Oh, the Memories!

Polystyrene Returns to Form

Introduction

Most familiar plastics, such as polyethylene and polystyrene, are made from thermoplastic polymers that soften when heated but regain their original properties when cooled. Many plastic objects that have been made by stretching and then cooling a softened polymer exhibit what is called *plastic memory*—they will return to their original dimensions or shape when heated. Heating a polystyrene cup provides a dramatic illustration of plastic memory.

Concepts

- Thermoplastic polymers
- Glass transition temperature
- Plastic memory

Materials

Balance, centigram
Beaker, borosilicate glass, 1-L
Boiling stones
Crucible tongs, 2
Forceps
Graduated cylinder, 25-mL
Heavy-duty scissors (optional)
Hot plate
Overflow can (optional)
Paper towel
Plastic cups, polystyrene, 8-oz, 4
Water

Safety Precautions

Exercise care when working with the boiling water bath. Use only borosilicate glass (e.g., Pyrex®) beakers and check glassware for cracks or chips before use. Wear safety glasses or chemical splash goggles whenever working with chemicals, heat or glassware in the laboratory.

Procedure

1. Set up a boiling water bath: Fill a 1-L beaker with about 800 mL of water and add several boiling stones. Heat the water to boiling on a hot plate at a medium-high setting.
2. Measure the mass of two small (8-oz) polystyrene cups and divide by two to determine the average mass of one cup.
3. Using crucible tongs, place a polystyrene cup in the boiling water bath and keep the cup submerged for about 20 minutes, until the cup begins to shrink and flatten out.
4. Remove the cup from the boiling water bath and place on a paper towel to cool. Compare the shape and appearance of the plastic cup before and after heating. *(The heated cup has a flat, disk-like shape, and the plastic is thick and translucent, almost opaque.)*
5. *(Optional)* Repeat steps 3 and 4 to prepare a second flattened cup.
6. Dry the flattened cup(s) and determine the average mass. Did the mass of the object change after heating?

Optional: Density is a characteristic physical property of a substance. The following test procedure (steps 7–14) may be used to determine the density of the plastic (polystyrene) before and after heating.

7. While the cup(s) are in the boiling water bath, weigh two more polystyrene cups and cut them into small pieces. Do not discard any of the pieces! (The cups must be cut up so they will fit in the overflow can when submerged.)
8. Fill an overflow can with water until water begins to pour out the spout on the side of the can.
9. Set the overflow can on a flat surface and make sure no more water is coming out of the spout.
10. Place a beaker under the spout of the overflow can to collect the displaced water.
11. Place *all* of the cut-up pieces from the plastic cups into the overflow can. Using forceps, carefully submerge the pieces

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without allowing the forceps to go under water.

12. When no more water flows out of the can, measure the total volume of water collected using a graduated cylinder. Calculate the average volume of **one** plastic cup.
13. Refill the overflow can and measure the amount of water displaced by the flattened (heated) polystyrene cup(s). (The fla tened cup does not have to be cut up.) Determine the volume of the polystyrene cup after it has been heated. Did the volume of the object change after heating?
14. Calculate the density (mass divided by volume) of a polystyrene cup before and after heating. Did the density of the plastic change?

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. Discarded polystyrene cups may be disposed of in the trash according to Flinn Suggested Disposal Method #26a.

Tips

- Make sure the plastic cups are polystyrene and *not* polyethylene terephthalate (PET or PETE). Polystyrene cups are rigid and clear (transparent) and are labeled with the recycling code #6 (PS). The recycling code for PETE cups is #1. (PETE cups are generally more flexible and less brittle than PS cups.)
- Use rigid, clear polystyrene cups, not polystyrene foam (Styrofoam®) cups. Heat and pressure are required to soften Styrofoam cups and return them to their original dimensions.
- Using the average mass and volume of the plastic cups to determine the density of polystyrene before and after heating gives more accurate results than using just one cup. This is particularly true for the volume of the cut-up polystyrene cup before heating.
- Polystyrene cups are quite brittle. Cutting up the plastic requires heavy-duty scissors and a lot of patience to keep track of all the pieces!
- The plastic memory of polystyrene can be used to make "shrinkable plastic" craft objects. Take a flat polystyrene lid from a deli container, trim the edges, and color or paint a design on the lid using permanent markers. Place the polystyrene on a lined cookie tray and heat in an oven at 162 °C (325 °F) for *one minute or less*.

Discussion

Synthetic polymers can be formed into fibers, drawn out into films, and molded into a variety of solid objects. Polystyrene is a hard, transparent plastic whose main use is in packaging. The solid polymer has an amorphous structure—there is no long range order or symmetry in the way the polymer molecules are arranged. Below a certain temperature, called the *glass transition temperature*, T_g, the polymer molecules are not very flexible or mobile and the polymer is a brittle, glassy solid. Heating the polymer above T_g increases the flexibility and mobility of the polymer molecules, and the polymer behaves more like a rubbery solid (it is easily stretched and deformed). The value of T_g for polystyrene is about 100 °C (the boiling point of water).

Thin plastic cups and other containers are made by heating polystyrene above 100 °C, stretching the plastic out into a film, and then quickly cooling it to "freeze" or lock in the new shape. The memory of the original shape returns when the plastic is reheated. When the plastic cup is heated to 100 °C or higher, the "frozen" molecules are released from their stretched out configuration, and the object returns to its original shape and dimensions.

The following results show that (a) the mass of the object does not change when it is heated, and (b) the density of the polystyrene does not change.

Data Table. Properties and "Plastic Memory" of a Polystyrene Cup

	Shape and Dimensions	Average Mass	Average Volume	Average Density
Before Heating	8 oz. cup (9 cm tall × 5 cm bottom diameter)	6.61 g	5.7 mL	1.2 g/mL
After Heating	Flattened disk (2 cm tall × 3 cm bottom diameter)	6.64 g	5.6 mL	1.2 g/mL

Connecting to the National Standards

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

Unifying Concepts and Processes: Grades K–12
Evidence, models, and explanation
Constancy, change, and measurement
Content Standards: Grades 5–8
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, properties and changes of properties in matter
Content Standard F: Science in Personal and Social Perspectives
Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure and properties of matter
Content Standard F: Science in Personal and Social Perspectives

Reference

This activity was adapted from *Polymers*, Vol. 21 in the *Flinn ChemTopic™ Labs* series, Cesa, I., Editor; Flinn Scientific: Batavia, IL (2006).

Materials for *Oh, the Memories!* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP4627	Overflow Can
GP1050	Beaker, Borosilicate Glass, 1 L

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