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1999 Volume V: How Do You Know? The Experimental Basis of Chemical Knowledge

Discovery Through Experimentation - Past and Present

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Overview

The idea of learning about one's surrounding through experimentation goes as far back as the 1600's. It was during that time that a French scholar, Pierre Gassendi, "was on of the first to suggest that the proper way of learning about the universe was to carry out experimentation.".1 Vast amounts of information pertaining to the make up of the world around us came from men using experiments to make investigations. This is especially true in chemistry. Much of the understanding of the structure of molecules and even their existence, not to mention atoms, was obtained in this fashion.

As stated in Professor McBride's seminar description of "How Do You Know? the Experimental Basis for Chemical Knowledge", it is much more beneficial for science students to "understand the logic of inference from experimental evidence" than to just accept information on the basis of being told. The goal of this unit is to allow students to gain an understanding through personal experience and a historical look at certain scientific discoveries of how research works. It can be used as an introduction to a major chemistry unit of a physical or integrated science course. A unit on matter that would include the definition of matter, explanation of the properties of matter (physical versus chemical, volume, mass, and density), as well as the states of matter and its phases should be covered before this one is used. Students should also be familiar with the metric system and how to use it in taking measurement. It may be necessary, depending on the backgrounds of the class to begin the unit with a review on how to conduct an experiment. The unit should take between two and three weeks. This would depend on where one starts with the unit. The target audience would be high school students who have very limited science backgrounds regardless of what grade level they are in. My hope is that upon completion of this unit, students will have gained an appreciation for the information they will learn; recognizing that the facts just didn't come out of thin air but came from evidence obtained through actual experiments. Perhaps this will facilitate their future learning.

During the first week or following the review, students will perform various activities and experiments. The purpose of this is to give the students practical and personal experience in obtaining information about something through experimentation. These exercises will investigate the following topics:

1. Physical properties of matter.
2. An example of a chemical reaction.
3. The use of experiments to gain indirect evidence on an object.

The second week will involve the students studying a few experiments that were done in the past. These will come from the history of chemistry. The objective for this part of the unit is that by studying the purpose, procedure, and results of these experiments, students will be able to give examples of the types of information scientists can gain from experimentation.

Week One

Investigating Physical Properties of Matter

Introduction

Experiments can be used to investigate the physical properties of matter. But what is matter? Another question would be, what is meant by the term physical properties. Matter is defined as anything that has mass and occupies space. The phrase “occupies space” is self explanatory. Another term for this phrase is volume. Mass on the other hand is defined as a measure of the amount of matter that a substance or object contains.

Physical properties are the ways scientists use to describe matter of any kind. An analogy would be if one asked to describe another person. In giving a description several physical features would be mentioned; such as the person’s height, body build, eye and hair color. So it can be said that physical properties are characteristics of a material. Some examples are: the color of something, its texture, whether or not it has an odor, if it does, what kind of odor, hardness, the object’s mass, volume, and density. (Density is the mass of a material per unit volume of that material.)

During the first two activities of this section air is examined. The question of seeing if air occupies space is looked at first. Following this a comparison of air to another gas is made. In the third activity certain physical properties will be used by students to compare and contrast different materials.

Activities

This section begins with assessing the class’s knowledge about air. The students are told the following scenario:

They have received a message from a sister and brother who have been

marooned on a small island somewhere in the Pacific Ocean. They have had no

contact with the world since they were five and six years old. They are now six-

teen and fifteen years of age. Being very intelligent, they have succeeded in building a communication device in which they can pick up conversations

While they are waiting for help to arrive, they happened to hear a discussion

going on in your classroom about air. The word “air” puzzles them. So they

have sent you a message inquiring about what is air.

Tell the students that their job right now is to spend the next five to ten minutes writing a description of air that can be sent back to the island. Ask for a few volunteers to read their descriptions. As they read, make a list on the board of the properties or characteristics of air that are mentioned. If the fact of air having volume (taking up space) does not come up, bring it up in the form of a question. If it is mentioned, ask the class how can they prove it. This will lead into the first activity designed to show that air takes up space. Students can work in small groups. They are given a five or eight ounce plastic cup (clear is better, but not necessary) and a sheet of paper towel. A source of water deep enough for the cup to be completely submerged is also needed for each group. (It is best if this is done near a sink). Instruct students to ball up the paper towel and insert it into the cup so it won’t fall out. The paper towel should not take up the entire volume of the cup. Demonstrate to the students how to place the cup into the water, as well as how to remove it from the water. The cup should be carefully submerged upside down into the water without tilting the cup in anyway. In other words, the cup should be slowly pushed straight down. After totally submerging the cup, slowly bring it straight up and out of the water; again be careful not to tilt the cup. When the cup is out of the water, dry the outside and bottom rim while it is still upside down. Then have each group remove the paper towel and examine it. The paper towel should be dry. Following clean up, discuss with the class what they observed. Have them give explanations for why the towel was dry. If there where any groups who did not get dry paper towels, tell them you will get back to them. The discussion should be guided to the place of air. No two things can occupy the same place at the same time. Since volume is the amount of space that something takes up (in its simplest definition), this would prove that air has volume.

In the next activity the students again are divided into groups. Each group is given a large paper bag containing two inflated balloons. One balloon contains helium. The other will contain air. Students are not told what each balloon contains; only that each balloon contains a different gas. The contents of each balloon will be compared in two ways. First the groups will drop the balloons at the same time and write down their observations. One should rise (the helium balloon). The other should float to the ground. The second comparison involves observing which balloon will deflate quicker. Balloons will be left in the classroom for four days. Using a string the diameter of each balloon will be measured once a day. Observations can be recorded on the following chart.

BALLOON DIAMETER IN CENTIMETERS

Day 1 Day 2 Day 3 Day 4

A

B

On the fourth day the students can answer the following questions:

1. Which balloon deflated faster? How do you know? (Explain your answer).
2. How do you think the gas got out of the balloon?
3. Give an explanation for why one gas escaped faster.
(Hint: It is very similar to why one gas was lighter.)

These questions should lead the class into realizing that the particles that make up the two gases found inside the balloons are different in both mass and size. After going over the questions, the class can be told the identity of the two gases. Summarize the lesson by asking them: “Based on this experiment, how can we compare air and helium?”

Teacher’s note: the helium balloons can be bought at a party store. The balloons used for air should be the same king as the helium balloons and inflated at the same time. (The day before is suggested.) Strings should be attached to the helium balloons for easy management.

Finally during the third activity of this first section, students will examine seven liquids and three powders. They will obtain information about these substances through observation. In describing each liquid, they will take note of color, odor, and viscosity (resistance to flow). When they examine the powders, they will observe texture, color, and shape of the particles that make up the powder. These are the liquids to be used: rubbing alcohol, Kayro syrup, oil , vinegar, hydrogen peroxide, water, liquid dish detergent (preferably yellow in color). The powders are: salt, baking soda, and any type of plain white powdered detergent. Both types of samples have been chosen so that some are very similar in appearance, but differ by their physical properties once one begins to examine them a little further. A small amount of each sample is placed in a clear covered container. (I suggest plastic pert dishes.) The samples are placed on a counter; depending on the size of the class, more than one observation stations may be set up. Students are to record their observations for the previous mentioned properties. A magnifying glass is used to examine the shape of the particles. The students will be tempted to want to identify the materials instead of observing the properties. Emphasize that you are more interested in the description of each item, rather than its identity. Tell the class that they will be told what each sample is at the end of the activity. Once the observations have been made, discuss them. Compare and contrast the properties of the liquids and those of the powders. Point out how the powders all have the same color, but differ in texture, and particle shape. Explain how these kinds of differences are helpful when you are learning about a new substance just discovered or are trying to understand the structure of an object.

An Example of A Chemical Reaction

Introduction

A chemical reaction can be defined as a process in which the physical and chemical properties of the original substance change as a new substance with different physical and chemical properties is formed.2 In other words the process in which a material changes into a new substance. The original substance (s) is termed reactant (s). The resulting new substance (s) is termed product (s). Many times a chemical reaction will involve the combination of two substances. Evidences of chemical reactions can include a temperature change (resulting from either the release or intake of energy), bubbling (indicating the formation of a gas) or the combination of both. Many of the elements, especially the gases, were discovered while early chemists were combining materials during experiments. Hydrogen gas was discovered in this fashion. As early as the 1600's it had been known that a certain gas (later named hydrogen) was formed when certain acids were combined with certain metals. In 1766, Henry Cavendish, an English chemist, proceeded to study this gas in a scientific way. In other words, once he made the gas by combining the acids and metals, and collected the gas; he investigated it by certain procedures. these included weighing the gas for its mass, and examining its inflammability. He found the gas to be very light (much lighter than air). It was also found to be very inflammable. This was done by Cavendish placing a candle or a burning ember inside a jar containing the gas. the result was that the gas would ignite and display a blue flame.

In the following activity the students will observe what happens when vinegar (an acid) is mixed with baking soda. In this reaction the gas released is carbon dioxide. Teacher's note: the term chemical property is used in the questions. If this is a new term for the students, explain the term during the pre lab discussion. (Chemical property: those characteristics that describe how a substance interacts, or fails to interact, with other substances to produce new substances. Another definition states that it is a property that describes how a substance changes into a new substance.

Activity

Begin by explaining to the class that they will be performing an experiment that will demonstrate a chemical reaction. They will be recording their observations and either answering questions or writing up a lab report at the end of the experiment. Students should work in pairs. Each group should obtain the following items: baking soda, vinegar, one foil cupcake baking cup, one zip lock bag, (a quart size is good), measuring utensils , one candle. Once all materials have been obtained, instruct students to place three teaspoons of baking soda into a zip-lock bag. Next, 25 ml of vinegar is poured into a foil cupcake baking cup. (The cup is large enough to hold the amount of vinegar that will produce a nice amount of carbon dioxide during the reaction, yet short enough to fit inside the bag). The cup is carefully placed inside the bag containing the baking soda without spilling any inside the bag. The bag is then sealed and the contents are gently mixed. Students will write down their observations. These should include what happened when the contents were mixed. They should note that bubbling or foaming took place as well as the bag expanding (from the gas production). Instruct the students to touch the bag as well while the reaction is going on and to record their observation. While the gas is forming the bag should feel cold. This is a result of energy going into the chemical reaction that occurred between the baking soda (sodium bicarbonate) and the vinegar (a weak solution of acetic acid). The students should also be instructed to notify the teacher once the gas has finished forming. The teacher will then light the candle at each group's station, and while the student is holding the bag open (still on its side), carefully insert the tip of the flame just at the opening of the bag (barely inside). The candle should go out. The observations can be done in note form, to be formerly written up later or could be done in the form of the following questionnaire. If a lab write up is done, make sure the topics in the questions are addressed in the write up.

1. What happened when the baking soda and vinegar were mixed?
2. How did the bag feel when you touched it while the reaction was going on?
3. What caused the bag to expand? Do you know the name of the material?

4. What happened when the lighted candle was placed near the opening of the bag?
5. Some gases have the chemical property of being able to support burning (allow something to burn). Does this gas have that property?
6. Another chemical property that a gas may have is the ability to burn itself. This is called flammability. Is this gas flammable?
7. How could you learn more about the material that caused the bag to expand?

An extension of this activity could be for the students to do a mini research project on the gas carbon dioxide. Topics would include how it was discovered, description of its properties both physical and chemical, and its uses. The second research topic could be for them to find out how a fire extinguisher works.

Gaining Indirect Information By Experimentation

Introduction

There are times when scientists are unable to actually touch or see whatever they are examining. The required technology that would allow them to do direct examination may not have been developed. This was especially true for the scientists during the nineteenth and early twentieth centuries who were investigating what was matter actually made of. A few believed that, all matter was made of atoms or tiny indivisible particles (that could not be seen). However although they could not see them, scientists of that day were able to make observations of indirect evidence. The work which Ernest Rutherford did in 1909 is one example. It was for this experiment that he was credited with the discovery of the nucleus.

At the time of this event Rutherford was very involved with the study of radiation. It was during one of his earlier investigations (1890's) that Rutherford named two types of rays emitted from radioactive material; alpha rays and beta rays. Rutherford was investigating the penetrating ability of these rays. He used uranium for the radioactive material. By methodically increasing the layers of sheets of aluminum foil of different thickness and measuring the amount of radiation that passed through the foil, he concluded that two types of rays existed.3 This was based on how far the rays penetrated the foil. The name beta rays was given to those rays which penetrated thicker sheets.4 It was later proven that these rays were actually particles.

A short time later, a German physicist by the name of Hans Geiger began working with scattering alpha particles. The purpose of these experiments was to test J. J. Thomson's theory of the structure of the atom. (For anyone not familiar with this model, information can be obtained from any high school chemistry text book). In his experiments Geiger fired alpha and beta particles at a piece of metal, foil. He then analyzed how they were scattered. Geiger devised a way to count the reflected particles. The angles of some deflections were found to be very large; 90 degrees or greater, sometimes 180 degrees. According to the account given in The Atomic Scientists, it was the large deflections reported in Geiger's work that prompted Rutherford's questioning the validity of Thomson's model of the atom.5 The fact that radioactive particles could pass through thin sheets of metallic foil served as an additional stimulus for a different idea about the structure of the atom; that is the atom consisted mostly of empty space.

So it was in this setting that Ernest Rutherford developed his famous experiment in 1909. To test his idea of the structure of the atom, Rutherford believed he could use the scattering of alpha particles. He shot a beam of alpha particles at a very thin sheet of gold foil. In order to produce the beam he placed some radioactive material into a lead box consisting of one tiny hole in one of its walls. He measured the angle of deflection by surrounding the foil with a screen coated with zinc sulfide. Wherever the alpha particles hit the screen, a flash of light was given off. The results of the experiment were that a large majority of the particles went straight through the foil. A very small amount, about one in 8,000, 6 were deflected at angles greater than or equal to 90 degrees. Also, just as Geiger had observed some were even deflected at 180 degrees. Rutherford concluded that since most of the alpha particles passed straight through, the atoms that made up the gold foil had to consist of mostly empty space. (There were no masses for them to ricochet off). He stated that most of the mass was concentrated in a tiny center. He further stated that the center consisted of positive material which accounted for the deflection of the positive alpha particles (like charges repelling each other).

As previously alluded to, this was an example of an experiment in which the actual object (in this case the atom) was never directly observed. However based on the data obtained from Rutherford's experiment new information about atomic structure was obtained. The first activity of this section involves investigating some of the physical properties of air using indirect evidence. Students are expected to have a working knowledge of the definitions of mass, volume, density, as well as the difference in particle arrangement found in solids, liquids, and gases before engaging in this investigation.

Activities

This first activity involves inflating one balloon with air and comparing it to the non inflated balloon in terms of mass and appearance. It from the Prentice Hall Activity Book: Matter, Building Block of the Universe; entitled "Using Indirect Evidence". Although it is not directed in the instructions, I recommend that both balloons be weighed before inflating one. This would insure that both balloons are identical. (The directions do not instruct the student to determine the mass of the balloon that is to be inflated before hand). Once one of the balloons is inflated, it is examined in terms of density, response to pressure, ability to make noise, volume, and response to temperature change. Following these investigations a few questions are asked pertaining to critical thinking and applications. Please refer to the actual book for directions and questions; pages 77-79.7

The second exercise involves students examining the contents of small containers without opening them. It is an adaptation of the Laboratory Investigation, Shoe Box Atoms, found in the same activity book mentioned above.7 In this exercise eight small numbered containers (small empty boxes) are filled with different items. The items include the following: packing peanuts, small wooden block or flat piece of wood (small enough to fit inside the container), ping-pong ball, golf ball, small magnet, screws, sheet of paper, plastic beads. Students can work in groups or if the class is small enough individually. The boxes can be divided up between the groups or students. More than one set of boxes can also be used. Before the boxes are distributed, the class is given the set of instructions. They are informed that they are to gather as much information as they can about the object (s) inside the boxes without opening them. They will determine the following properties for the item (s): magnetic, mass, number of items and shape, ability to bounce or flip. Magnetic properties will be checked by observing the results of placing a magnet near the box. This will tell if the object (s) contain some type of metal and how much of an attraction to a magnet it has. It can also show if it contains magnetic material by repelling the magnet. A iron nail will also be placed near the box. It will also demonstrate if the material is magnetic material by attracting the nail. If it is, it should attract the nail. If the content (s) of the box is non-magnetic, nothing should happen when the nail is placed near the box. Mass will be determined by first weighing the container and subtracting its mass from that of the other container. Tilting the boxes will give information that will help determining the quantity and shape of the object (s). If one hears the sound of something rolling, it can be assumed that the object (s) have rounded sides. On the contrary, if a sliding noise is heard, one can assume that the shape is something with flat sides. Bouncing or flipping can be determined by shaking the box (es). Data can be recorded on a chart made by the students. See appendix _ for the actual chart. Next, students are to draw a picture of what they think is in each box they investigated based on their observations. Only after they have made their drawing should they be told the contents of each box. (In order to simplify reuse of the boxes, it is advisable to tell them and show an example of each box content, rather than have them open each box. The boxes can be referred to by number). In the lab write up, students should describe the content for the box (es) they had. This should include the number of objects, as well as an explanation of why they described it the way they did. For example: The object in box #1 is a round object rolled. It has a mass of 10g. It does have metallic properties. When a metal screw was placed near the box it stuck, etc. An example of this kind should be explained to the class. At the end of their write up, students should say whether or not their description fit the object (s). If it didn't, they should give an explanation based on their data. During the post lab discussion the class should address the issue of how information can be obtained on something even though it can't be seen. They should refer to their write ups.

Week Two

A Historical Look at Experimentation

Introduction

Historically experiments have played a major role in providing scientific information concerning the world around us. This is especially true in the field of chemistry. The experimental approach to investigating substances or phenomena dates back to the 1600's. Scientists like Evangelista Torricelli, Otto von Guericke, and Robert Boyle proved that air has pressure through their experiments. Torricelli showed air could support a column of mercury about thirty inches. He did it by placing mercury inside a long narrow tube (longer than thirty inches) and inverting it into a bowl of mercury. The column of mercury dropped to a level of thirty inches above the level of mercury in the bowl.8 In 1654 Otto von Guericke, after inventing an air pump, sealed two metal hemispheres together. He then removed the air from between them. He demonstrated the force of air pressure by trying to pull the hemispheres apart with horses. They were unsuccessful. However when he allowed air to re-enter the hemispheres, they fell apart.9 (The outside pressure was counter acted by the air pressure inside.) Robert Boyle went one step further and showed that air could be compressed. In his apparatus, he used a long J shaped tube, closed at the short end. After trapping air in the short end of the tube, Boyle observed the effects of increasing and decreasing the amount of mercury in the tube. He discovered the volume of the trapped air would either decrease or increase depending on the addition or removal of mercury, respectfully. This led to the formation of Boyle's law, which states that the volume of a fixed amount of gas varies inversely with the pressure of the gas.

One of the most celebrated chemists was, the French scientist Antoine Lavoisier (1743 -1794). Among his many accomplishments, he was known for his precise experimentation and making extremely careful measurements. He also gave very detailed documentation of his experiments. Examples of his writings can be seen in Great Books of the World, vol. 45 Lavoisier, Fournier, Faraday. Up until his time careful measurements were not done; sometimes resulting in erroneous conclusions. (Unfortunately because of his status in society, he met an untimely death with the guillotine.)

In this part of the unit two of the experiments of Lavoisier will be studied. They will include his disproving the theory that water was the source of earth, and the discovery of the composition of air. Following Lavoisier, the unit will end with the students researching the famous 1909 experiment by Ernest Rutherford which led to the discovery of the atomic nucleus. In each of the experiments (either Lavoisier's or Rutherford's) students will be looking for four things. These are the purpose of the experiment, how it was done, the results of the experiment, and the conclusions.

Experiments of Antoine Lavoisier

First Example

The first experiment students will examine is the one that showed earth does not come from water. This idea came from the earlier philosophy the all matter came from four basic elements: earth, fire, air, and water. This belief dates back to the time of the early Greeks, approximately 300 BC. The idea of water being a source for some forms of earth was reinforced by the process of distillation. Early scientists observed that after distilling a liquid, a residue was always found in the container that held the original liquid. This was true even when only water was the liquid. They concluded from this evidence that water was a source for some forms of solid material. This is the background setting for the account of Lavoisier's experiments given in Tom McGowen's book, Chemistry, The Birth of a Science.10 McGowen begins by saying Lavoisier didn't believe that water was changing into this residue. Lavoisier used a specially designed glass container to boil water in this experiment. The container was constructed so that as steam rose from the boiling water to the top of the container, it would condense and return to the bottom of the container. This would prevent the water from evaporating out. In order to insure the accuracy of his experiment, Lavoisier cleaned and weighed the empty container before filling it with the "purest water he could find".11 Next he weighed the container with the water in it. He was able to get the weight of the water by subtracting the weight of the empty container from the weight of the container with water. Once this was done, Lavoisier proceeded to boil the water until he got enough residue that he could weigh it. This took a little over three months. After allowing the container to cool, Lavoisier removed the water and the residue from the container. he weighed the water and the residue separately. he dried and cleaned the empty container; then weighed it again. His results were as follows:

1. The weight of the empty container was a little less than its original weight.
2. The water weighed the same as it did before boiling.12
3. The weight of the residue was almost equal to the weight loss of the glass container.

He concluded that the residue came from the glass and not the water, since it was the container that lost weight.

The information on this experiment will be given to the students in the form of a simulated newspaper article written in Paris, France; during the year of 1770. Students will read the article, then answer the questions. The questions will be reviewed in a discussion. The article and the lesson plans for this section are included at the end of the unit.

Second Example

The second experiment of Lavoisier is the one from which he made the discovery of the composition of air. In trying to understand combustion, many of the earlier scientists would burn materials and make observations. Sometimes what would be left after the material was burned was a powdery substance called calx.. It could be formed from metals as well as nonmetals. Scientists also discovered that when the calx was heated it changed back into its original substance and a gas was released.

Lavoisier set up a two part experiment to investigate these phenomena. The following is a summary of his account from the book Great Books of the World, vol 45 Lavoisier, Fournier, Farady. During the first part he heated a certain measured amount of mercury in a special flask. The flask had a long neck bent to feed into an empty bell shaped jar. The jar was placed upside down in a bowl like container of mercury. This served as a closed container.13 As the mercury heated up a red calx appeared. At the end of twelve days no more red calx had formed. Once the flask was cool , Lavoisier measured the amount of air left in the flask. He found it to be about one sixth less than the initial amount. He also tested the air for its ability to support combustion and respiration. This was done by placing a lighted candle inside the air. The candle went out. Animals were used for respiration. When placed inside the air they “suffocated”. This experiment was repeated several times yielding the same results. Lavoisier termed the left over air from the formation of the mercury calx “noxious air”or the “non-respirable parts of air”14 Later this part of air once carbon dioxide was removed from it, would be called nitrogen.

In the second part of this experiment, Lavoisier took the red calx formed from the mercury and heated it. He used a container that was designed to receive gases that might form . It had two parts, one in which the calx was placed and the other that received the gas. As the calx was heated it disappeared and mercury formed in the receiving end of the container. A gas was also collected in this section. Lavoisier tested the gas for combustion with a lighted candle, charcoal, and phosphorous. The candle burned brighter. Instead of burning quietly without a flame, the charcoal burned noisily with a flame. The phosphorus burned with a blinding light. Animals were found to breath easier when they were place in the gas. Lavoisier called this gas “highly respirable air”. Later he changed the name to “vital air”.15 This gas was oxygen. Lavoisier concluded that air was composed of two gases which were of “different and opposite qualities”.16

As previously done for the first example, the information for this experiment can be given to the students in the form of a hand out. After reading the handout students will give a written summary of what was done in each part of the experiment. Next they will make a list of the results. Finally they will explain Lavoisier’s reasoning for his conclusion.

Rutherford’s Experiment

The historical background for Ernest Rutherford’s 1909 experiment with alpha particles and gold foil can be found earlier in this unit under the introduction section of Gaining Indirect Information by Experimentation. A detailed description of the actual experiment is also given in that section.

An excellent account of this experiment is found in Prentice Hall’s Chemistry: The Study of Matter, pages

119-121. Students are to read this account. As stated before, there are four objectives for studying each historical experiment. They are determining the purpose, procedure, results, and conclusion of each experiments. These can be met either through a discussion format or written assignment. In addition, students are to copy the drawing of the apparatus used on page 120 of this book. If this book is not accessible, another text should be consulted that would provide the same information.

Conclusion

It is hoped that upon completion of this unit, students will have a better understanding of how information about the topics are taught in science classed is obtained. They should have an increased awareness of some of the roles experiments play in science. An extension of this unit could be a mini research project on one of the following topics:

1. The discovery of radiation.
2. The discovery of X rays.
3. The discovery of Nitrogen and Oxygen
4. Pick an element from the periodic table; research its discovery, physical and chemical properties, and its use.

Investigating Physical Properties of Liquids and Solids

Teacher’s Lesson Plan

Objective: Students will use physical properties to compare and contrast certain

substances. **Materials:** (the number of containers is per set up>)

Magnifying glass (students can share)

10 petri dishes or clear containers with covers for samples

alcohol, kayro syrup, cooking oil, vinegar, hydrogen peroxide, water, liquid dish detergent (preferably yellow in color) **,** salt, baking soda, powdered detergent (white in color.

Procedure:

1. Place a small amount of each sample in covered containers or petri dishes. (Number each container. Keep a log of the numbers and sample identity)

2. Students are to write down the following observations for each of the samples:

Liquids: color, odor, ability to flow (viscosity)

Powders: texture, color, shape of the particles (use magnifying glass)

3. Emphasize that you are interested in the description of each item, more than its identity. Tell students they will be told the identity of the items at the end of the activity. Stress that tasting is not allowed!

4. Hand out the activity sheets. Students do activity.

5. Discuss the observations for the liquids and powders; comparing and contrasting. Point out how the powders all had the same color, but the texture and particle shape was different (especially the particle shape). Explain what they just observed were examples of what is termed physical properties of matter.

Investigating Physical Properties of Liquids and Solids

Student Activity Sheet

Background:

When you are asked to describe a person you know, what do you do? You tell about that person's physical features. You might mention how tall someone is, describe the way their body is built, and give the color of their eyes and hair. Physical properties are the way scientists use to describe matter of any kind. You could say that these are the characteristics of a material. They can include the color of something, how it feels when you touch it (texture), whether or not it has an odor, and if it does, what kind of odor. Other characteristics are the shape of the material, whether or not it will flow (only for liquids), as well as mass and density. In this activity you will examine 7 liquids and 3 powders. You will describe and record your observations of certain physical properties.

Materials:

magnifying glass

10 petri dishes or clear containers with covers containing unknown samples (already set up by your teacher.)

Activity:

Examine the samples. You are to describe each sample in the following way:

Liquids: color

odor

ability to flow (viscosity)

Powders: texture

color

shape of particles (use magnifying glass)

Use the number on the container to identify your samples. You will be given each sample's identity at the end of the activity.

@2H(after1H):Examining a Chemical Reaction

Teacher's Lesson Plan

Objective: Students will observe what occurs during a chemical reaction.

Teacher's note: Depending on the class, students can either do a lab write up or answer the questions at the end of the activity. The activity sheet has been written up so that the questions are to be answered. If a lab write up is chosen, omit the question section.

Materials:

See student activity sheet.

Procedure:

1. Explain the definition of chemical reaction. Discuss with the class the terms

reactants and products. include in the discussion the signs or evidence of a

chemical reaction. If possible, do a demonstration of combining chalk with

vinegar. (The chalk will bubble as it is reacts with the vinegar.)

2. Hand out the activity sheet; allow students to get materials and do the experiment.

Remind them to touch the bag as the reaction occurs.

3. Instruct the students to notify you when the reaction is completed. This is when

the gas will be tested to see if it supports combustion (burning). Light the candle,

have one student carefully open the bag. Barely insert the candle into the bag or

hold it just at the opening. The flame should go out.

4. After students have completed the activity, but before they complete the questions

lead a discussion that would highlight the subjects addressed by the questions. 5. Students answer the questions.

Questions to be used:

1. What happened when the baking soda and vinegar were mixed?
2. How did the bag feel when you touched it while the reaction was going on?
3. What caused the bag to expand? Do you know the name of the material?
4. What happened when the lighted candle was placed near the opening of the bag?
5. Some gases have the chemical property of being able to support burning (allow something to burn). Does this gas have that property?
6. Another chemical property that a gas may have is the ability to burn itself. This is called flammability. Is this gas flammable?
7. How could you learn more about the material that caused the bag to expand?

Student Activity Sheet Name:______________________

Background:

A chemical reaction is a way in which a material changes into a new substance. The original substance (s) is termed reactant (s). The resulting new substance (s) is termed product (s). Once the reaction takes place, you no longer have the original substance. Many times a chemical reaction will involve the combination of two substances. Evidences of chemical reactions can include a temperature change (resulting from either the release or intake of energy), bubbling (indicating the formation of a gas) or the combination of both. In this activity you will observe what happens when vinegar an (acid) reacts with baking soda.

Materials:

baking soda 1 zip lock bag

vinegar 1 foil cupcake baking cup

small birthday candle teaspoon or measuring equipment

match (teacher only) graduated cylinder

Procedure:

1. Place 3 teaspoons baking soda into bag

2. Pour 25ml vinegar into foil baking cup

3. Carefully place the foil cup into the bag without spilling it. Seal bag while it is flat on the counter.

4. With bag sealed, spill the vinegar into the baking soda. Observe what happens. Touch the bag as the reaction is going on. Record your observations here:

5. Notify your teacher when the reaction is finished.

6. Answer the questions.

Simulated Article on Lavoisier' s Water Experiment

Teacher's Lesson Plan

Objective: Students will explain how data from an experiment was used to disprove a scientific belief.

Materials:

Copy of simulated newspaper article, 1 per student

Questionnaire, 1 per student

Teacher's note: Explain the term distill, if students are not familiar with it.

Procedure:

1. Before handing out the article and questionnaire, give a brief introduction to

Lavoisier. Use the information under the section entitled "Experiments of

Antoine Lavoisier for a reference.

2. Hand out the article and questionnaire. Instruct students to read the simulated

article and answer the questions. Point out that although the idea of the article is

fictitious, the experiment actually took place.

3. Go over the questions in a discussion.

Questions for the article:

1. What was purpose of the experiment?

2. List in order the steps of this experiment. Draw a picture of what you think the set up looked like.

3. What were the results of the experiment

4. Why did Lavoisier weigh the empty container twice?

5. Why did Lavoisier state that the glass container was the source of the residue?

(Simulated Newspaper Article)

LOCAL SCIENTIST DESTROYS LONG STANDING THEORY

Paris, France 1770

Yesterday, Monsieur Antoine Lavoisier confidently made the claim that solid materials such as wood could not come from water. this was a great shake up to the scientific world. Scientist have believed for a long time that water can be a source for solid materials. This is because they believed that water is one of the four elements from which matter came from. As we all know an element can be defined as a basic material from which all the physical world is mad of. the other three elements are air, fire, and earth. this belief has been around since the early 300's BC, when the early Greeks lived. Furthermore the scientific community has had evidence that reinforces this theory. It is an old fact that whenever one distills a liquid, a residue (left over solids) always forms in the bottom of the container used for distilling. The residue formed even when plain water was distilled. Up until yesterday, this had been the long standing theory about where some solid matter came from.

All has changed since M. Lavoisier has disclosed the results of an experiment he performed. This experiment was designed to challenge the theory which he had long time suspected to be untrue. Lavoisier says that he began by using a specially designed glass container to boil water in. The container was constructed so that as steam rose to the top of the container, it would condense and return to the bottom of the container. This would prevent the water from boiling out. Next, Lavoisier cleaned and weighed the empty container. After that he filled it with water. Before he began to boil the water, he first weighed the container with the water inside of it. He was able to get the weight of the water by subtracting the weight of the empty container from the weight of the container with water. Once this was done, Lavoisier proceeded to boil the water until he got enough residue that he could weigh. this took a little over three months! After allowing the container to cool, Lavoisier removed both the water and the residue from the container. He weighed the water and the residue separately. He dried and cleaned the empty container; then weighed it again. he found that the second weight of the empty container was a little less than the first time it was weighed at the beginning of the experiment. The weight of the water was the same as it was before. However the weight of the residue was almost equal to the weight loss of the special container.

Lavoisier concludes that the source of the residue is the glass container; not the water. His proof is the fact that the weight of the residue was almost equal to the amount of weight the glass container lost. The water had not lost any weight. So part of the container had dissolved into the water.

This truly is an amazing discovery! Why didn't anyone else think of testing this element theory? What other dazzling discoveries will this fascinating man make?

Materials List

Investigating Physical Properties of Matter Activities

5oz or 8oz plastic cup metric ruler rubbing alcohol water weighing scale kayro syrup

paper towel cooking oil vinegar

balloons, helium and air salt liquid dish detergent

hydrogen peroxide baking soda white detergent powder

magnifying glasses petri dishes

Examining a Chemical Reaction

baking soda 1 zip lock bag

vinegar 1 foil cupcake baking cup

small birthday candle teaspoon or measuring equipment

match (teacher only) graduated cylinder

Indirect Evidence Activities

magnets iron nails small empty boxes packing peanuts

screws ping-pong balls small wood blocks golf ball

plastic beads small magnets paper balloons

Endnotes

1Isaac Asimov, How Did We Find Out About Atoms? (New York: Walker and Company,1976), 13.

2Henry Dorin, Peter E. Demmin, and Dorothy L. Gabel, Prentice Hall Chemistry: The Study of Matter, 4th ed. (Needham, Mass.: Prentice Hall, Inc.,1992), 800.

3Henry A. Boorse, Lloyd Motz, and Jefferson Hane Weaver, The Atomic Scientists: A Biographical History (New York: John Wiley & Sons, Inc., 1979), 119,120.

4Boorse, 120.

5Boorse, 180.

6Isaac Asimov, Atom: Journey Across the Subatomic Cosmos (New York: Dutton, 1991), 95.

7Prentice Hall Science: Activity Book, Matter: Building Block of the Universe. (Englewood Cliffs, N.J.: Prentice Hall, 1994), 77-79, 93-94.

8James Bryant Conant et al, Harvard Case Histories in Experimental Science, ed. James Bryant Conant, vol 1 (Cambridge, Mass.: Harvard University Press, 1957), 5.

9Conant, 37.

10Tom McGowen, Chemistry: The Birth of a Science, (New York: Franklin Watts, 1989), 57-59.

11McGowen, 58.

12Isaac Asimov, A Short History of Chemistry, reprint. ed. (Westport, CT.: Greenwood Press, 1979), 59.

13Great Books of the Western World: vol. 45, Lavoisier, Fourier, Faraday, ed. Robert Maynard Hutchins, Encyclopedia Britannica Inc., (Chicago: William Benton,1952), 17.

14ed. Hutchins, 17.

15ed. Hutchins, 17.

16ed Hutchins, 18. **@SH: Bibliography**

Teacher's resources

Asimov, Isaac. A Short History of Chemistry. reprinted. Westport, CT.: Greenwood

Press, 1979.

The history of chemistry from the stone age to nuclear bombs; given in narrative

style and chronological order.. Easy to understand the terminology. A few

sketches of instrumentation used are included.

Atom: Journey Across the Subatomic Cosmos. Truman Talley Books. New York:

Dutton, 1991.

Covers the history of the atom; not in chronological order but grouped under major

topics such as matter, light, electrons, nuclei, isotopes, neutrons, and breakdowns.

Boorse, Henry A., Lloyd Motz, and Jefferson Hane Weaver. The Atomic Scientists: A

Biographical History. Wiley Science Editions. New York: John Wiley & Sons,

Inc.,

1989.

A history of the atom and the scientists who made contributions to the theory of

the atom. Given in biographical form. Starts with Lucretius ((99-59BC) ends with scientists born in 1915 and 1920; discoveries go up to 1950’s.

Cobb, Cathy and Harold Goldwhite. Creations of Fire: Chemistry’s Lively History from Alchemy to the Atomic Age. New York: Plenum Press, 1995.

Covers exactly what the title states. Each section contains biographical background and contribution descriptions for various scientists. Prose format used. Chapters are divided up by dates.

Conant, James Bryant, Leonard k. Nash, Duane Roller, and Duane H. D. Roller. Harvard Case Histories in Experimental Science. ed. James Bryant Conant. vol. 1. Cambridge, Mass.: Harvard University Press, 1957.

Case histories of certain key scientific concepts. One of two volumes. In this volume the following are covered: Robert Boyle’s pneumatic experiments, how the phlogiston theory was disproved, the early development of the concepts of temperature and heat, and the development of the Atomic-Molecular theory. excerpts from actual writings with commentary are included.

Dorin, Henry, Peter E. Demmin, Dorothy L. Gabel. Prentice Hall, Chemistry: The Study of Matter. 4th ed. Needham, Mass.: Prentice Hall, Inc.,1992.

High school chemistry text book formerly used in the New Haven Public School System.

Great Books of the Western World: vol. 45, Lavoisier: Fouler: Faraday. Robert Maynard Hutchins, ed. in chief. Encyclopedia Britannic, Inc.Chicago: William Benton, 1952.

Contains the original writings of the a fore mentioned scientists. The works of Lavoisier and Fourier have been translated into English. The names of each document are as follows: Lavoisier: “Elements of Chemistry”; Fourier: “Analytical Theory of Heat”; Faraday: “ Experimental Research In Electricity”.

McGowen, Tom. Chemistry: The Birth of a Science. A Venture Book. New York:

Franklin Watts, 1989.

Found in the juvenile section, but very informative and reliable information. Can

be used for grades 9-11. Covers contributions of Greek scholars, alchemists, and Lavoisier. Contains a glossary. Excellent in details about some experiments.

Prentice Hall Science Activity Book, Matter: Building Block of the Universe.

Englewood Cliffs, N. J.: Prentice Hall, Inc.,1994.

Activity book on matter; compliments the text, Prentice Hall Science, Matter:

Building Block of the Universe.

Students' Reading List

Amiss, Isaac. How Did We Find Out About Atoms?. New York: Walker and

Company,1976.

Found in juvenile section. Easy to read, covers history of the atom from early

Greeks to arrangement of atoms.

McGowen, Tom. Chemistry: The Birth of a Science. A Venture Book. New York:

Franklin Watts, 1989.

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