Jenny Bayley and Sunny Kung

Lesson Plan: Exploring Chemistry
Lesson Type: Module-based

Teaching Plan:
Introduction: ~10 min
-Discuss “chemistry” in general and find out what is already known
-Introduce the concept of chemical reaction and physical properties such as surface tension and macromolecules (penny demo and baking soda and vinegar)

Activity 1: Acid Attack ~30 min
Lesson Goal: In this activity, students explore the effect of chemical erosion on statues and monuments. They will use chalk to observe what happens when limestone is placed in liquids with different pH values. In addition, they will also learn about several things that engineers do to reduce the effects of acid rain on the environment.

-Explain the concept of an acid and base and how it relates to pH
-Discuss the cause of acid rain and its effects on the environment in terms of chemical erosion
-Introduce the problem of the effects of acid rain and limestone
-Pass out Acid Attack Activity Worksheet
-Perform activity
-Explain that engineers work to stop acid rain by finding cleaner ways to create energy as well as modifying existing technologies (cars, industrial plants, etc.) so that they create less air pollution and acid rain.

Activity 2: Color Changing Milk ~20 min
Lesson Goal: Students will learn about macromolecules and surface tension. They will use food coloring in milk to observe the properties of different types of molecules.

-Explain the different types of macromolecules in milk (fat, vitamins, minerals, protein, water)
-Show the water on penny demo to explain surface tension
-Perform activity and its explanation

-Review, Discuss, and Conclusions ~10 min

Mentors Scientific Background
1) Acid Attack:

Acid rain is an environmental problem that concerns many environmental and chemical engineers. The effects of acid rain include damage to the limestone and marble in statues and buildings; weakening of the exposed metal on bridges and cars; damage to bodies of water, wildlife, plants, forests and crops; and the contamination of the drinking water supply. Acid rain is formed by complex chemical reactions involving air pollution. The two main pollutants in acid rain are oxides of nitrogen and sulfur that react with rain moisture to form nitric and sulfuric acid. Mainly, these erosive pollutants are the result of manmade sources such as cars or fossil fuel-

burning plants. Acid rain contaminates the environment not just through rain, but also in the form of snow, fog, dew and dust. Acid rain occurs when air pollution chemicals, which come from fuel-burning factories or cars, react to form acids in the air. The acids from burning fuel in the air attach to water molecules in the air and then fall as rain or snow. We call the breakdown caused by acid rain, *chemical erosion*.

One way that we can help prevent acid rain is by burning less fossil fuel. We can also make laws that prevent large factories from burning fossil fuels or that require them to limit (minimize) their pollutant output. Engineers have developed many useful technologies for this purpose, but the companies must adhere to the laws. For example, emissions from cars have been reduced because cars now have catalytic converters that remove the poisonous gases from exhaust fumes.

Unfortunately, air and wind can move pollutants great distances. In fact, pollutants that contribute to acid rain may be carried hundreds of miles by wind before being deposited on the Earth. Because of this, it is sometimes difficult to determine the specific sources of these acid rain pollutants. For example, Canada has an acid rain problem because of manufacturing in the mid-western states of the U.S. Sulfur dioxides are produced in the industries in Ohio, Illinois and Pennsylvania, and are carried over the land by the weather patterns. The acids then combine with rain over Canada and the Adirondack mountains in New York, making those lakes lifeless.

In addition, the effects of acid rain include damage to the limestone and marble in statues and buildings. Two materials used often in building countertops and floors are limestone and marble, which both contain calcium carbonate. In fact, many historical buildings and monuments are built out of limestone and marble as it was readily available at the time of their construction. For example, many of the monuments in Washington D.C. are made of marble. Acid rain is harmful to many of these monuments and buildings due to the fact that the acid breaks down the calcium carbonate in them more quickly than with other building materials.

The acids, lemon juice and vinegar, are used in this activity to simulate acid rain. Chalk is made up of limestone, which will simulate a statue. Limestone contains calcium carbonate ($CaCO_3$), which will react chemically with the acid, causing it to deteriorate or erode. This happens because the acid causes the calcium (Ca) and carbonate (CO_3) in the limestone to separate into calcium and carbon dioxide gas (CO_2). Although the lemon juice and vinegar acids used in this activity are actually more concentrated than acid rain, they successfully demonstrate the erosive effects of acid rain over time.

2) Color Changing Milk:

Milk is mostly water but it also contains vitamins, minerals, proteins, and tiny droplets of fat suspended in solution. Fats and proteins are sensitive to changes in the surrounding solution (the milk).

When you add soap, the weak chemical bonds that hold the proteins in solution are altered. It becomes a free-for-all! The molecules of protein and fat bend, roll, twist, and contort in all directions. The food coloring molecules are bumped and shoved everywhere, providing an easy way to observe all the invisible activity.

At the same time, soap molecules combine to form a *micelle*, or cluster of soap molecules. These micelles distribute the fat in the milk. This rapidly mixing fat and soap causes swirling and churning where a micelle meets a fat droplet. When the micelles and fat droplets have dispersed throughout the milk the motion stops, but not until after you've enjoyed the show!

There's another reason the colors explode the way they do. Since milk is mostly water, it has surface tension like water. The drops of food coloring floating on the surface tend to stay put. Liquid soap wrecks the surface tension by breaking the cohesive bonds between water molecules and allowing the colors to zing throughout the milk.

Introduction for the Mentees:

1) Acid Attack:

What do you already know about acids and bases? Did you know that almost every liquid you see is an acid or a base, except water? The amount of tiny particles called ions in a liquid determines if something is an acid or a base using the term *pH*. An acid has a low pH value 0-7 and a base corresponds to a pH value from 7-14. Measuring pH is fundamental science that is used by many engineers: Environmental and chemical engineers examine pollutant substances to find out whether they are acid or base to know what kind of reactions they cause. Electrical engineers design batteries. Chemical engineers design everything from pharmaceuticals to soap to glue to bubble gum to household cleaning products. Civil engineers design water and waste treatment plants for towns and factories.

There are many acids and bases around your own home. For example, bleach and household cleaners are examples of bases and vinegar is an acid. Did you know that a really strong acid or base can break something apart? If you add straight bleach to a piece of clothing, it can take the color away or even put a hole in the item. An example of an acid around your home is lemon juice, vinegar and cola. Very strong acids can put holes in items as well.
Acids can also be found in the air around us — specifically in polluted air. Acid rain happens when air pollution chemicals, which come from fuel-burning factories or cars, react to form acids in the air. The acids from burning fuel in the air attach to water molecules in the air and fall as rain or snow. We call the breakdown caused by acid rain, *chemical erosion*. The effects of acid rain (chemical erosion) include: damage to statues and buildings; weakening of the exposed metal on bridges and playground equipment; damage to wildlife, plants, forests and crops; and the contamination of drinking water supplies.

Two materials used often in building countertops and floors are limestone and marble, which both contain calcium carbonate. In fact, many historical buildings and monuments are built out of limestone and marble as it was readily available at the time of their construction. For example, many of the monuments in Washington D.C. are made of marble. Acid rain is harmful to many of these monuments and buildings because the acid breaks down the calcium carbonate in them more quickly than with other building materials. Today we are going to see what an acid can do to a basic building material, limestone.

-Introduce chemical reactions with demo of baking soda and vinegar and relate to chemical erosion

2) Color Changing Milk:

What do you drink in the morning to grow tall and strong? Milk, right? Does anyone know what is in milk? Water, protein, fat, minerals that are all essential for your body! What is soap made out of? Soap is a molecule made up of two different parts. The head of the soap molecule is hydrophilic, meaning 'water-loving'. The tail part is hydrophobic, meaning that it's 'scared of water'. A round ball of soap molecules forms a micelle. When you add dish soap to dirty dishes, the soaps form micelles. Inside the micelle is the hydrophobic part, which absorbs fat, which is hydrophobic and leaves the water on the outside. Proteins are a different type of macromolecule made up of subunits called amino acids. The bonds between the amino acids are broken up when soap is added. So when you mix milk with soap in a fluid motion, the molecules of protein and fat bend, roll, twist, and contort in all directions. The food coloring molecules are bumped and shoved everywhere, providing an easy way to observe all the invisible activity. The rapid mixing of fat and soap causes swirling and churning where a micelle meets a fat droplet. There's another reason the colors explode. Since milk is mostly water, it has surface tension like water. Surface tension is the ability of a liquid's molecule to stick together. Water has an unusually high surface tension as demonstrated by the penny demo. The drops of food coloring floating on the surface of the milk tend to stay put. Liquid soap wrecks the surface tension by breaking the bonds between water molecules and allowing the colors to zing throughout the milk.

Modules/Demos, or Project

Introduction:
-penny and water demo to introduce the concept of surface tension
-baking soda and vinegar demo to introduce the concept of chemical reactions

1) Acid Attack:

-students explore a chemical reaction by examining the effect of chemical erosion on statues and monuments. They will use chalk to observe what happens when limestone is placed in liquids with different pH values. In addition, they will also learn about several things that engineers do to reduce the effects of acid rain on the environment.

Procedure:

1. Prepare three cups for each group: one containing tap water, one with lemon juice, and one with vinegar. Clearly label each cup using a waterproof maker with the group name and the liquid each cup contains.
2. Pass out Acid Attack Worksheet and have students begin the worksheet.
3. Show pictures of chemical weathering. Explain to students that rain is normally a little acidic to begin with, but sometimes it can become even more acidic because of

pollution. The amount of damage that acid rain causes depends on how acidic it is. Also explain that damage can occur with just a little bit of acidity over long periods of time.

4. Pass out the prepared cups of liquid, three nails and three pieces of chalk to each group.
5. Have each student use a nail to carve a picture in one piece of chalk. Then, have students draw a picture of their chalk on their worksheets. Tell them the picture does not have to be exact; it can just be a quick sketch.
6. When finished, each group member should put their piece of chalk in a container of liquid (as shown below: one piece of chalk in each of the cups of water, lemon juice, or vinegar) and wait 10 minutes.

Activity set up: testing for acidity.

7. While students are waiting, have them measure the pH of each of the three liquids with litmus paper.

8. After ten minutes, have students remove the chalk from

9. Finally, students should compare their chalk with the other members in their group and fill out the remainder of the worksheet.

2) Color Changing Milk:

Water on Penny demo: Can keep adding water to top of penny and it won't fall down due to surface tension.

Procedure:

1. Pour enough milk in the dinner plate to completely cover the bottom. Allow the milk to settle.
2. Add one drop of each of the four colors of food coloring - red, yellow, blue, and green - to the milk. Keep the drops close together in the center of the plate of milk.
3. Find a clean cotton swab for the next part of the experiment. Predict what will happen when you touch the tip of the cotton swab to the center of the milk. It's important not to stir the mix. Just touch it with the tip of the cotton swab. Go ahead and try it.
4. Now place a drop of liquid dish soap on the other end of the cotton swab. Place the soapy end of the cotton swab back in the middle of the milk and hold it there for 10 to 15 seconds. Look at that burst of color! It's like the 4th of July in a bowl of milk!
5. Add another drop of soap to the tip of the cotton swab and try it again. Experiment with placing the cotton swab at different places in the milk. Notice that the colors in the milk

continue to move even when the cotton swab is removed. What makes the food coloring in the milk move?

Repeat the experiment using water in place of milk. Will you get the same eruption of color? Why or why not? What kind of milk produces the best swirling of color: skim, 1%, 2%, or whole milk? Why?

Closing Activity and Discussion.

Expand on the topic--what are problems engineers are trying to solve today? What are the some problems that engineers are trying to solve in the future? How is this relevant to the mentees' daily/future lives? How is it relevant to the lesson topic? Can use a socratic discussion method to address these questions.

After finishing the two activities, the students will be asked questions:

- What do you know about acids?

(Possible answers: it is a substance that has a high pH, often tastes sour, turns litmus paper blue and can break things apart or create holes.)

- Can you name any acids?

(Possible answers: lemons, vinegar, cola, car battery acid, and hydrochloric acid.)

- What causes acid rain?

(Answer: Acid rain happens when air pollution from fossil fuel-burning plants or cars chemicals react to form acids in the air. The acids in the air then attach to water molecules and fall as rain or snow.)

- What effects does acid rain have on statues and monuments?

(Answer: Acid rain can dissolve away statues, monuments and buildings over time.)

- How do engineers try to clean up acid rain?

(Answer: Engineers work to find ways other than burning fossil fuels to get energy, such as electric cars. Engineers also design filters for smoke stacks so less air pollution is released into the atmosphere from industrial factories.)

- Does the quality of our air matter? Is clean air important?

(Answer: Yes, polluted air can cause serious problems for us and our environment.)

- How does air get dirty? What is air pollution? What are air pollution sources?

(Answer: Air pollution is caused by several things that people do, especially burning fossil fuels.)

- What could happen if you breathe polluted air?

(Answer: Polluted air can cause itchy eyes, coughing and diseases for humans and other life on Earth, as well as change or destroy our buildings, etc.)

1. What types of molecules are in milk?
2. What does hydrophobic and hydrophilic mean?
3. How does soap work?

Discuss why hydrophobic and hydrophilic molecules are important parts in our body.

Worksheet

-Acid Attack Worksheet:

-coincides with completion of activity: prediction, data, results, and conclusions (fill in the blank format)

Acid Attack Activity – Attack Worksheet

Draw a picture of your chalk "sculpture."

Predict

What do you think will happen when you put your chalk into the liquid?

_____

_____

Data

What liquid did you put your chalk in? _____

While you are waiting, use your litmus paper to measure the pH of all three liquids:

The pH of **lemon juice** was _____.

The pH of **tap water** was _____.

The pH **of vinegar** was _____.

Results

Draw a picture of your chalk after it set in liquid.

Conclusions

Compare your chalk with the chalk of the other members of your group. Which chalk looked the worse?

_____

Which liquid — **lemon juice**, **tap water** or **vinegar —** is the most acidic (dissolved the chalk the most and lowest pH value)?

Materials

Introduction:

- 1 penny
- pipette?
- baking soda (2 tablespoons?)
- vinegar (1 cup?)
- small clear plastic cup for each group of 3 students

Acid Attack:
For each group of 3 students:

- ½ cup tap water
- ½ cup lemon juice
- ½ cup white vinegar
- 3 pieces/sticks white chalk (**must be Prang** brand chalk, not Crayola because there isn't enough calcium carbonate in it)
- 3 small cups labeled with group names (**must be clear plastic**)
- 3 nails (or other sharp objects that could scratch chalk)
- 3 strips litmus paper

For the teacher/instructor:

- Watch/clock, stopwatch or timer

Color Changing Milk:

- Milk (whole or 2%)
- Dinner plate
- Food coloring (red, yellow, green, blue)
- Dish-washing soap (Dawn brand works well)
- Cotton swabs

References/Citations

1) Acid Attack activity Lesson Plan Adapted from Teach Engineering: "TE Activity: Acid Attack" http://www.teachengineering.org/view_activity.php?url=http://www.teachengineering.org/collection/cub_/activities/cub_earth/cub_earth_lesson5_activity2.xml
2) Color Changing Milk http://www.stevespanglerscience.com/experiment/00000066