

FLOAT YOUR BOAT

(A study of the effects of concentration on a reaction)

Objectives:

- Evaluate the effects of changing temperature on the products of a chemical reaction.
- Relate changes in energy to an increase in activation energy and the development of an activated complex.
- Use the relationship between mass and volume to calculate density based on changes in concentration and temperature.
- Explore the production of polymers and relate this to industrial processes.
- Graph the relationship between the independent and dependent variables in the experiment.

Resources:

Flinn Scientific Inc. Chem-Fax Publication Number 270.10

Hewitt, P. (2001). *Conceptual Physics*. Menlo Park, CA: Addison-Wesley Publishing Company, Inc.

Murphy, J.T., Hollon, J.M., & Zitzewitz, P.W. (1995). *Physics: Principles & Problems*. Westerville, OH: Glencoe/McGraw-Hill.

Tzimopoulos, Nicholas D., Metcalfe, H. Clark, Williams, John E., & Castka, Joseph. (1993). *Modern Chemistry*. Austin, Tx: Holt, Rinehart and Winston.

Safety: Safety glasses, aprons and gloves must be worn throughout this lab. The polyurethane System Part A & B may contain skin and tissue irritants. Do not touch the foam. It will take about 15 minutes for the surface to firmly set and may contain unreacted material for up to 24 hours.

Materials:

Polyurethane Foam System (Part A & B) (Available from Flinn Scientific)

Clear plastic disposable cups

Stirring rods or popsicles sticks

Food coloring (optional)

Graduated cylinders to pre-measure amounts (Do not put chemicals into cylinders as this sticks to the sides and makes cleaning them difficult.)

Clear plastic tubs

Sharpies or grease pencils

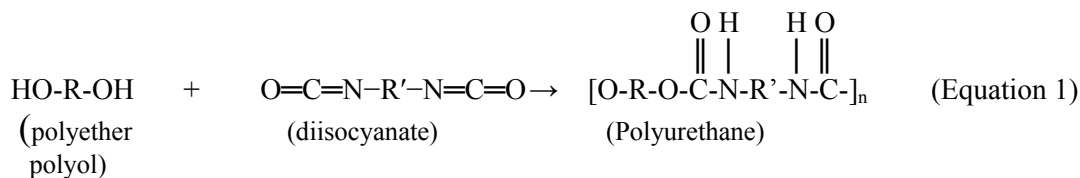
Thermometer

Mini loaf pans or any square or rectangular container that can be used as a boat form

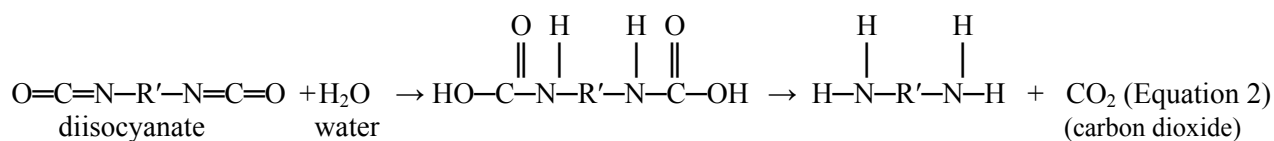
1 Graduated Cylinder

Instructional Concepts:

This activity will familiarize students with the injection molding process which is used throughout industry to form manufactured products. Injection molding is used in the manufacture of furniture, packaging, insulation, floatation devices and many other items. It is used extensively in the marine industry to inject polyurethane foam into fishing and ski boats to insure they float correctly. Polyurethane can be found in the form of fibers, elastomers, flexible foams, and rigid foams. The foam used by the marine industry is rigid foam. In this lab you will mix polypropylene glycol $[\text{HO}(\text{C}_3\text{H}_6\text{O})_n\text{H}]$ (Part A) and diisocyanate $[(\text{C}_6\text{H}_5)_2\text{C}(\text{NCO})_2]$ (Part B). When these two are mixed together they will expand to about thirty times their original volume and become rigid in about 5 minutes. This process takes place in two steps. The first step involves an exothermic reaction that produces the polyurethane.



During the course of the polymerization reaction, a small amount of water reacts with some of the diisocyanate causing a decomposition reaction. This results in the production of carbon dioxide gas, thus causing the solution to foam and expand in volume. The gas ultimately creates visible pores in the rigid substance within minutes.



Prelab:

- The instructor will discuss the injection molding process and how it is used in industry.
- The instructor will explain how monomers are linked together to form polymers.
- The instructor will demonstrate the formation of light weight polyurethane foam from the combination of polypropylene glycol (Part A) and diisocyanate (Part B).
- The instructor will have students brainstorm to suggest conditions (changes in concentration, temperature, etc) which might affect the volume and quality of foam produced.
- The instructor will list the students' suggestions on the board. After a discussion of each, the students will conduct the procedures below.

Procedure #1: The Relationship between Concentration and Temperature:

- Materials: 3-Mini loaf pans or plastic containers to use as a mold, 3-test tube, 1-thermometer, 6-clear plastic cups, 3-spoons and paper to put on the table.
- Spread the white paper onto the table top to keep any foam that might spill over from getting onto the table.
- Record the mass of the mold and the test tube on the data sheet.
- Fill a large plastic container with water. The water should be at a depth that will provide for you to submerge the mold containing the foam. *Carefully* mark the water level on the side of the plastic container.
- Place the pan and the test tube in the water.
- Place a glass stirring rod in the center of the mold and press down to submerge the mold below the water level. Carefully mark the new water level. Remove the mold from the water, dry it off and sit to the side.
- Use a graduated cylinder to add enough water to raise the water level from the original mark to the mark recorded when the pan was submerged. Record the amount of water added as the volume of the mold.
- Fill a graduated cylinder with 40 mL of water. Pour the water into a clear plastic cup and *carefully* mark the depth with a sharpie. Repeat this with a second plastic cup. Prepare another cup by measuring 20 mL of water in a graduated cylinder and pouring it into the cup and again *carefully* mark the depth of the water. Repeat with a second cup. Finally fill a graduated cylinder with 60mL of water and pour it into a clear plastic cup as above and mark carefully. Repeat with a second cup.
- Take two of the cups that you have marked at 40ml. Pour Polyurethane Foam System Part A into one cup and Polyurethane Foam System Part B into the other cup.
- Pour the liquid from each cup into one of the molds. Quickly stir with a spoon or stick. Hold the test tube in the center on the mixture and insert the thermometer into the test tube. Record the initial temperature of the mixture. When the temperature starts to change (when the foam starts rising), begin recording the temperature at one minute intervals. Continue recording the temperature until it begins to fall. Set the mold to the side and let it cool until all experiments are run.
- Record the mass of a second mold and test tube on the data sheet.
- Pour 60 mL of Polyurethane Foam System A into one of the cups prepared previously and 20 mL of Polyurethane Foam System B into another cup. Pour both of these into the mold. Place the test tube in the center of the pan and insert the thermometer into the test tube. As above, record the initial temperature of the mixture. Continue recording the temperature until it begins to fall. Set the mold to the side and let it cool until all experiments are run.
- Record the mass of the third mold and test tube on the data sheet.

- Pour 20 mL of Polyurethane Foam System A into one of the cups prepared previously and 60 mL of Polyurethane Foam System B into another cup. Pour both of these into the mini loaf pan. Place the test tube in the center of the pan and insert the thermometer into the test tube. As above, record the initial temperature of the mixture. Continue recording the temperature until it begins to fall. Set the pan to the side and let it cool until all experiments are run.
- Record the mass of the mold and the foam. Record this on the answer sheet as mass -1. You will use this mass to calculate the energy change.
- Take a flat spatula and remove a good size piece from the top of each pan. Do not go below the side of the mold. Compare the flexibility of each piece. Examine each piece and determine if there are any differences in the size of the holes in the foam.
- Use the spatula to remove any material that may have expanded beyond the sides of the pan. Cut horizontally across the top of the pan using care not to break the test tube. Cut vertically as someone would do in cutting bread. Carefully cut around the test tube. Upon completion, the top of the foam should be level with the top of the mold. The test tube will be protruding through the center.
- Record the mass of the mold and foam after cutting. Record this on the answer sheet as mass-2. You will use this mass to calculate the density of the foam.
- Fill a large plastic container with water. The water should be at a depth that will provide for you to submerge the pan containing the foam. Carefully mark the water level on the side of the plastic container.
- Place the mold containing the foam in the water. Make observations as to how it sits in the water. Does it sit level or does it tend to list to one side?
- Place a glass stirring rod in the test tube and press down to submerge the pan with the foam below the water level. Carefully mark the new water level. Remove the mold from the water and sit to the side.
- Use a graduated cylinder to add enough water to raise the water level from the original mark to the mark recorded when the pan was submerged. Record the amount of water added as the volume of the mold and foam.
- Repeat the above procedure with the other two pans of foam.

Applications in the Workplace:

Team work is an important quality that all industries wish to see in their employees. This activity allows students to model the injection molding process that is used extensively in industry. It provides students with practice in measuring and allows them to evaluate the consequences of improper measuring. Students also gain insight into the effects of weather changes on the storage of raw materials. Students also gain experience in graphing techniques.

Integration Across the Curriculum:

The procedures in this activity require students to integrate skills learned in chemistry, physics and mathematics classes. Students use skills learned in chemistry to measure and mix reactants, determine mass and volume and calculate density. Students use their knowledge of physics by using density values to calculate buoyancy. Graphing skill learned in mathematics classes and physics are also a part of this activity. Art could also be incorporated into this activity by having the students decorate their boats.

Additional Activities:

Students could design lab activities to test some of the conditions that were suggested in their original brainstorming activity.

Students could design and build their own molds to determine the effects of shape.

Students could remove their boats from the mold, shape them to hold weights to determine how much weight they will hold before sinking.

A Boat That Floats – Data Sheet

(An exercise in polymers, density and buoyancy)

NAME(s) _____ DATE _____ PERIOD _____

Data Table 1	40A/40/B	60A/20B	20A/60B
Mass of Mold + Test tube	_____	_____	_____
Mass 1 of Mold + Foam	_____	_____	_____
Mass 2 – After Top is removed	_____	_____	_____
Calculating mass	_____	_____	_____
Volume of water Displaced by Mold+ Test tube (before)	_____	_____	_____
Volume of water Displaced by Mold+ Test tube (after)	_____	_____	_____
Change in volume	_____	_____	_____
Density (g/mL)	_____	_____	_____
Change in Temperature	_____	_____	_____
Energy Relationship (kg . ΔT)	_____	_____	_____
Buoyancy	_____	_____	_____

Data Table 2

40A/40B

60A/20B

20A/60B

Time (min)

Temperature

Temperature

Temperature

0

1

2

3

4

5

6

7

8

9

10

11

12

13

14

15

16

17

18

19

20

Answer the questions below based on the data collected in the lab.

1. Would you expect the enthalpy value for this reaction to be positive or negative? Why?
2. It took a few minutes before changes were observed in this reaction. Explain what you think was happening during this period of time.
3. Would this reaction be considered spontaneous? Why/why not?
4. Would you expect the entropy in this reaction to be positive or negative? Why/why not?
5. Compare how your boats sit in the water. Which of the three floated best? Use your density and buoyancy calculations to account for differences in the way the three boats floated.

6. The two reactants used in this experiment were used at room temperature. Suppose you are a boat manufacturer. These same two reactants are delivered into your factory through pipes and on into hoses where they can be sprayed simultaneously into the hull of the boat. If one of the reactants fails to flow properly because of an unusually cold winter, what effect would you predict this to have on the flotation of the boat? Be sure to fully explain your answer.

7. At which point in this reaction does the activated complex occur?

8. Would your reaction most likely have a high or low activation energy? Why?

9. What are some factors that might be adjusted to make this reaction run faster? Explain your answer.

10. Would you predict the first reaction or the second to be the rate determining step in this reaction? Why?

11. Use one of the physics textbooks in the room and calculate the buoyancy force of each of your boats. How do they compare. How did the change in concentration effect buoyancy?