Polyurethane Foam

Preparation of Polymers

Introduction

Try this amazing demonstration! Simply mix two liquids together and watch as the mixture expands to about 30 times its original volume. The result is a hardened, lightweight polyurethane foam.

Concepts

- Polymers
- Catalysis

Materials

Polyurethane Foam System (Part A and Part B)

Acetone (optional)

Disposable cups (clear plastic, if available), 2

Disposable glove, clear (optional)

Food coloring (optional)

Paper towels or newspaper

Tongue depressor or stirring rod

Safety Precautions

This activity should only be performed in a fume hood or well ventilated area. Avoid breathing any vapors produced and avoid skin contact, as both Part A and Part B may contain skin and tissue irritants. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Procedure

1. In a fume hood or well ventilated area, pour approximately 20 mL of liquid Part A in a disposable cup. *Note:* The exact volume is not critical. *Do not use glassware!* It is almost impossible to remove the hardened foam. Please use only disposable materials for the handling and mixing of the chemicals.
2. Place approximately 20 mL of liquid Part B in a second disposable cup. *Note:* The volume of Part B should be approximately equal to that of Part A.
3. If desired, add several drops of food coloring to one of the cups and stir thoroughly to mix.
4. Spread a paper towel or newspaper flat on the table and place one of the cups in the center of the paper towel.
5. Pour the contents from the second cup into the cup on the paper towel and stir thoroughly until you see the foam beginning to expand. Remove the stirring rod. *Note:* Use a disposable stirring rod, such as a tongue depressor, to stir the contents.
6. Observe the foam as it expands to about 30 times its original volume. The cup will get warm, indicating an exothermic reaction. Do not touch the foam until it is completely hardened.

Disposal

The disposable cups may be thrown in the trash. Any leftover liquids should be mixed together, allowed to react, and then the solidified polymer may be disposed of in the trash according to Flinn Suggested Disposal Method #26a. Please consult your current *Flinn Scientific Catalog/Reference Manual* for proper disposal procedures.

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Tips

- For a fun alternative, place about 35 mL of Part A and Part B in a paper cup, mix, and then pour the mixture into a latex glove. Make sure some of the mixture is in each finger of the glove. Now watch the foam expand and fill the glove. When completely hardened, the glove can be removed (probably not in one piece), if desired. You will have made a "hand" out of the polyurethane foam. The liquid may also be placed in plastic molds.
- Any 50/50 mixture of Part A and Part B may be used, but take into consideration the amount of expansion when measuring out the liquids.
- Acetone may be used to remove any hardened polymer on the table.
- 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. Some people will have allergic reactions to unreacted monomers.

Discussion

There are many forms of polyurethane such as fibers, coatings, elastomers, flexible foams, and rigid foams. The foam in this system is a rigid foam that is used in furniture, packaging, insulation, flotation devices, and many other items. Here, a rigid polyurethane foam is produced by mixing equal parts of two liquids, called Part A and Part B. This lightweight foam expands to about thirty times its original liquid volume and will become rigid in about five minutes.

Part A is a viscous cream-colored liquid containing a polyether polyol, a silicone surfactant, and a catalyst. The polyether polyol may be a substance such as polypropylene glycol [$HO(C_3H_6O)_nH$]. The hydroxyl (–OH) end of the polymer is the reactive site. The silicone surfactant reduces the surface tension between the liquids. The catalyst is a tertiary amine that aids in speeding up the reaction without being chemically changed itself. Part B is a dark brown viscous liquid containing diphenylmethane diisocyanate [$(C_6H_5)_2C(NCO)_2$] and higher oligomers (dimers, trimers or tetramers) of diisocyanate. When the polyether polyol (Part A) is mixed with the diisocyanate (Part B), an exothermic polymerization reaction occurs, producing polyurethane (see Equation 1).

$$\underset{\text{Polyether polyol}}{HO{-}R{-}OH} + \underset{\text{Diisocyanate}}{O{=}C{=}N{-}R'{-}N{=}C{=}O} \longrightarrow \underset{\text{Polyurethane}}{\left[{-}O{-}R{-}O{-}\overset{\overset{\displaystyle O}{\|}}{C}{-}\overset{\overset{\displaystyle H}{|}}{N}{-}R'{-}\overset{\overset{\displaystyle H}{|}}{N}{-}\overset{\overset{\displaystyle O}{\|}}{C}{-}\right]_n} \qquad \textit{Equation 1}$$

During the course of the polymerization reaction, a small amount of water reacts with some of the diisocyanate. A decomposition reaction occurs and produces carbon dioxide gas, thus causing the solution to foam and expand in volume. Pores in the mixture are created from the gas; these pores are visible when looking at the rigid substance. The multifunctionality of both reactants leads to a high degree of crosslinking in the polymer, causing it to become rigid within minutes. (See Equation 2.)

$$\underset{\text{Diisocyanate}}{O{=}C{=}N{-}R'{-}N{=}C{=}O} + \underset{\text{Water}}{H_2O} \longrightarrow HO{-}\overset{\overset{\displaystyle O}{\|}}{C}{-}\overset{\overset{\displaystyle H}{|}}{N}{-}R'{-}\overset{\overset{\displaystyle H}{|}}{N}{-}\overset{\overset{\displaystyle O}{\|}}{C}{-}OH \longrightarrow H{-}\overset{\overset{\displaystyle H}{|}}{N}{-}R'{-}\overset{\overset{\displaystyle H}{|}}{N}{-}H + CO_2(g) \qquad \textit{Equation 2}$$

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Constancy, change, and measurement
Content Standards: Grades 5–8
Content Standard B: Physical Science, properties and changes of properties in matter
Content Standards: Grades 9–12
Content Standard B: Physical Science, structure and properties of matter, chemical reactions

Answers to Worksheet Questions

1. Describe what happened in this demonstration. Include any and all observations about the substance produced.

   Two liquids, one cream-colored and one dark-brown, were poured together and stirred. Once thoroughly mixed, the solution began to bubble, and then foam rose and expanded. When the reaction was done, the foam had hardened to a very rigid but lightweight material.

2. What physical changes occurred? What chemical changes occurred?

   The container the reaction took place in became hot, and the mixture expanded to many times its original volume, both indicating physical changes. Chemically, the mixture changed color, became viscous, produced heat and gas bubbles, and finally became rigid and hard, very unlike its original liquid form.

3. One of the products of the reaction between the two solutions was carbon dioxide. What is the purpose of the carbon dioxide in the formation of the foam?

   The carbon dioxide gas allowed the bubbling and foaming to take place, thereby leading the mixture's volume to expand. It is also responsible for the foam's lightweight nature after the reaction is over. The gas created pores in the foam that kept the material very light.

4. Research two commercial uses of polyurethane foam. What function does it tend to serve?

   This type of foam is used in furniture and floatation devices. Since it is rigid and lightweight at the same time, it allows these products to stay firm, yet not heavy when lifted or carried.

References

Rosato, D. V. Rosato's Plastics Encyclopedia and Dictionary; Hanser: New York, 1993; pp 318–320, 572.

Shakashiri, B. Z. Chemical Demonstrations: A Handbook for Teachers of Chemistry; University of Wisconsin: Madison, 1983; Vol. 1, pp 216–218.

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Polyurethane Foam* activity, presented by Bob Lewis, is available in *Preparation of Polymers*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Polyurethane Foam* are available from Flinn Scientific, Inc.

Catalog No.	Description
C0335	Polyurethane Foam System
A0009	Acetone
V0003	Vegetable Dyes (Food Coloring), Set/4

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

Polyurethane Foam Demonstration Worksheet

Discussion Questions

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2. What physical changes occurred? What chemical changes occurred?

3. One of the products of the reaction between the two solutions was carbon dioxide. What is the purpose of the carbon dioxide in the formation of the foam?

4. Research two commercial uses of polyurethane foam. What function does it tend to serve?