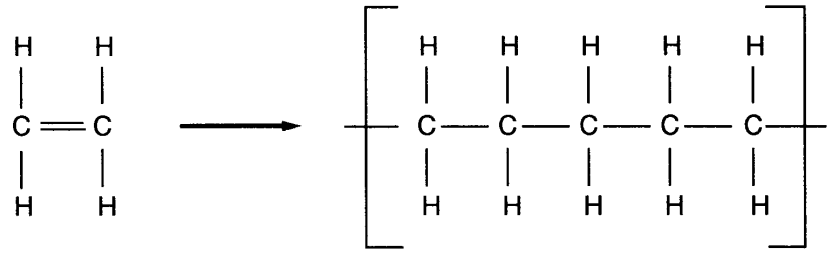
Polymers

Introduction

As you look around, you will find plastic materials almost everywhere. Plastics are part of a chemical family called polymers, which also includes elastomers (rubber) and adhesives. Some polymers, such as cellulose are naturally occurring, but most are chemically synthesized using chemicals derived from petroleum, which are called petrochemicals. The main petrochemical used for making polymers is natural gas.

Petroleum is a widely used product in our world, consuming billions of gallons daily for powering everything from automobiles to motorbikes and producing other forms of power (i.e., electricity through power generation). Petrochemicals use only 5% of this available petroleum, and only about half of the petrochemicals go into making polymeric materials.

Polymers (poly-mers), meaning many units, are created by joining together monomers (single units, usually a chemical compound such as ethylene gas as demonstrated in the example), using various combinations of heat, pressure, and catalysts. For instance, polyethylene is created by polymerizing ethylene gas as shown in the following chemical equation. A combination of heat, pressure, and a catalyst cause the double bond between the two carbon atoms in the ethylene gas to break and attach to other ethylene molecules. A polyethylene molecule is thus formed.



The brackets in the above equation indicate that the polyethylene molecule continues out to very long lengths relative to the size of the carbon and hydrogen atoms.

Polymers have become such an integral part of our lives that most of the time they are not recognized. Of course, we all recognize plastic bags, pens, telephones, fast food containers, and other common things as plastic, but we often fail to recognize other important polymer applications such as contact lenses, clothing fabrics (Dacron, Orlon, Nylon, Spandex, and Rayon), carpet fibers, automobile tires, foam cushions in furniture and mattresses, shoe soles, paints, pipes,

computer chips, and masks to produce electronic “chips,” automobile bumpers, and innumerable other objects. Plastics influence our lifestyle more than we could ever imagine. If we ever were to use just natural fibers (cotton and wool) instead of polymeric fibers for clothing, carpets, etc., all the available land in the United States would have to be used to raise sheep or cotton to maintain our present lifestyle.

Classification of Plastics

Thermoplastic

Basically, two types of plastics exist, thermoplastics and thermosets. Thermoplastics can be melted and reformed or reused. Typical thermal plastics include polyethylene, polypropylene, PVC, and nylon. Thermoplastics are converted to usable products by melt processing, (injection molding, extrustion, blow molding, and thermofoaming) which are explained below.

Injection molding forces melted polymer into a cold mold under pressure. When the polymer cools, it produces a part such as a pen barrel, a comb, a Tupperware container, a garbage can, or a refrigerator liner. Extrusion forces the melted polymer through a die to form continuous shapes such as pipe, tubing, sheet, or decorative molding. Blow molding uses air pressure to blow up the melted plastic like a balloon inside of a mold. When the plastic cools, it forms a bottle or other hollow shape. Thermoforming takes heated sheets of plastic and draws them into a mold with a vacuum to form such things as butter tubs, drinking glasses, small boats, and pick-up-truck bed liners.

Thermoset

Thermoset polymers “cure” or crosslink by a chemical process to become a stable material that cannot be melted. Typical thermosets include epoxy, polyester, phenolic, polyurethane, and silicone.

Thermoset materials are often used with reinforcements such as glass, Kevlar, and carbon fibers to make strong, lightweight parts such as fiberglass boats, airplane wing panels, Corvette car bodies, skis, gasoline storage tanks, septic tanks, chemically resistant pipe, and many other things. They are also used as adhesives that can be formulated to bond almost anything.

Some thermosets are very hard and tough (bowling balls), while others are soft and pliable (rubber tires, balloons, baby squeeze toys). Some are used for paints and some for bonding thin sheets of wood to make plywood.

Slime

Instructor Notes

Reliability

This lab works very well. It does take time for the polyvinyl alcohol to dissolve. Make sure the solution is clear.

Estimated Time for Activity

One class period.*

Teacher Tips

1. Polyvinyl alcohol can be purchased as a solid or as a 4% solution from supply houses. If it is purchased as a solid, you need to get a 99% hydrated, 170,000 + molecular weight variety.
2. Adding the 4% sodium borate causes the establishment of cross links making the "slime." To make 100 mL of a 4% solution, add 8 g of $Na_2B_3O_7 \cdot 10H_2O$.
3. To speed the process of making slime, the polyvinyl alcohol can be dissolved ahead of time. A very quick method with very little mess is to place the solid polyvinyl alcohol and water in a capped, appro-priately sized jar or bottle and place it in a microwave. **Be sure the cap is not on tight**. Heat in the microwave for about 2 min. This should make the water very warm but not hot. Tighten cap and, shake for a minute or two. If it has not all dissolved. heat for an additional minute (**loosen cap again**) and shake. This method eliminates the sticky gooey mess of stirring and heating for a pro-longed period on a hot plate. The solution dissolves very readily this way and gives a nice clear solution.
4. Adding food coloring is not necessary. It gives color only.
5. If students take the product home, they should realize it does not keep well. If left uncovered, it dries out. If left sealed, after han-dling, mold will begin growing on it in a few days.
6. Solutions of polyvinyl alcohol and sodium borate are stable and can be stored indefinitely.
7. References: Casassa, et al. 1986. "The Gelation of Polyvinyl Alcohol with Borax." *Journal of Chemical Education*, vol. 63, 70.1 pp. 57-60.

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*One class period is approximately 1 hour.

Suggested Questions

8. Describe the polyvinyl alcohol solution before the borate (cross-link) is added.
9. Write a paragraph describing the product.
10. Is it a solid or a liquid?
11. What does “poly” mean?
12. What does “polymer” mean?
13. What does the cross-link do when it is added to the polymer? How is the viscosity of the solution affected and why?

Safety

1. The polyvinyl alcohol is FDA-approved for indirect food use (food packaging) and opthalmologic (eye treatment) solutions, i.e., contact lens solutions. A 1959 study determined polyvinyl alcohol was an animal carcinogen (Flynn Scientific Chemical Catalog, 1992).

Activity: Slime

Student Learning Objectives

At the end of the activity students will be able to:

- observe and describe the properties of a prepared substance
- describe the nature of a polymer
- describe how crosslinking affects a polymer using models, drawings, discussion, and writing.

Materials

- Water, 96 mL
- Food coloring, a few drops
- Polyvinyl alcohol, 4.0 g
- Sodium borate, 4% solution (6 mL)
- Paper cup, 6 oz

Equipment

- Beaker, 250 mL
- Stirring rod
- Thermometer
- Graduated cylinder, 100 mL
- Graduated cylinder, 10 mL
- Plastic sandwich bag
- Hot plate

Procedure

1. Measure out 96 mL of water into a 100-mL graduated cylinder.
2. Carefully pour the water into a 250-mL beaker, and place it on a hot plate.
3. Heat the water to near boiling (95°C, approximately).
4. Add a few drops of food coloring to the warm water, if desired.
5. Accurately weigh out 4.0 g of polyvinyl alcohol into a 6-oz. paper cup.
6. Remove the water from the hot plate. Slowly, while stirring, add the polyvinyl alcohol to the warm water.

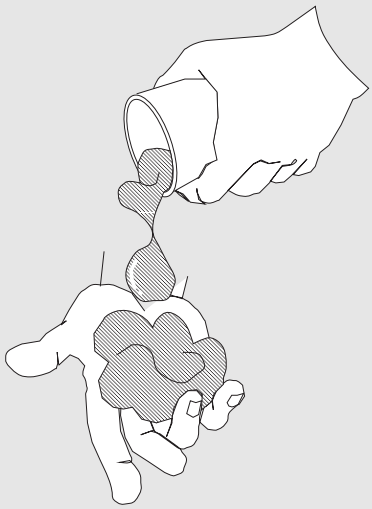

Figure 7.1. Slime

7. Place the beaker back on the hot plate until the temperature reaches about 90°C. Keep stirring until the polyvinyl alcohol is completely dissolved. Be patient.
8. Add 6 mL of 4% sodium borate, stirring constantly as you add the solution.
9. Pour the product into your plastic sandwich bag to cool before studying its properties.
10. Clean your equipment. (Hint: Roll product around in beaker to clean out most of the product, then wash.)
11. As students study the material they enjoy handling it. Have students try pouring it into their hands (Figure 7.1).

Extension Activity

1. Try adding more polyvinyl alcohol or a stronger or weaker concentration of sodium borate to the slime. Observe how these chemical changes affect the properties of the materials. Be sure and record this information in your journal.
2. Use a funnel or cheap paint “viscosity cup” to note the effect of changing variables on the viscosity of a product.

   Note*: Viscosity is an indirect indication of the amount of cross-linking that has taken place.*