or red inks mixtures? Experiment to find out.

2. We used washable, or water soluble inks in this activity. Some inks are permanent. What solvent could be used to separate them? Do black permanent markers contain the same pigments as nonpermanent markers? Experiment to find out.

APPENDIX C-VI

LAB 6: **FRACTIONAL DISTILLATION**

Introduction: In this experiment you will separate a mixture of two colorless liquids - water and isopropanol. These two liquids look identical so it is difficult to know when you have actually separated them. Therefore, you will first examine the properties of alcohol and water. Then you will mix the two together and then try to separate them by fractional distillation. Finally, you will compare the properties of the fractions to the original liquids to see if you successfully separated the mixture.

Part I : Properties of Water and Isopropanol

Procedure:

Follow each of these procedures for the water and isopropanol. Create a data table to show your results.

1. Smell the sample. Classify the odor as strong, moderate, or nonexistent.
2. Test for flammability by rolling a piece of paper towel into a point. Dip the end in the liquid and try lighting the end of the moistened paper. Be sure to hold the flaming end upright and do this above the sink in case the paper burns. Extinguish any fires immediately.
3. Place about 1/4 ml of sugar in a test tube. Add 1 ml of the liquid. Stopper and shake. Does the sugar dissolve?
4. Determine the density of the liquid. Density equals mass divided by volume. Write out the procedure you use and your calculations in your lab book.
5. Determine the boiling point of the liquid. Set up the apparatus as shown on the instructor's desk. Add 5 ml of water and two boiling chips to the test tube. Record the temperature every 30 seconds from the time the Bunsen burner is turned on until only a little liquid remains in the test tube.
   Graph the results in a time vs. temperature graph.

Conclusion:

1. Use full sentences to summarize the differences between alcohol and water.
2. Which of these properties do you think you could use to separate a mixture of alcohol and water? Develop a procedure to separate these two liquids for tomorrow's lab.

3. Think about what happened in steps 2, 3, and 5. Classify each as a chemical or physical change. Explain.

Part II: Fractional Distillation

Procedure:

1. Set up the apparatus as shown on the front desk.
2. Add 25 ml of the water/isopropanol mixture and several boiling chips to the test tube.
3. Heat the test tube gently - just so the liquid boils. If the liquid starts to boil up into the tubing, lower or remove the flame.
4. Record the temperature every 30 seconds.
5. You should begin collecting your first filtrate when the mixture begins boiling. The temperature should stay constant. Collect liquid in this tube until the temperature starts to rise. Switch test tubes and stopper and label the first tube "Fraction 1".
6. When the temperature levels off again, switch tubes. Stopper and label this tube "Fraction 2".
7. Collect liquid in the third tube until only a small amount of mixture remains in the original test tube. Stopper and label the third collecting tube "Fraction 3".
8. Create a time vs. temperature graph of the distillation. Draw arrows on the graph where you switched test tubes.

Conclusion

1. What do you think is in each of your fractions? Explain.

Part III: Properties of the Fractions

The purpose of this part of the lab is to test your fractions to see if you successfully separated the alcohol and water.

Procedure

1. Repeat the procedures from Part I #1-4 to determine the properties of fractions 1, 2, and 3. Be careful! If you only have a small amount of fraction, order the tests so that you do not waste any material.

2. Present your data in a table.

Conclusion

1. Were you successful in separating the mixture into alcohol and water? Explain using your results from part I and part III and by stating what the major components of each fraction was.

2. What were the difficulties you encountered using this procedure? How could you improve the purity of your fractions?

3. When water and alcohol are added together do you believe a new substance is created? Explain your answer.

4. Classify each of the following as a chemical or a physical change. Explain.
   - mixing alcohol and water
   - separating alcohol and water by fractional distillation.

APPENDIX C-VII

MIXTURES AND PHYSICAL CHANGES - CONCLUSION QUESTIONS

Labs 2,3, and 4 have all involved physical changes and mixtures. We made mixtures, observed their properties, and separated them. Review these past labs then answer the questions below. Use your own words.

1. Define physical change. Give several examples of physical changes.

2. Lab 1 involved water which is a pure substance and not a mixture. Labs 2, 3, and 4 involved mixtures. In your own words explain what a mixture is and explain how it differs from a pure substance.

3. When a mixture is created or separated does the mass change? Explain using the particle theory and sketches.

4. State whether each if the following is a mixture or pure substance. If you say it is a mixture, give a method you could use to separate the mixture into its parts.

substance	mixture?	method to separate?
milk		
Kool-Aid		
Pop		
Vegetable Soup		
Sugar		
Salad Dressing		
Salt		
Coffee		
Gasoline		
Total Cereal		
Cinnamon		
Aluminum foil		
Brass		
Diamond		
Penny		
Stainless Steel Fork		
Sterling Silver Fork		
14 Carat Gold Ring		
Nail		
Baking Soda		

Follow-up

Discuss the questions -

Be sure students get the proper definition of mixture which includes
- a combination of two or more substances
- substances combine in any proportion
- substances retain their own properties and compostion when mixed.
- mixtures can be separated using physical changes

Be sure students get the proper definition of physical change -
- any change in matter which does not result in a change in identity

Examples include
- filtration
- boiling
- freezing/melting
- cutting
- dissolving
- mixing

Discuss question 4

Brass is a mixture, 1/3 copper, 2/3 zinc
Sterling silver is a mixture, 7% copper, 93% silver
Stainless Steel is a mixture of iron, chromium, nickel, and iron
Nail is mainly iron - some are pure substaces
Penny is a mixture of copper and zinc
Pewter is a mixture of tin, copper, bismuth, and antimony

Extension-

Have students bring some of these items in from home and actually try to separate them using the procedures they devised.

APPENDIX D-I

LAB 7: **IRON AND SULFUR**

Introduction: Earlier we worked with a mixture of iron, sand, sulfur, and salt. You found the iron was easily separable from the mixture using a magnet. Today we will heat a mixture of iron and sulfur and examine the results.

Procedure:

1. Examine the sulfur and iron. Describe the texture, odor, color and magnetism of each.
2. Mass out 1.75 g of iron and 1.00 g of sulfur. Combine them in a test tube.
3. Heat the mixture over a Bunsen burner until it glows.
4. Place the hot end of the test tube in a beaker of cold water.
5. Remove the iron and sulfur.
6. Examine the product and describe the texture, odor, color and magnetism.

Conclusion:

1. How did the product differ from the reactants?
2. Was this a physical or chemical change? Explain.
3. Would you consider the product a mixture of a compound? Explain.

APPENDIX D-II

LAB 8: **MIXING TWO SOLUTIONS**

Introduction: What happens when two solutions are mixed? Is something new created? Does the mass increase?

Materials:
balance
solutions A, B, C, D, and E in disposable pipettes
wax paper squares

Procedure:

1. In your results section, describe each solution. Consider appearance, odor, viscosity, etc.

2. Mass one square of paper, the pipette with solution A, and the pipette with solution B. Record the mass.

3. Place 10 drops of solution B on the paper, add 10 drops of Solution A. Record your observations.

4. Mass the paper with the mixed solution and pipettes A and B. Record.

5. Repeat steps 2-4 with pipette A and C, A and D, and A and E

Results

Observations of Original Solutions

A:

B:

C:

D:

E:

solutions	mass before	mass after	mass change	observations of mix.
A&B				
A&C				
A&D				
A&E				

Conclusion:

1. Did your mass change when the solutions were mixed? Compare your results to other groups.

2. Where do you think the new colors came from? Explain.

3. Sketch the particles in solution A & B when they were in their own pipettes and also after they were mixed.

4. Repeat #3 for solutions A & E.

5. How could you separate these mixtures and get the two solutions back to their original states?

6. Did mixing these solutions involve chemical or physical change? Explain.

Notes for Instructor

Solution A= lead nitrate (15 g solid in 100 ml water)
Solution B= sodium iodide
Solution C=sodium chloride
Solution D=copper sulfate
Solution E=Epsom salt (magnesium sulfate)

precipitates = lead iodide, lead chloride, lead sulfate

LAB 9: MASS OF A GAS

Introduction: In this experiment you will mix a solid with water and create a gas.

Procedure:

1. Fill a plastic bottle 2/3 full of water.
2. Mass the bottle with water, its cap, and 1/4 antacid tablet.
3. Drop the antacid tablet in the bottle and *quickly* screw on the lid.
4. When the antacid tablet has dissolved, mass again and record.
5. Loosen the cap of the bottle, and mass again.
6. Calculate the change in mass between steps 4 and 2 and steps 5 and 2.

Conclusion:

1. What were the bubbles that formed when the tablet was added to the water? How did they form? What were they made of?

2. How did these bubbles differ from the bubbles you observed when water boils?

3. Did the mass between #2 and #4 change very much? (compare with other groups) Explain this.

4. What did you hear when you loosened the lid in step 5? What was this? How do you know?

5. Sketch the particles in this system in steps 2 and 4 of the procedure.

6. Could you get the antacid tablet back out of this solution? Explain.

7. Is adding antacid tablet to water a chemical or physical change? Explain.

APPENDIX D-IV

QUESTIONS: **COMPOUNDS AND CHEMICAL CHANGE**

The last three labs involved mixing two substances and creating a new substance called a *compound. The changes you observed were chemical changes. Review those labs, then answer the questions below.*

1. Let X's represent iron. Let O's represent sulfur.
   a) Iron and sulfur are mixed. Draw this mixture at the particle level.

   b) The mixture of iron and sulfur is heated over a Bunsen burner until it glows red. Draw the product at the particle level.

2. Define chemical change using your own words. Give examples of a chemical change.

3. Define compound. How is it different from a mixture?

4. In lab 7 (Mixing Two Solutions) a new solid appeared. In lab 8 (Mass of a Gas) a solid disappeared. In both cases, the mass did not change. Explain how this could have occurred.

Instructor's Notes for Discussion

A chemical change is one in which the identity of a substance changes. Signs of chemical change include creation of a precipitate, gas, light and heat given off, heat absorption.

A compound is a pure substance that can not be easily separated. The substances that make up a compound do not retain their properties when chemically joined. Later labs and activities will show that the elements in compounds join in a set ratio with each other.

APPENDIX D-V

LAB 10: **DECOMPOSITION OF WATER**

Introduction In the last two labs you created compounds. In this lab you will learn how to take a compound apart. Water is a compound. We know it is not a mixture because it does not breakdown after heating, freezing, filtering or distilling. To separate it into simpler parts a new technique called electrolysis must be used.

Procedure

1. Set up the apparatus as demonstrated
2. Invert a test tube filled with water over each electrode. Do not allow any air bubbles to enter the test tubes.
3. Connect the battery and wait about 15 minutes, or until one test tube is atleast half filled with gas.
4. Disconnect the battery and mark the waterline with a was pencil.
5. Remove the test tubes from their clamps but keep them inverted.
6. Place a lighted splint into each tube. Record your observations.
7. Use water displacement to calculate the amount of gas which collected in each tube.
8. Calculate the ratio of the volume of hydrogen to the volume of oxygen.
9. Create a data table showing the class results for volume of hydrogen, volume of oxygen, and ratio of volume of hydrogen to volume of oxygen

Conclusion

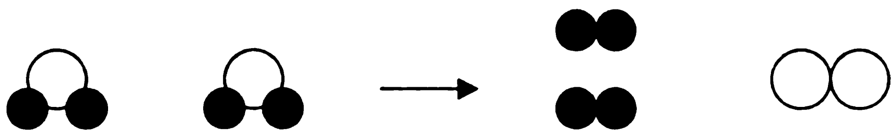
1. Each group started with a different amount of water in their beaker. Did this effect the ratio of hydrogen to oxygen that resulted when the water decomposed?

2. Would you classify electrolysis as a physical or chemical change? Explain.

3. Compare the properties of the hydrogen gas and oxygen gas to the water you started with. How does this provide evidence that water is a compound and not a mixture?

4. Johnny told you that after completing electrolysis of water he gathered 18 ml of hydrogen. Assuming no experimental error, how much oxygen did he collect? How do you know?

5. Examine the diagram below which shows the decomposition of water on the particle level. Then answer the following questions.



WATER → HYDROGEN + OXYGEN

$2H_2O \rightarrow 2H_2 + O_2$

A. What compound did we start with?______________________________

B. What two elements make up that compound?______________________

C. What two elements did we end up with?____________________________________

D. How many atoms of hydrogen did we start with?_________ end with?________

E. How many atoms of oxygen did we start with?__________ end with?_______

F. If we had a means of measuring the mass of the system before and after electrolysis, do you think it would change? Explain.

____

____

<u>Extension</u>

1. Calculate the mass of hydrogen and oxygen produced in the lab. Then calculate the mass ratio of hydrogen to oxygen. (Use the following in your calculations: density of oxygen = 1.3×10^{-3} g/ml and density of hydrogen = 8.4×10^{-5} g/ml)

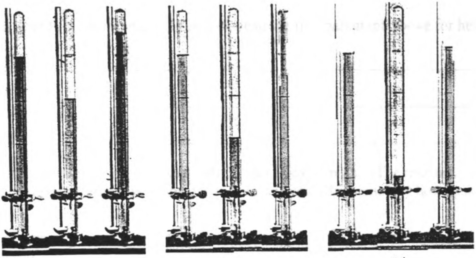
2. Repeat #1 using the data from at least three other groups. How does the mass ratio compare?

APPENDIX D-VI

QUESTIONS: **SYNTHESIS OF WATER**

We discovered in lab 9 that when water is decomposed it always breaks down into a ratio of two parts hydrogen to one part oxygen. What happens when a mixture of hydrogen and oxygen gas are ignited to form water? Do the gases always get used up in a two to one ratio?

An experiment was done to answer this question. Three test tubes (a, b, and c) were set up. Each of the photographs firsts shows each tube after 1 part oxygen has been added by water displacement. The second photograph in each series shows the tubes after a certain amount of hydrogen was added to the oxygen. Then the mixture of gases was ignited and some gas is left over. The left over gas is shown in the third tube of the series. Study the diagram below and then answer the following questions.



(a) (b) (c)

(Source: Introduction to Physical Science, 4th ed., p122)

1. Assume one part oxygen was added to each tube a, b, and c. Look at the second photo of each tube. How much hydrogen was added to the oxygen? (State 1 part, 2 parts, or 3 parts).

   tube a has ________________ parts hydrogen

   tube b has ________________ parts hydrogen

   tube c has ________________ parts hydrogen

2. In which tube a, b, c were all the gases used up after the mixture was lighted? ___

What was the ratio of Hydrogen to Oxygen in this tube?_________

3. One gas was left over in tube C. Which do you think it was?__________

Approximately how much gas was left over?________________

What was the ratio of Hydrogen to Oxygen in this tube?_______

4. In tube A one gas was left over. Which gas?_________

Approximately how much gas was left over?___________

What was the ratio of Hydrogen to Oxygen in this tube?___________

5. What does this experiment tell you? (Reread the first paragraph above for help)

____

____

____

6. 300 ml of hydrogen gas is mixed with 300 ml of oxygen gas. The mixture is lit and water forms. Will any gas remain? If yes, which one and how much?

____

7. Determine the mass of the gas that remains.
(Density of Oxygen = 1.3×10^{-3} g/ml , Density of Hydrogen = 8.4×10^{-5} g/ml)

8. A mixture of 350 ml hydrogen and 300 ml oxygen is ignited. What mass of water is formed?

9. Diagram the synthesis of water on the particle level. Remember the Law of Conservation of Mass!

APPENDIX D-VII

TAKE HOME LABS: **PHYSICAL OR CHEMICAL CHANGE?**

Choose a minimum of two of the labs shown below. You must choose either Lab 1 or Lab 2, and either Lab 3 or Lab 4. Ask your parents permission before doing any of these labs. Perform each lab, record your observations, and answer the conclusion questions. Finally, perform at least one lab for one of your parents (or another adult). Explain the lab to them using the conclusion questions. Then have your parent complete the form at the back. Turn in your lab write-ups and the form by ______________________.

LAB 1 - Black Sugar

Materials

sugar
aluminum foil
cookie sheet
oven

Procedure

1. Place a piece of aluminum foil on a cookie sheet.
2. Place one teaspoon of sugar on the foil.
3. Place the cookie sheet in the oven and set the oven to 400 degrees.
4. Wait 15 minutes.
5. Turn off the oven and remove the cookie sheet.

Questions

1. Record at least 10 observations. Include observations of the sugar before and after heating and include observations of what occurred while heating.

2. If you look at the bottom of the sugar after heating you will see small holes. What do you think created the holes?

3. The formula for sugar is $C_6H_{12}O_6$ - it contains atoms of carbon, hydrogen, and oxygen bonded together. Do you think this compound turned into a new substance? If yes, what was produced and how did this occur?

4. Name several other food products which undergo a similar change as sugar did when heated.

5. Would you consider this change to be chemical or physical? Explain.

LAB 2 - Why do pennies shine?

Materials

Shiny, new penny
aluminum foil
cookie sheet
oven

Procedure

1. Put a piece of aluminum foil on a cookie sheet.
2. Place the cookie sheet in the oven.
3. Set the oven temperature to 400 degrees.
4. Wait at least 30 minutes.
5. Remove the penny.

Questions

1. Record at least 5 observations of the changes which occurred.

2. If you had massed the penny before and after it was heated, you would find that it gained mass. What do you think occurred as the penny was heated?

3. Would you consider this change physical or chemical? Explain.

4. If you look at many pennies you will find the older ones tend to be darker and less shiny. Relate this to the experiment you just did.

5. Pennies are coated with copper. Can you think of other metals around your house which also undergo the same change as a penny?

6. Is there any way you could get your penny shiny again? Describe you method and try it! What happens?

LAB 3 Baking Soda

Materials Baking Soda
Cup
Water
Vinegar

Procedure
1. Add a teaspoon of baking soda to 1/4 cup water. Observe.
2. Add a teaspoon of baking soda to 1/4 cup vinegar. Observe.

Questions
1. Write down atleast four observations for each experiment.
2. Did the baking soda and water undergo a chemical or physical change? Explain.
3. Did you create a compound or a mixture in step 1? Explain.
4. Did the baking soda and water undergo a chemical or physical change? Explain.
5. Did you create a compound or a mixture in step 2? Explain.

LAB 4 Sugar

Materials sugar
water
yeast
two cups

Procedure
1. Add one teaspoon of sugar to 1 cup of luke-warm water. Observe.
2. Add one teaspoon of sugar to 1 cup of luke-warm water, then add 1/2 package of yeast. Observe.

Questions
1. Write down at least four observations for each experiment.
2. Did the sugar and water undergo a chemical or physical change? Explain.
3. Did you create a compound or a mixture in step 1? Explain.
4. Did the sugar, water, and yeast undergo a chemical or physical change? Explain.
5. Did you create a compound or a mixture in step 2? Explain.

LAB 5 What's In A Glass Of Water?

Materials: water
clean cooking pot
stove

Procedure:

1. Fill a cooking pot with water and let it stand at room temperature for 2 hours. Observe the sides of the pot carefully.
2. Pour most of the water out, and heat the water on the stove until the pot is dry. (Warning: Turn off the burner just before all the water is gone) Observe the sides of the pot, and scrap the sides with a knife.

Questions:

1. What formed on the sides of the pot in step one? Where did they come from?

2. What was left on the sides of the pot in step two? Where did it come from?

3. Were the changes which occurred in steps one and two chemical or physical? Explain.

4. Is water out of the tap a mixture or compound? What is your evidence?

APPENDIX D-VIII

LAB 11A: SYNTHESIS OF ZINC CHLORIDE

Introduction Hydrogen and oxygen join in a definite ratio no matter how much oxygen and hydrogen are mixed together. Do zinc and chlorine also combine in a definite ratio? In this lab you will dissolve zinc in hydrochloric acid to form zinc chloride. Each lab group in the class will start with the same amount of hydrochloric acid, but add different amounts of zinc. A solid, zinc chloride, will form. You will mass the zinc chloride and determine the mass of zinc used up. Then you will calculate the ratio of zinc to zinc chloride and compare this ratio to that of other groups.

Materials:
- zinc
- hydrochloric acid
- balance
- large test tube
- 250 ml beaker
- cold water
- evaporating dish
- Bunsen burner
- safety glasses
- ring stand
- graduated cylinder

Procedure:
1. Mass zinc
2. Place zinc in a test tube, add 10 ml hydrochloric acid, and put the test tube in a beaker of cold water. (this reaction gives off a lot of heat!)
3. Let tube stand overnight to be sure the reaction is complete.
4. Mass empty evaporating dish.
5. Pour liquid from the tube into the dish.
6. If zinc remains in your test tube, wash it with 5 ml of water, and pour the the water into the evaporating dish.
7. Dry the zinc and mass it
8. Heat the evaporating dish *slowly* until only solid remains.
9. Continue to heat until the solid starts to melt. Remove from heat.
10. Cool the dish and mass.

Data: Create your own table which neatly shows the data you gathered during the procedure and the data you calculate below.

Calculations: Calculate the following:

1. Mass of zinc that reacted
2. Mass of the product (zinc chloride)
3. Mass ratio of zinc that reacted to zinc chloride produced.

Conclusion:

1. Compare your ratio to that of other groups. Did the fact that you started with different amounts of zinc cause the ratio to differ?
2. What are some sources of error that would cause your results to differ?
3. Was this a chemical or physical reaction? What evidence do you have?
4. Describe the properties of the zinc and hydrochloric acid which you started with. How are they different from the zinc chloride created?
5. Is the zinc chloride produced in this lab a mixture or compound? What is your evidence?
6. Sketch on the particle level what you think occurred during this experiment.

Extension:

1. Suppose that in the synthesis of zinc chloride, you dissolved 3 g of zinc.
   a) how much product would you get?
   b) what would be the ratio of zinc to the product?

APPENDIX IX

LAB 11B: **MODELING A SYNTHESIS REACTION**

Introduction What is occurring on the atomic level when atoms of zinc and chlorine combine? Why do they always combine in the same proportions when added together? This lab will model the synthesis of zinc chloride and help you visualize what just went on in your test tube! You will be given a box of nuts and bolts. Each nut will represent one zinc atom and each bolt will represent one chlorine atom. To represent the synthesis of zinc chloride you will join the nuts and bolts together.

Procedure

1. Obtain a box of nuts and bolts. The nuts represent chlorine (Cl) and the bolts represent zinc (Zn).
2. Separate the nuts from the bolts and mass each set. Record in a data table.
3. Calculate the mass ratio of nuts to bolts. Record.
4. Answer conclusion questions 1 and 2.
5. Now create the compound zinc chloride whose formula is $ZnCl_2$. To do this attach 2 nuts to one bolt. Make as much of the compound as your supply will allow. It's okay to have leftovers!
6. Mass out all your compound. Record in a second data table.
7. Determine the mass of zinc used in your compound.
8. Calculate the ratio of the mass of zinc which reacted to the mass of zinc chloride produced.
9. Record all this information in a data table and then answer the remaining conclusion questions.

Conclusion Questions

1. Compare the mass ratio of nuts and bolts in your box to that of other groups.

2. Would you consider the contents of your box to be a mixture or pure substance? Explain.

3. How did step 5 of the procedure represent a chemical change?

4. Compare your ratio of zinc to zinc chloride with other groups. Does the ratio depend on how big a sample you make?

5. Compare your ratio in this lab to the ratio from Lab 10 in which we actually made zinc chloride. How come the ratios are not the same?

6. Was there a reactant in excess in your model? How did this effect the mass ratio of the compound you created? Which reactant(s) were in excess for you during yesterday's lab?

7. How does this model provide evidence that zinc chloride is a compound?

8. When zinc and chlorine combined to make zinc chloride in yesterday's lab, do you think just one zinc chloride molecule was formed or were many formed? Explain.

9. How could you show a decomposition reaction using this model? Could you also provide evidence for the Law of Conservation of Mass? Explain.

APPENDIX D-X

FINAL DEMONSTRATIONS/ Questions

Burn Magnesium

1. Is this a chemical or physical change? Explain.

2. Magnesium is combining with oxygen to make magnesium oxide. Sketch out this reaction on the particle level.

Sugar in Sulfuric Acid

1. Physical/chemical change?

2. Was a new substance created? Where did the black mass come from?

3. If this is massed before and after the reaction, it loses mass. Does this show the Law of Conservation of Mass is false? Explain.

Heat Potassium Chromate

1. Was this a physical or chemical change? Explain.

Decompose Ammonium Dichromate (Shakashiri p. 81)

1. Was this a physical or chemical change? Explain.

Ethanol in A Jug (or methane bubble)

1. Physical or Chemical change? Explain.

2. Ethanol burns with oxygen to produce carbon dioxide and water. Diagram this reaction.

Sodium in Water

1. Sodium reacts with water to from sodium hydroxide and hydrogen gas. Diagram this reaction.

Gummi Bear in Melted Potassium Chlorate

Iron Oxide and Aluminum Powder (Thermite Reaction)

Fe_2O_3 + Al ----> Al_2O_3 + Fe

use magnesium ribbon as fuse, light with propane torch, if add nails touching will fuse

Do outside.

Two Solutions

Mix two solutions - one of HCl, the other of NaOH

1. Was this a physical or chemical change?
   Pour plain HCl over zinc, a reaction should occur
   Pour the mixture over zinc, a reaction should not occur
2. Did the new liquids in the new solutions retain their identies? (no)
3. Was this a physical or chemical change?

Waft NaOH and HCl vapors together

1. Was this a physical or chemical change?
2. How does this provide evidence that invisible gases are made of molecules?

APPENDIX E

PRE -TEST/POST-TEST

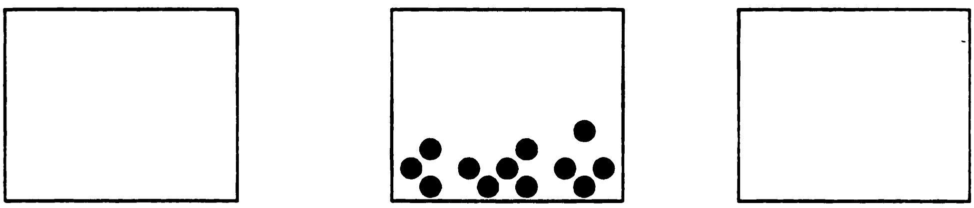
CHANGES IN MATTER

Directions: *Answer all questions to the best of your ability. You may use diagrams or sketches in your answer.*

1. a) Watch the demonstration of the balloon in the jar. Explain how the balloon entered the flask.

   b) How could you get the balloon out of the jar without touching the balloon?

2. The sketch in the middle shows molecules in the liquid state.
   In the box on the <u>right</u> draw what the box would look like if it was <u>heated.</u>
   In the box on the <u>left</u> draw what the box would look like if it was <u>cooled.</u>



3. Distinguish between an atom and a compound.

4. Distinguish between a compound and a mixture.

5. Classify each of the following as an element, compound, or mixture

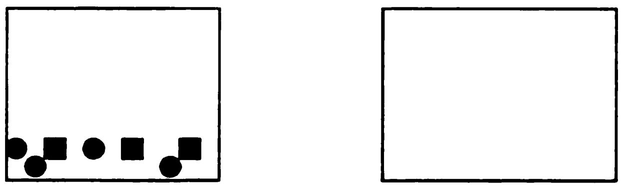
copper______________ ice____________________

lemonade______________ tea______________________

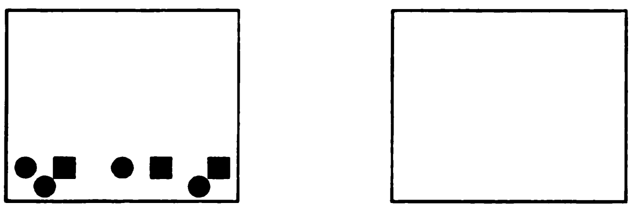
salt water______________ oxygen__________________

6. How might you separate a mixture of sand, salt, and sawdust?

7. In the box to the right, draw what would happen to the substance in the left box if it underwent a <u>physical change.</u>

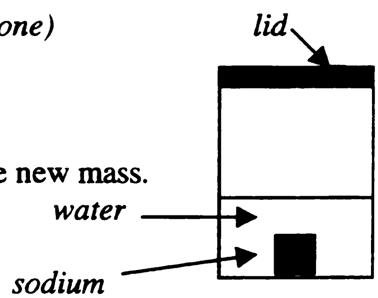


8. In the box to the right, draw what would happen to the substance in the left box if it underwent a <u>chemical change</u>.



9. A piece of sodium was dropped into a large flask with a small amount of water as shown in the diagram. The mass of the flask and its contents equaled 510 grams. The sodium caught fire and let off smoke until it all burned. After cooling, the flask and its contents were massed again.

a) Would you expect the final mass to be . . .*(circle one)*
   A. More than 510 grams
   B. 510 grams
   C. Less than 510 grams
   D. Not enough information to judge the new mass.



b) Explain your choice:

10. If you eat pure metallic sodium you will die. If you inhale chlorine gas you will die. If you mix the two together you create something to sprinkle on your popcorn to make them taste better. Explain what is going on!

11. Classify the following changes as physical or chemical. Give a reason for each answer.

    a. Purifying salt out of seawater

    b. Water boiling to steam

    c. Wood burning to ashes

    d. Mixing copper and zinc to make brass

    e. Digesting a banana

12. Assume all matter is made of particles X, Y, and Z. They are represented by the following symbols:

X = ■ Y = ▲ Z = ●

Use these symbols to show the following in the boxes below:

A mixture of X, Y, and Z

A compound made of X and Y

A sample of pure X

13. Propose a method you could use to

a) separate the mixture of X, Y, and Z

b) separate the compound of X and Y

14. Use the above symbols to represent a substance with the formula

X_2YZ_2

15. Use the above symbols to represent the following reaction:

$$X_2Y + 2Z \rightarrow X_2YZ_2$$

APPENDIX F

Matter Unit Follow-up Test March, 2000

The following questions are designed to assess how much information you have retained since our science unit this fall. Please think hard about each question and answer it to the best of your ability.

1. One way to empty the contents of an egg without breaking the shell is to poke holes in both ends and blow the contents out. Another much faster way is to again poke holes in each end, but rather than blowing the egg out, do the following:

   1. Soak a cotton ball in alcohol
   2. Drop the cotton ball in an Erlenmeyer flask.
   3. Drop a match into the flask to light the cotton ball.
   4. Immediately place the egg over the opening of the flask.

   As soon as the cotton ball stops burning and the flask cools slightly, the contents of the egg should immediately come out into the flask. Explain how this occurs. Use your knowledge of the fundamentals of nature in your explanation.

2. State at least TWO differences between . . .
   a. An atom and a compound

   b. A compound and a mixture

3. Classify the following as a compound, element, or mixture

   Gold____________ Carbon dioxide______________

   chicken noodle soup________

4. Propose a method to separate:

   a. a mixture of alcohol, water, and salt

   b. water into hydrogen and oxygen

5. When both are placed on a scale, a jar of water with a lid and a 10 pop rocks have a mass of 25 g. The pop rocks are placed in the water and the lid is placed on the jar immediately. The pop rocks fizzle and let off a gas and are no longer visible. You mass the jar and its contents again.

   a) Would you expect the final mass to be
      a. more than 25 g
      b. less than 25 g
      c. 25 g
      d. not enough information to judge the new mass

   b) explain your choice

6. Water , H_2O, is essential to life. Hydrogen peroxide, H_2O_2, is toxic and bleaches hair. How can each contain the same elements, yet be so different?

7. Assume all matter is made of particles X, Y, and Z. They are represented by the following symbols

X= ■ Y= ● Z= ▼

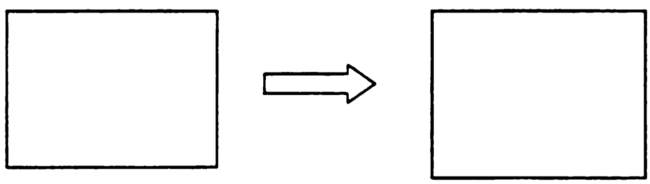
Use these symbols to show:

a) A mixture of X, Y, and Z

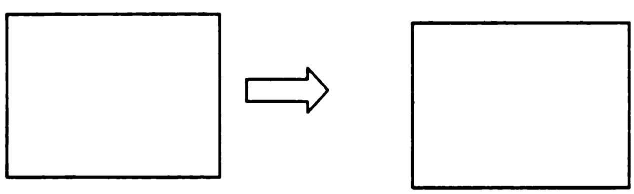
b) A compound with the formula $X_3Y_2Z_3$

c) The following reaction: $2X + Y_2 \rightarrow 2XY$

d) A physical change



e) A chemical change



APPENDIX G

STUDY OF MATTER UNIT – Follow-up Survey for Participants

Please answer the following as honestly as possible. Your honest responses will help me evaluate this program and make changes for next year.

1. How much did you enjoy the science unit we had during second quarter?

1	2	3	4	5
did not enjoy at all	disliked	indifferent	enjoyed	enjoyed very much

2. How much do you enjoy science in general?

1	2	3	4	5
do not enjoy at all	dislike	indifferent	enjoy	enjoy very much

3. How much of what we covered in the ESC unit was also being covered in your Earth Science class?

1	2	3	4	5
none	a little	some	most	all

4. This unit was based on experiments followed by discussion with no textbook assignments. How effective is this teaching style for you?

1	2	3	4	5
not at all effective	slightly effective	somewhat effective	mostly effective	very effective

5. How much of this unit would you recommend be repeated next year?

1	2	3	4	5
none of it	a little of it	some of it	most of it	all of it

6. How much did your experiences in this unit help you in your performance in Earth Science class?

It helped me . . .

1	2	3	4	5
not at all	a little	some	most of the time	all of the time

7. **Please explain what you liked/did not like about this unit. How can it be improved?**

Please rank the following activities on a scale of 1-5, with 5 meaning you really found the activity valuable and enjoyable and 1 meaning you felt the activity was by no means beneficial.

"Discovery Stations" (dancing dime, ruler flip, "stop the leak")

no benefit	little benefit	some benefit	mostly beneficial	very beneficial	not sure
1	2	3	4	5	0

Demonstration – Balloon entering flask

1 2 3 4 5 0

Exploding Pop Can

1 2 3 4 5 0

Discussion – Salt/water, Ice to Water, Mixing Salt and Sulfur

1 2 3 4 5 0

Lab – Mixture Separation

1 2 3 4 5 0

Lab – Chromatography (separation of ink on filter paper)

1 2 3 4 5 0

Demo – Fractional Distillation (separation of liquids)

1 2 3 4 5 0

Lab – Heating iron and sulfur

no benefit	little benefit	some benefit	mostly beneficial	very beneficial	not sure
1	2	3	4	5	0

Lab – Mixing two solutions (and forming a colored solid)

1	2	3	4	5	0

Lab – Mass of a gas (antacid tablet and water)

1	2	3	4	5	0

Decomposition of Water (by electrolysis)

1	2	3	4	5	0

Synthesis of Water (by igniting the gases H_2 and O_2)

1	2	3	4	5	0

Demonstrations (sodium in water, burn magnesium, sugar in sulfuric acid, etc.)

1	2	3	4	5	0

APPENDIX H

Individual student written responses to the survey question, "Please explain what you liked/did not like about this unit. How could it be improved?".

"I liked doing the experiments where something happened. Sometimes I think you could have explained things better because I didn't always get it without a little extra help."

"[I] liked what we were doing – hands on!…[I] disliked writing so much."

"[want] more hands-on – discussion more as a class"

"I liked that it was mostly hands-on projects. It could be improved by maybe doing things once a week and not repeating so many of the concepts."

"Really enjoy science, learned a lot."

"[Want] more things we won't learn in Earth Science."

"I liked the way it was taught. Hands-on activities and actually talking about them made it easier to understand. We covered things more in depth in here than we ever did in science – that was good."

"It was cool doing all the things about physical/chemical changes – but some of the writing was weird."

"[I liked] the hands-on and visual parts of it"

"It was every other day so it was kind of hard to remember what happened in every experiment. I don't know how that could be improved."

"I liked the experiments but didn't like all the writing."

"I liked the experiments/hands-on part of the unit. I think it could cover a larger variety of subjects."

"I liked the labs."

"Do some of the experiments [again next year] and [add]some new ones."

"I didn't like how it took time out of doing my homework but I thought the experiments were good."

"I didn't like moving to a different room."

“It got repetitive, [need] more blowing-up stuff, and such.”

“I didn’t like it”

“Nothing much needs changing”