Chemistry Celebration Weekend
May 3, 2003
University of Wisconsin-Madison

Science is Fun: Polymers
presented by the
Wisconsin Initiative for Science Literacy

POLYURETHANE FOAM

When two viscous liquids are mixed, a rigid foam is produced, whose volume is 10–20 times that of the original mixture.

MATERIALS

- 40 mL Part A and
- 40 mL Part B of a two-component polyurethane foam system
- 200-mL disposable cup
- newspaper to cover an area of about 0.5 m x 0.5 m
- plastic gloves
- flat wooden stirrer

PROCEDURE

Place the 200-mL disposable cup in the center of a mat of newspaper about 0.5 m x 0.5 m. Wearing gloves, pour equal amounts of Parts A and B into the disposable cup. Stir the mixture thoroughly with the wooden stirrer. The mixture will first change color. When the mixture begins to to expand, stop stirring. As the mixture foams, it rises out of the cup, overflows, and forms a bell-shaped solid that adheres to the paper.

Because the freshly prepared foam usually contains unreacted material, it should not be handled until it has cured several hours in a well-ventilated area.

SLIME: A GEL FROM POLY(VINYL ALCOHOL) AND BORAX

Two clear, colorless liquids are mixed and almost immediately form a gel. The gel can be formed into a ball, but if left unhandled, it flattens and runs.

MATERIALS

- 50 mL of a 4% solution of poly(vinyl alcohol), $[CH_2CH(OH)]_n$
- 5 mL of a 4% (by weight) solution of sodium tetraborate, $Na_2B_4O_7$
- 50-mL graduated cylinder
- 10-mL graduated cylinder
- 100-mL disposable plastic cup
- flat wooden stirrer
- food coloring (optional)
- plastic sandwich bag

PROCEDURE

Pour 50 mL the poly(vinyl alcohol) solution into the plastic cup. Add a drop or two of food coloring, if a colored gel is desired, and stir the mixture. Add 5 mL of sodium borate solution to the cup and stir the mixture vigorously with the wooden stirrer. Gel formation begins almost immediately, and a material, "slime," with interesting physical properties results. Knead the gel into an elastic ball. The consistency of the gel will change as it is kneaded, and after a couple minutes of kneading it will be uniform. Hold the ball in the palm of your hand and tip your hand. The ball will stretch out into a long column. Attempt to stretch the column abruptly; it will break. The gel may be preserved by sealing it into a plastic sandwich bag. If it is not enclosed, it will dry out over several days.

NEEDLE THROUGH A BALLOON

How does a magician push a needle through a balloon without popping it? Is it just "magic" or can science help us to explain this trick? In this activity students discover that an understanding of some of the unique characteristics of polymers can help us to perform a trick that seems to defy common sense.

MATERIALS

- rubber balloon
- sharp bamboo skewer
- petroleum jelly

PROCEDURE

Inflate the balloon, but leave it somewhat underinflated. Tie it closed. (Make sure the balloon is not larger than the length of the skewer.) Dip the tip of the bamboo skewer or needle into a small container of petroleum jelly and spread the jelly along the entire length of the skewer. Insert the skewer or needle with a gentle twisting motion into the nipple end of the balloon (the end opposite the opening) where the rubber is thickest. (See Figure 1.)

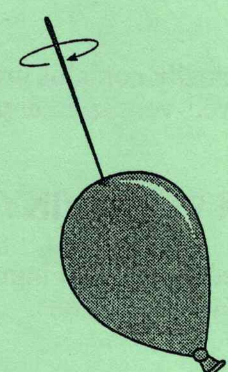

Figure 1: Twist the skewer into the nipple end of the balloon.

Continue pushing and twisting the skewer to the other side and out through the thicker rubber near the tied end. The balloon will not burst. (See Figure 2.)

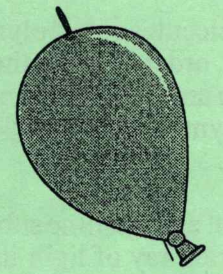

Figure 2: The needle emerges from the end of the balloon.

Push the needle or skewer all the way through the balloon so that it comes out at the tied end. Place your hand over the holes to feel the air leaking out. To show that this was a real balloon, jab the needle through the side where the rubber is stretched. The balloon will pop!

SUPERABSORBENT POLYMER

Farmers and parents of infants have at least one thing in common. They both need to manage moisture. Farmers need to keep moisture in the soil to promote seed germination and root development in the plants they grow. Parents need to keep their infant's cradle clean and dry. Both farmers and parents get help from the same source, a white powder called a superabsorbent polymer. This polymer is a white powder that can absorb water many times its volume, forming a stiff gel. The powder is incorporated in soil and in diapers to retain moisture.

MATERIALS

1 teaspoon (5 milliliters) superabsorbent polymer powder
2 water glasses
1 teaspoon (5 milliliters) table salt
food coloring (optional)
spoon

PROCEDURE

Place the powder in an empty, dry drinking glass and examine it. What color is it? Is it fine or coarse?

Fill the second drinking glass with water. You may add a drop or two of food coloring and stir the mixture to make the experiment more colorful. Pour the water quickly into the glass containing the powder. Pour the mixture back and forth from one glass to the other. As you pour, the mixture will thicken, and eventually become so thick that it will no longer pour. How long does this take? What does the thickened mixture look like?

Sprinkle about a teaspoon of table salt on top of the thickened mixture. Stir the salt into the mixture with a spoon. What happens as you stir? Does the mixture become thin enough to pour again? Add more salt and stir some more. Does the mixture become more fluid?

OBSERVATION OF POLYMERS BETWEEN POLARIZERS

The arrangement of the chain-like molecules in a polymer can be either random, with the chains tangled around each other, or highly ordered with the chains lying parallel to each other. The randomly coiled orientation is called an amorphous arrangement while the highly ordered orientation is called a crystalline arrangement. Polymers are usually amorphous, but they can contain crystalline regions.

One of the most interesting properties of a crystalline substance is its birefringence. This is the ability of a material to separate a single entering ray of light into two rays of light emerging from it. This property causes the material to appear bright when examined in polarized light. In general, the more crystalline a polymer, the brighter it appears in polarized light.

Often, the arrangement of the molecules of a polymer can be changed by stretching it. When a piece of soft and amorphous polymer is stretched, some molecule chains line up parallel to the stretched direction. This makes the polymer more crystalline and makes it appear brighter in polarized light.

Also, stretching a polymer sample causes its thickness to vary. When viewed in polarized light, a crystalline material will exhibit bright colors as a result of this variation in thickness. This is a beautiful phenomenon. The colors produced are called interference colors.

MATERIALS

two polarizing filters in frames
desk lamp
several different samples of uncolored, transparent polymer films
(e.g., pieces of sandwich bags, plastic wrap, clear adhesive tape, CD box, plastic cup)

PROCEDURE

Turn on the desk lamp. Set one polarizing filter between you and the lamp. Look through the filter at the lamp. The light you see through the filter is polarized in one direction, either vertically or horizontally. Hold the other filter and look through it toward the first filter and the lamp. Rotate the filter you're holding. As you rotate the filter, you will observe a position where the first filter appears completely dark. In this position, the filter you are holding is polarizing light in a direction perpendicular to the other filter. After you rotate the filter 90 degrees from this position, the two filters are polarizing light in the same direction, and the first filter appears brightest.

Set the second filter onto the bench so its polarization is 90 degrees from the first. In this position, the first filter will be dark when you look at it through the second filter. Take a sample of polymer (about 5 cm x 5 cm) and hold it between the two polarizers. Rotate the sample and see if there are any changes in brightness. If the sample shows variation in brightness as you turn it, hold it in the brightest position and gently stretch the sample. See if any colors appear.

Repeat this procedure with some of the other polymer films. Do some plastics show more colorful effects than others? What does this indicate about the arrangement of the molecules in the samples?
