The Collapsing Bottle

Introduction

Completely collapse a two-liter soda bottle using chemicals! Simply fill the bottle with carbon dioxide gas, add sodium hydroxide, and observe as the bottle gets hot and completely crushes inward.

Concepts

- Acid–base chemistry
- Liquid–gas reactions
- Gas solubility

Materials

Soda bottle, 2-L, empty PET* bottle
Sodium hydroxide, NaOH, 6 M, 30 mL
Carbon dioxide (CO_2) gas cylinder
or
Carbon dioxide gas generator: Sodium bicarbonate
Hydrochloric acid or sulfuric acid (3 M or higher)
Gas generator setup

* To identify PET bottle, look for a triangle with a "1" on the bottom.

Safety Precautions

Sodium hydroxide solution is a corrosive liquid; avoid all body tissue contact. Do not reuse the 2-liter soda bottle, strong bases will decompose PET bottles over time. 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.

Preparation

1. To prepare a 6 M sodium hydroxide solution, dissolve 24 g of sodium hydroxide in 100 mL of distilled water.
2. Fill an empty, clean 2-L polyethylene terephthalate, PET* soda bottle with carbon dioxide gas, CO_2. Use either a CO_2 refillable gas cylinder, lecture bottle or generate CO_2 in the lab. To generate CO_2 in the lab, add sodium bicarbonate (calcium carbonate also works) to 6 M HCl (3 M and/or sulfuric acid also works) in a 500-mL Erlenmeyer flask equipped with a one-hole stopper and a glass tube connected to plastic tubing. As soon as the bicarbonate is added, place the stopper on the flask and the plastic tube in the 2-L soda bottle to collect the carbon dioxide. Carbon dioxide is approximately 1.5 times heavier than air. Keep the soda bottle *upright* and fill from the bottom up. Then cap the bottle.

Procedure

1. Remove the cap from the 2-L soda bottle, add approximately 30 mL of 6 M NaOH and quickly reseal the bottle. Shake the bottle once and it will immediately collapse.
2. Vigorously shake the bottle and it will completely collapse until the sides are touching. The heat generated by the exothermic reaction can be felt through the walls of the bottle.
3. Allow the collapsed bottle to sit overnight. By the next morning, large crystals of sodium carbonate will have formed.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedure governing the disposal of laboratory waste. The solution may be flushed down the drain with excess water according to Flinn Suggested Disposal Method #26b. The soda bottle may be rinsed out and disposed of in the trash.

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Connecting to the National Standards

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

Unifying Concepts and Process: Grades K–12
Constancy, change, and measurement

Content Standards: Grades 5–8
Content Standard B: Physical Science, properties and changes of properties in matter, understanding of motions and forces, transfer of energy.

Content Standards: Grades 9–12
Content Standard B: Physical Science, structure of atoms, structure and properties of matter, chemical reactions, motions and forces, conservation of energy and increase in disorder, interactions of energy and matter.

Tips

- The importance of surface area in gas–liquid reactions can be demonstrated by performing this demo in two identical bottles. Shake one bottle, creating greater gas–liquid surface area while letting the other bottle sit without shaking. The shaken bottle will collapse much quicker.
- Solid sodium hydroxide pellets will work but require much longer reaction times than sodium hydroxide solutions.
- Alka-Seltzer tables in water also work very well for producing carbon dioxide.

Discussion

Carbon dioxide is a slightly acidic gas that readily dissolves in water to produce carbonic acid (1). Carbonic acid will neutralize the sodium hydroxide in solution (2). The net result is the conversion of gaseous carbon dioxide to an aqueous solution of sodium carbonate. As the amount of carbon dioxide decreases, the pressure inside the soda bottle decreases while the atmospheric pressure on the outside remains the same, leading to a collapsing bottle. This reaction is often used as a carbon dioxide trap in laboratory experiments.

$$CO_2(g) + H_2O(l) \rightarrow H_2CO_3(aq) \qquad \textit{Equation 1}$$

$$H_2CO_3(aq) + 2NaOH(aq) \rightarrow Na_2CO_3(aq) + 2H_2O(l) \qquad \textit{Equation 2}$$

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Materials for *The Collapsing Bottle* are available from Flinn Scientific, Inc.

Catalog No.	Description
S0242	Sodium Hydroxide Solution, 6 M, 500 mL
S0279	Sodium Hydroxide, 500 g
LB1060	Carbon Dioxide, 1 lb, Refillable Gas Cylinder
LB1005	Carbon Dioxide, 0.5 lb, Gas Lecture Bottle

Consult the Flinn Scientific website for current prices.

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