Prince Rupert's Drops are Stronger than Steel

Properties of Solids

Concepts

- Bonding
- States of matter (amorphous solids)

Background

Theoretically, silica glass (with types of network covalent bonds) should be up to five times stronger than steel (with metallic bonds). However, most glass is weaker than bonding theory might suggest. One reason for this difference is the internal stress from disordered bonding rather than a strong crystalline network covalent compound such as quartz, SiO_2 or SiO_4.

An exception to "weak glass" is Prince Rupert's Drop, a tadpole-shaped drop of stressed glass that can be hammered without breaking. However, if the Rupert's Drop has its thin tail broken near the drop, the entire drop instantly shatters!

Materials

Beaker, 1-L	Pliers
Gloves	Polarizing film, 2 pieces
Hammer	Propane torch (with fine point tip)
Plastic bag, heavy duty, zippered	Soft glass rod

Safety Precautions

Exercise caution when handling the propane torch, the hot glass, and the bits of glass. Gloves should be used when breaking off the tail of the drop to prevent possible glass cuts. Safety goggles must also be worn. Follow all laboratory safety guidelines.

Procedure

1. Fill the 1-L beaker with about 800 mL of tap water.
2. Hold the glass rod vertically over the beaker of water, and heat the bottom of the rod with a hot flame from the propane torch. Rotate the glass rod as it is heated.
3. As the glass softens, turns red, and begins to sag, keep the flame on the bottom of the glass drop. The molten glass will fall into the water with a loud noise and MANY will instantly break. Try again, and be patient.
4. Allow the successful glass drops to cool in the water until safe to handle. Retrieve the drops and carefully break off the-long tails of glass thread until only 3–4 cm remains. *Caution:* Breaking the tail off too close to the drop will cause the dropto shatter.
5. Place the Rupert's Drop between pieces of polarizing film and view the colors, which indicate internal stresses in the glass drop.
6. Place a glass drop in a heavy-duty zippered plastic bag. Using a safe surface, firmly tap the glass drop on its head with a hammer.
7. With the drop still in the plastic bag, carefully snap off the tail of the drop. You may need to use pliers on some drops. *Caution:* The drop shatters with a slight explosive force that may sting if the drop is held in the hand.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. The glass dust, glass threads, and unsuccessful drops can be collected and placed in a

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zippered plastic bag and disposed of according to Flinn Suggested Disposal Method #26a. Broken glass may also be placed in a glass disposal container.

Discussion

If glass is cooled too quickly, stresses can be trapped inside. Usually, the stresses are great enough that the glass shatters. The warmer glass on the inside bursts its way through the cooler skin—as with the unsuccessful Rupert's Drops. Sometimes, the molten glass cools and a tough skin (similar to surface tension on water) forms, allowing the glass drop to withstand pounding with a hammer without breaking. However, if the glass drop is scratched on the surface or if the thin tail is broken near the drop, the glass instantly releases the internal stress causing the drop to shatter into a fine powder.

This special glass was named for Prince Rupert of Bavaria (1619–1682). It is unclear whether Rupert invented or only introduced this phenomenon to England in the 1640s. Rupert was the grandson of James I, King of England, and the nephew of Charles II. He was a military commander for England and enjoyed experimenting in science.

This demonstration can be used to show glass as an amorphous solid, relate the strength of network covalent bonds to metallic and molecular bonds, and to show why stressed or cracked glass should not be used in the lab.

An extension of this demonstration would be to place pieces of clear, molded polystyrene plastic between pieces of polarizing film. This plastic is found in disposable drinking cups, plates, etc. that shatter easily when squeezed. The process of molding the plastic produces internal stress (as evidenced by the colors seen with the polarizing film) similar to the glass.

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
Form and function

Content Standards: Grades 5–8
Content Standard B: Physical Science, properties and changes of properties in matter
Content Standard G: History and Nature of Science, history of science

Content Standards: Grades 9–12
Content Standard B: Physical Science, structure and properties of matter
Content Standard G: History and Nature of Science, historical perspective

Acknowledgement

Steve Long obtained information for this activity from Jeanne Murgado Dyer, Demonstration: Prince Rupert Drops

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Prince Rupert's Drops are Stronger Than Steel* activity, presented by Steve Long, is available in Properties of Solids and in Open House Demonstrations, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Prince Rupert's Drops are Stronger Than Steel* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP8913	Polarizing Film, 6″ × 6″
GP9035	Rods, Soft Glass

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