FACTORS AFFECTING RATE OF REACTIONS

PROBLEM PRESENTATION / EXPLORATION

A. Provide for each group the following:
   1. A bowl of ice water
   2. A beaker of hot (at least 60°C) water
   3. A balloon large enough to fit over a one-holed rubber stopper that has been inserted into a 125 mL Erlenmeyer flask
   4. A 125 mL Erlenmeyer flask
   5. A No. 5 one-holed rubber stopper
   6. Alka-Seltzer® tablets
   7. Mortar and pestle
   8. Graduate cylinder

B. The contest is to see which group can make the Alka-Seltzer® react the fastest.
   1. Everyone must use 50 mL of water in their Erlenmeyer flask
   2. The timing will begin from the time the Alka-Seltzer® enters the flask and last for exactly two minutes.
   3. At the end of the two minutes the balloon must be pinched off and tied. (A representative from another group should be an observer so people don't blow into their balloon to increase their volume.)
   4. The winner will be the group that has made their reaction go the fastest over the two minute interval.
   5. If there is any doubt about who has won, the class must devise a way to measure the volume of each balloon.
   6. The group having the balloon with the largest volume wins.

CLASS RESPONSE / CONCEPT INVENTION

A. What were the factors considered by the groups in deciding how to make the reaction take place faster? Have the groups express their thoughts.
   1. Temperature of the water
   2. Number of tablets
   3. Surface area of the tablets (grinding them up creates more surface area)
   4. Agitation

B. How could we find out which of these factors is the most important? Once again this is a perfect opportunity for the students to practice separation and control of variables. Have them design ways to test for only one variable while holding all the others constant.

C. Temperature
   1. Place only one tablet that has not been ground up in 50 mL of water in the Erlenmeyer flask. Do not agitate the contents. Place the flask/balloon apparatus in the ice cold water and wait for two minutes. Tie off the balloon at the end of the two minutes.
   2. Place only one tablet that has not been ground up in 50 mL of water in the Erlenmeyer flask. Do not agitate the contents. Place the flask/balloon apparatus in the warm water and wait for two minutes. Tie off the balloon at the end of the two minutes.
   3. Measure the volume of the gas generated in each reaction by submerging the balloon in water and measuring the volume of the water displaced.

D. Concentration
   1. Place two tablets that have not been ground up along with 50 mL of water. Do not agitate the contents. Place the flask/balloon apparatus in the ice water and wait for two minutes. Tie off the balloon at the end of the two minutes.
   2. Measure the volume of the gas generated by submerging the balloon in water and measuring the volume of the water displaced. Compare with C1.

E. Surface Area
   1. Grind up one tablet with the mortar and pestle and transfer it to the first flask

along with 50 mL of water. Do not agitate the contents. Place the flask/balloon apparatus in the ice water and wait for two minutes. Tie off the balloon at the end of the two minutes. (Compare with C1)

2. Grind up two tablets with the mortar and pestle and transfer it to the second flask along with 50 mL of water. Do not agitate the contents. Place the flask/balloon apparatus in the ice water and wait for two minutes. Tie off the balloon at the end of the two minutes. (Compare with D2)
3. Measure the volume of the gas generated in each reaction by submerging the balloon in water and measuring the volume of the water displaced.

F. Agitation

1. Place one tablet that has not been ground up along with 50 mL of water. Place the flask/balloon apparatus in the ice water and constantly swirl for the entire two minutes. Tie off the balloon at the end of the two minutes.
2. Measure the volume of the gas generated by submerging the balloon in water and measuring the volume of the water displaced. Compare with C1.

G. Which of the factors tested were important in determining the rate of the chemical reaction? From the class observation which set of conditions would result in the very fastest reaction?

1. Determining which single factor was most important will probably be difficult because the volume of CO_2 will not be sufficiently different to give a clear answer.
2. It should be clear, however, that the reaction is speeded up if the reaction is carried out at increased temperatures, if the concentration of the Alka Seltzer® is greater, if the surface is large (powder form), and if the reaction mixture is continually agitated.
3. A very elementary explanation for this is that in order for the chemicals to react they must "bump into" each other. The greater the number of collisions, the greater the rate of reaction. By increasing the temperature the molecules move faster and have more collisions. By putting more Alka Seltzer® in the water there are more molecules to run into each other. By powdering the tablets there is more surface area for collision with the water. Likewise, the agitation brings more of the reacting molecules in contact with each other. In these ways we can account for the reaction rate being faster.

H. There is another factor that affects the rate of some reactions. To introduce this factor you will need some 3% hydrogen peroxide. This is the same hydrogen peroxide that you buy at the drug store. Also you will need some steel wool and some sand.

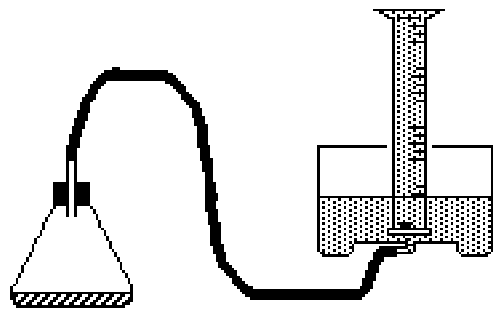
1. Place about 20-25 mL of hydrogen peroxide in each of the three beakers. Observe for a couple of minutes and note any activity.
2. Add a small piece of clean steel wool to the second beaker, and a small amount of sand to the third beaker.
3. Compare the rate of formation of bubbles of oxygen in each of the three beakers for a few minutes.
4. After 10 or 15 minutes more pour the liquid from each beaker down the sink. Flush it with a lot of water. Examine the steel wool and the sand. Are there any changes in appearance?
5. What happened to the rate of the reaction upon adding the steel wool? (It speeded up.) Did the steel wool get used up? (No).
6. What we have seen is an example of a CATALYST. A substance that changes the speed of a reaction but is not used up is called a catalyst. The steel wool was a catalyst, while the sand was not.

I. It was obvious that the steel wool and sand didn't get used up in the above reaction. The same reaction can be carried out using a catalyst that dissolves in the hydrogen peroxide and will not be seen after the reaction but is still there. If the liquid would be evaporated off it would be the same as with what we started.

1. In the sink or in a bucket submerge 50 mL graduated cylinder. Push one end of a rubber hose up into the submerged graduated cylinder.
2. Attach to the other end of the hose to the glass part of an eye dropper from

which the rubber bulb has been removed.

3. Insert the other end of the dropper into a one holed rubber stopper that fits into a 125 mL Erlenmeyer flask.
4. Place about 10 mL of 3% hydrogen peroxide in the flask. Add 15 ml distilled water. With tweezers drop in one crystal of potassium iodide and quickly put the stopper into the flask.



5. Measure the volume of gas generated as the gas pushes the water out of the cylinder.
6. Repeat this same procedure with new hydrogen peroxide but leave out the crystal of potassium iodide. [It will take place at a slower rate]
7. Compare the rate of generation of oxygen gas with and without a catalyst. [Faster rate with the catalyst.]

J. There are many biological catalysts inside our bodies that speed up or slow down reactions. Many of these are proteins that participate in reactions at the cell level. These proteins are called enzymes. The enzymes that slow down reactions are normally called inhibitors, and in the food industry they are called preservatives since they slow down the decay of food and preserve it for long periods of time. A listing of ingredients on many different types of food indicated the presence of these preservatives. Two of the major types of preservatives are "antimicrobials" (prevent spoilage by bacteria, molds, fungi, and yeasts) and "antioxidants" (prevent changes in color or flavor because of oxidation.)

1. Antimicrobials
   - a.) ascorbic acid (vitamin C)
   - b.) benzoic acid
   - c.) sodium benzoate
   - d.) citric acid
   - e.) lactic acid
   - f.) calcium lactate
   - g.) butylparaben
   - h.) methypparaben
   - i.) propylparaben
   - j.) propionic acid
   - k.) calcium propionate
   - l.) potassium propionate
   - m.) sodium propionate
   - n.) sodium diacetate
   - o.) sodium erythorbate
   - p.) sodium nitrate
   - q.) sodium nitrite
   - r.) sorbic acid
   - s.) calcium sorbate
   - t. potassium sorbate
2. Antioxidants
   - a.) ascorbic acid (vitamin C)
   - b.) BHA (butylated hydroxyanisole)
   - c.) BHT (butylated hydroxytoluene)
   - d.) citric acid
   - e.) EDTA (ethylenediaminetetraacetic acid)
   - f.) propyl gallate
   - g.) TBHQ (tertiary-butylhydroquinone)
3. Have students check twenty foods at home to see which seem to be the most widely used antimicrobials and antioxidants.
4. Have students discuss whether it is better to buy foods that have no artificial preservatives.
5. There has been a large controversy about the use of using sodium nitrate and sodium nitrite in foods in the past few years. Have students research the

pros and cons of this type of use.

CONCEPT EXTENSION

A. Preparation for the Formaldehyde Clock Reaction
   1. In preparation for this reaction the following solutions must be made:
   2. Phenolphthalein Solution - Place 1.0 gram of phenolphthalein solid in a flask. Add 50 mL ethyl alcohol and 50 mL distilled water. Mix thoroughly. (If you do not have access to phenolphthalein, grind up an Exlax® tablet (not the chocolate kind) and dissolve it in rubbing alcohol. Filter off the solid particles that don't go into solution. You can use this without adding any more water.)
   3. Formaldehyde Solution (SOLUTION A) - Put 23 mL of formaldehyde (37-40% aqueous solution) in a 1.0 liter flask. Add 15 mL of the phenolphthalein indicator solution. Now add 962 mL of water and thoroughly mix.
   4. SOLUTION B is made in two parts B1 and B2 which are then equally mixed to make SOLUTION B.
   5. Solution B1 - Add enough water to 20.8 g of sodium bisulfate ($NaHSO_3$) to make 1.0 L of solution
   6. Solution B2 - Add enough water to 6.30 g of sodium sulfite (Na_2SO_3) to make 1.0 L of solution.
   7. Now combine B1 and B2 to make SOLUTION B.
   8. The solutions may be prepared a day or two in advance, but they will decompose if stored longer than one week.

B. The Formaldehyde Clock Reaction
   1. Measure out 10 mL of SOLUTION A into a graduated cylinder and pour it into a clean beaker.
   2. Measure out 10 mL of SOLUTION B into a different graduated cylinder and pour it into a different clean beaker.
   3. A third clean beaker, larger than the other two, will serve as the reaction vessel. Both solutions from the small beakers should be poured at the same time into the larger beaker. Swirl the larger beaker for about five seconds and set it on top of a piece of white paper on the table.
   4. Start measuring the time from when the two solutions were poured into the larger beaker. Record how long it took for the color to form.
   5. Repeat the reaction with clean cylinders and beakers with one difference. Before adding SOLUTION A and SOLUTION B together, cool the solutions by letting them sit in their small beakers in ice water for about five minutes.
   6. What do you predict will happen to the reaction time for this reaction compared with the one conducted at room temperature?
   7. Predict what would happen if you only used 5 mL of SOLUTION A + 5 mL of water instead of 10 mL of SOLUTION A as before? Would it take longer or shorter for the color to appear?

C. Meat tenderizers contain an enzyme called papain. Have students find out what papain does by doing some research. To give them an example of what happens carry out the following demonstration.
   1. Prepare some gelatin according to the directions on the package.
   2. Divide the gelatin into two portions. To the first portion sprinkle some meat tenderizer containing the papain. To the second portion add nothing.
   3. Set the two portions of gelatin out on the table at room conditions. Note the changes after a few minutes.

D. One of the most important factors affecting the rate of reactions is temperature. Although almost any chemical system could demonstrate this, there is a neat, simple, and quick system that you may never have thought about. It is the light stick that is so prominent around Halloween time. Technically you want to get a Cyalume® light stick from the American Cyanamid Company.
   1. Light sticks feature chemiluminescent reactions that give off light (glow) in the dark.
   2. Chemiluminescence is a phenomenon wherein chemical molecules produced in a chemical reaction are produced in a chemically excited state that

releases light energy. In most reactions where energy is released at room temperature, heat rather than visible light is emitted. The normal place where we see this phenomenon is in fireflies. Light sticks are based upon the same sorts of chemical reactions as take place in fireflies.

3. In one of the formulations for a light stick, hydrogen peroxide is stored in a thin glass ampoule. When the ampoule is broken by manipulation of the external plastic tube, the hydrogen peroxide reacts with another chemical called phenyl oxalate. The energy released is transferred to a dye. The dye fluoresces, and this is the light that we see when our light stick glows. By using a different dye, the color of the chemiluminescent light can be changed. [Normally, there are white, green, blue, and red light sticks available at Halloween. If you wait until after Halloween, you can pick them up at about half what they go for prior to Halloween. It is very difficult to find the light stick at times other than Halloween.]
4. Have students investigate ways to study how temperature affects the rate of reaction of a light stick.
   a. Prepare a hot water bath, an ice bath, and a room temperature bath.
   b. Activate three light sticks following the manufacturer's instructions. Place one light stick in each bath.
   c. Darken the room. Note the relative intensity of light emitted from each stick.
   d. Develop a method for determining how long a light stick will continue to give out light. Compare the length of time for a light stick that had remained in the freezer overnight before being activated with one that had been heated in boiling water for ten minutes before being activated with one that had been activated at room temperature.
   e. Activate a light stick at room temperature. Now place it in the freezer overnight. What will happen as the temperature is increased to room temperature. Will the light stick continue to give off light after the temperature was raised?
   f. As long as the plastic outer liner has not been punctured, the used light stick can be disposed of in the trash can.