RESEARCH EXPERIENCE FOR TEACHERS

ANN PHINNEY-FOREMAN

CORNELL CENTER FOR MATERIALS RESEARCH

CURRICULUM PROJECT

Cats, Brass Monkeys, Napoleon's Army, and Gum

What do all of these have in common?

Materials Science

Regents Chemistry
Ann Phinney-Foreman

Waverly High School
Waverly, New York

Napoleon's Buttons

Purpose:

In this experiment, students will melt tin metal. They will pour the molten metal into a mold and make tin buttons. They will then test the malleability of the buttons as a function of temperature and time.

Description:

This experiment is appropriate for high school chemistry classes. This experiment will be used with the study of elements, especially metals, and their different allotropic forms. When heated the surface of the tin pellets oxidizes, so an equation can be written for the synthesis of tin (IV) oxide. By massing the tin pellets before melting, and knowing the density of tin, students could also calculate the volume of their button.

Time Required:

Approximately 40 minutes will be needed for the making of the buttons, and one cold winter or artificially cold conditions over a period of months for the change of white to gray tin.

Materials:

<u>Chemicals:</u>

Tin shot (approximately 1 gram per student).

<u>Equipment:</u>

Crucible and lid, tripod or ring stand and iron ring, crucible tongs, metal spatula, burner, piece of scrap wood approximately 2x4x6 inches, two small nails and a hammer, and a stainless steel washer. The stainless steel washer should have a whole the size you want to make your button, safety goggles and a flame retardant apron.

Hazards:

Hot metal will burn skin and clothing. The tin sometimes pops out of the crucible, therefore, the lid should be kept on while heating. Hot metal will burn the wood. Move the washer around on the wood so that one spot does not get too hot. A flame retardant apron and safety goggles must be worn at all times.

Procedure:

- Mass approximately one gram of tin shot into a clean, dry crucible. Record the mass of the tin to the closest one hundredth of a gram.
- Place the crucible containing the tin in a clay triangle in the tripod or in an iron ring attached to a ring stand.
- Place the lid on the crucible.
- Place the metal washer on the block of wood close to your crucible assembly.
- Heat the crucible strongly for about 30 seconds. Remove the heat from the crucible. Take off the lid and examine the tin with the metal spatula. Scrape off the coating with your metal spatula until you see a bright shinny silver liquid that looks just like mercury.
- If you have "played" too long your tin may have cooled and resolidified. If this happened just reheat it for about 15 seconds and it will become molten again.
- Using the crucible tongs, pour the contents of the crucible into the center (open hole) of the metal washer on top of the wooden block.
- Gently, tap the top of the metal to flatten into the washer circle. Using the hammer pound one of the nails into the soft metal to make a button "hole." Very close to the first hole make another by pounding in your second nail.
- Carefully, using the top of the hammer pull out your two nails.
- You now have a tin button!
- You can pound the button to flatten it out a little, and you are ready to sew.
- Sew your button onto the French flag or some other material and expose it to winter weather.
- If you are going to store it in a freezer or Dewer flask it doesn't need to be sewn on fabric.
- Check on the malleability of your button weekly by hammering it. Record the date and your results. If you are exposing it to winter conditions you should record the daily temperatures. Determine how long your button has to be exposed to cold before it becomes brittle and breaks. Compare results. Calculate an average.

Disposal and Clean Up:

Any left over tin can be recycled. When cool, the crucibles can be scraped out with a metal spatula, this will take a few minutes but it comes out fairly well with a little elbow grease. You may be able to line the crucibles with Al foil to make clean up easier, but you would have to be careful that the Al didn't hang out over the sides of the crucible because it would oxidize, and hot flakes could fall away from the crucible.

Discussion:

Tin is found chiefly in cassiterite (SnO_2). Most of the world's supply comes from Malaya, Bolivia, Indonesia, Zaire, Thailand, and Nigeria. The U.S. produces almost none, although occurrences have been found in Alaska and California. Ordinary tin is composed of nine stable isotopes: 18 unstable isotopes are also known. Ordinary tin is a silver-white metal, is malleable, somewhat ductile, and has a highly crystalline structure. The element has two allotropic forms at normal pressure. On warming, gray, or alpha tin, with a cubic structure, changes at 13 °C into white, or beta tin, the ordinary form of the metal. White tin has a tetragonal structure. When tin is cooled below 13°C, it changes slowly from white to gray. The gray form is a very brittle semi-metallic form with a covalent giant structure like diamond. There are few if any uses for gray tin.

When Napoleon's Army invaded Moscow they wore trousers and tunics fastened with shiny white tin buttons that in the severe Russian winter turned into brittle gray tin which crumbled away.

Data Analysis:

1. Look up the density of tin. Using the density and the mass used, find the volume of your button.
2. What is the most obvious error in the calculation of the volume of your button?
3. Define the terms malleable and ductile.
4. Look up the two most common oxidation states for tin.
5. Write and balance two chemical equations (one for each oxidation state of tin) representing what happened that caused the dull film on the surface of your hot tin.
6. Write an electron configuration notation for Sn.
7. Does the configuration correspond to the two most common oxidation states of Sn? Why or Why not?
8. What is the difference between an allotrope and an isotope?
9. What is a metallic bond?
10. Name four other substances that are bonded with metallic bonds.
11. What is an alloy?
12. Research three alloys that use tin as one of their components.
13. Gray tin is also called tin plague. Why?
14. When was tin plague first noticed? Find the connection of Aristotle, or Plutarch or the Zeit church in Germany to tin plague.
15. From the following list of metals, determine which of following could be used to make buttons using the same procedure you used to make your tin buttons. If a metal is not suitable, explain why.
    Uranium
    Barium
    Zinc
    Bismuth
    Gold
    Iron
    Mercury
    Tungsten
16. In what year did Napoleon's invade Moscow? What was the outcome of the battle? Did Napoleon's Army have any problems besides keeping up their trousers?

Notes:

I have not yet tried this experiment with students. I hope to use this experiment this coming school year and will let you know how it goes. I would also appreciate any suggestions you may have for improving it.

References:

Harrison, W.D.; School of Education, North East Wales Institute of Higher Education, Wrexham, North Wales; www.newi.ac.uk/buckleyc/materials.htm

WebElements.com

Regents Chemistry
Ann Phinney-Foreman

Waverly High School
Waverly, New York

Gum

Purpose:

In this experiment students will examine a property of polymers called glass transition temperature. Students will observe the temperature at which gum, which contains polymers, changes from a brittle material to a flexible, chewy substance.

Description:

This experiment is appropriate for any grade level. It can be adapted to suit any age student and is a simple example of one of the unique properties of polymers. This experiment can be used with the study of polymers, melting points, or van der Waals intermolecular attractions. By changing the procedure to include a massing of the gum, before and after chewing, the percent composition by mass of sugar in the gum could also be determined.

Time Required:

Approximately 20 minutes will be needed to record observations and draw conclusions.

Materials:

3 pieces of chewing gum, sticks are preferable, one should be a stale piece, and one refrigerated, one room temperature.
A thermometer, or room thermostat.

Hazards:

Diabetic students or those wearing braces should not chew gum.

Procedure:

1. Obtain a piece of cold gum. Record the temperature of the container in which it was stored.
2. Bend the gum in half, like you were going to make two pieces the same length. Does it bend or break?
3. Set it aside with its wrapper, and obtain the second piece of gum, which is stale, but at room temperature. Bend it the same way you did the cold gum. Does it bend or break? Put the piece of stale gum is your mouth and time how long it takes before it is "easily chewable."
4. You can spit the stale gum out as soon as you have made it chewable. Make sure you spit it out into the wrapper and put the wrapper in the trash.
5. Now take your cold temperature gum (which should have warmed a little), and try bending it again, did it bend or break this time? Put the gum into your mouth and time how long it takes to become chewable.
6. Lastly, obtain a third piece of gum, this one at room temperature. Bend it like you did with the other two pieces. Did it bend or break? Instead of chewing it right away, try continuing to bend it over and over again. Does it bend or break? Now you may chew it, and again time how long it takes to become "chewable."

Disposal and Clean Up:

Make sure all gum and wrappers are properly disposed of in the trash.

Discussion:

You have studied changes of state for elements, and compounds, and studied phase change diagrams. Can all materials be characterized by their melting and boiling points? No, some materials, like polymers, don't ever really melt, they just get soft. When you slowly heat a polymer nothing happens for a while then there comes a temperature at which it starts to gradually change from a hard solid to a more flexible, softer solid. The temperature at which this starts is called the glass transition temperature. Glass behaves in a similar way- it starts to soften and flow but it does not melt and become a liquid like milk or water.

Because polymers are usually solid or extremely viscous, they must be given the ability to flow before they can be used for different applications.

Heating to the glass transition temperature is commonly used in the polymer industry when plastic is extruded into pipes, drawn into food wrap, or blown into bottles.

Chewing gum is either based on the natural polymer, chicle, from the sapodilla tree or synthetic based on polyvinyl acetate. It is a relatively brittle material at room temperature – a stick of gum straight from the pack is not chewable. Most chewing gum has a glass transition temperature of around 25-30°C.

Data Analysis: (Optional)

1. Define polymer. Give five examples of materials that are made out of polymers.
2. Research the glass transition temperature of several other polymers.
3. What is a plasticizer?
4. Do you think gum has plasticizers ?
5. What do you think gum loses or gains when it gets stale?
6. Polymers experience both van der Waals and hydrogen bonding between chains. Research the composition of cotton and see why its chains can hydrogen bond. How would the presence of hydrogen bonds effect the glass transition temperature of a polymer?
7. What is the average body temperature in degree Celsius?
8. Can you think of any other things you eat that seem to reach their glass transition temperature somewhere between room temperature and mouth temperature?

Notes:

I have not yet tried this experiment with students. I hope to use this experiment in the coming school year and will let you know how it goes. I would appreciate any suggestions or corrections you can offer.

References:

Harrison, W.D.; School of Education, North East Wales Institute of Higher Education, Wrexham, North Wales; www.newi,ac.uk/buckleyc/materials.htm

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The Cat's Meow

Purpose:

In this experiment students will examine the interaction of milk, food coloring and detergent. They will practice making descriptive observations. They will also propose a hypothesis to explain their observations. The students will then design a new experiment to test their hypothesis.

Description:

This experiment can be used in grades K-12. I use this as an opening day experiment for my high school juniors in classes that I have at least one full period. This is a great experiment and you can build from it and go in several directions. I use it the first day because there are no special safety concerns, its gets the students involved in the lab immediately, and it is FUN. This is a painless way to review the scientific method for high school juniors. It also appeals to their artistic side, and is a good starting off point to practice writing descriptive observations. This is also a good experiment because they are not finished with it after one period. It lends itself to redesign to test their hypothesis, if you want to emphasize the scientific method. It is important to stress that we are not interested in the "right" answer. If students believe they know the "right" answer in a science experiment they often miss the important, experimental part.

Time Required:

One forty minute period for explanations, experiment, and clean up. The actual experiment only takes about 10 minutes, but the students always like to "play" after they have finished.

Materials:

For each group: enough (milk that has been sitting out for an hour or so works best) milk to cover the bottom of a pie pan, a set of four colors of food coloring, dish detergent, a tooth pick, a container such as a pie pan.

Procedure:

At each step in the experiment, starting with #7 it is important for you to record copious, descriptive observations. Someone who hasn't done this experiment should be able to visualize what you are seeing by reading your observations.

1. Obtain the bottom of a pie pan. Make sure YOU rinse it well with water several times.
2. Pour enough of the whole milk into the pan to cover the bottom completely.
3. Place a circle of blue food coloring the size of a quarter (2 drops) at "12 o'clock."
4. Place a circle of red food coloring the size of a quarter (2 drops) at "3 o'clock."

5. Place a circle of green food coloring the size of a quarter (2 drops) at "6 o'clock."
   Place a circle of
7. BE CAREFUL NOT TO MOVE OR JAR THE PAN.
8. Obtain a small (10 drops) amount of dish detergent and a toothpick.
9. Dip the toothpick in the detergent, and then dip it dead center in the middle of the pan of milk. RECORD YOUR OBSERVATIONS.
10. Repeat step #9 five more times, recording your observations each time.

Disposal and Clean Up:

CAREFULLY and SLOWLY pour the contents of the pan into the sink. Food coloring stains so be careful not to splash. After testing your water pressure, gently run some rinse water into the pan, or you can fill another container such as a beaker first, and pour that water into the pan to help prevent splashing. After all of the remaining food coloring has been rinsed out, you want to hold the pan under running water and rinse the thoroughly, this is very important. Any residual soap film will ruin the experiment for the next group. Dry the pan to prevent rusting. Tidy up your area, making sure to wipe up any spilled food coloring.

Discussion Questions:

1. Propose a hypothesis which may explain the phenomenon which you have observed.
2. Design an experiment in which you would test your hypothesis..
3. Ask for a volunteer from study hall who has not taken chemistry. Read your descriptive observations to her and ask her to either draw a picture or explain back to you what she "sees" from your descriptive observations.
4. The word phases has several meanings in science. Find two and give there definitions. How could both of these meanings be used to describe this experiment.
5. What does milk look like before it gets "homogenized?"
6. How long does homogenized milk stay homogenized?
7. The spread of the food coloring throughout the milk could be called diffusion. Can you think of any way you could have changed the experiment to speed up or slow down the diffusion?
8. Can phases of matter other than liquids diffuse together? Give examples.

Notes:

I first saw this experiment at a workshop for new Regents chemistry teachers. I use it now regularly as my opening day experiment. The students love it.

Reference:

Participant Demonstration by John Hugo,
Participant in the 1988 Woodrow Wilson Foundation Institute for High School Chemistry Teachers, Princeton University.