The Collapsing 1-Liter Bottle

Enthalpy, Entropy and Free Energy

Introduction

Completely collapse a 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

- Carbon dioxide gas
- Acid–base reaction
- Gas solubility
- Atmospheric pressure

Materials

Carbon dioxide (CO_2) gas* (if a cylinder is not available, follow directions for generating CO_2 using Alka Seltzer® tablets)

Phenolphthalein indicator solution, 1%, 1 mL

Sodium hydroxide, NaOH, 1 M, 50-100 mL

Water, distilled, 50-100 mL

Soda bottle, 1- or 2-L, empty PETE** (polyethylene terephthalate) bottle, with lid

*For making CO_2 using Alka Seltzer®:

Alka Seltzer tablets, 3–6

***To identify a PETE bottle, look for the recycling symbol triangle with a "1" on the bottom*

Safety Precautions

Sodium hydroxide solution is a corrosive liquid and is especially dangerous to the eyes; avoid all body tissue contact. Do not reuse the plastic soda bottle—strong bases will decompose PETE 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. Fill a clean, empty 1- or 2-L polyethylene terephthalate (PETE) soda bottle with carbon dioxide gas (CO_2) from a cylinder, or generate the gas using the following steps:
   a. Place 50–100 mL of water in the soda bottle.
   b. Break 3–6 Alka-Seltzer tablets in half so they will fit in the bottle opening, and drop the tablets into the water. Allow the tablets to completely react with the water.
2. Cap the bottle tightly.

Procedure

1. Remove the cap from the soda bottle filled with carbon dioxide gas and add 3-4 drops of 1% phenolphthalein followed by 100 mL of 1 M sodium hydroxide solution to the bottle.
2. Quickly replace the cap on the bottle.
3. Vigorously shake the bottle to ensure mixing of the gas and liquid inside the bottle.
4. Observe as the bottle dramatically collapses inward until the sides are touching. Carefully feel the outside of the bottle—it will be quite hot! The heat generated by the exothermic reaction can be felt through the walls of the bottle.
5. Allow the bottle to sit overnight. By the next morning, large crystals of sodium carbonate should be visible in the bottle.

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Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory wastes. Any solution remaining in the bottle may be neutralized and disposed of according to Flinn Suggested Disposal Method #10.

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
Evolution and equilibrium
Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure and properties of matter, chemical reactions, conservation of energy and increase in disorder, interactions of energy and matter

Tip

- The importance of surface area in gas–liquid reactions can be shown by performing this demonstration in two bottles side-by-side. Shake one bottle to create a greater gas–liquid surface area contact, and let the other bottle sit without shaking. The shaken bottle will collapse much quicker.

Discussion

Carbon dioxide is a slightly acidic gas that readily dissolves in water to produce carbonic acid (Equation 1). Carbonic acid neutralizes the sodium hydroxide added to the bottle (Equation 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 of the bottle remains the same, leading to a collapsing bottle. The reaction of carbon dioxide with sodium hydroxide (or another strong base) is often used to trap carbon dioxide gas in laboratory experiments.

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

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

Although the equilibrium represented by Equation 1 lies far to the left, it is shifted to the right by the neutralization of the product with sodium hydroxide, according to LeChâtelier's principle. As a result, all of the carbon dioxide gas is consumed and the bottle collapses.

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of *The Collapsing 1-Liter Bottle* activity, presented by Michael Heinz, is available in *Enthalpy, Entropy and Free Energy*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *The Collapsing 1-Liter Bottle* are available from Flinn Scientific, Inc.

Materials to perform this activity are available from Flinn Scientific, and may be purchased separately.

Catalog No.	Description
LB1005	Carbon Dioxide Gas, Lecture Bottle, 0.5 lb
LB1060	Carbon Dioxide Gas, Refillable Cylinder, 1.0 lb
A0111	Alka-Seltzer® Tablets, 24
P0019	Phenolphthalein Indicator Solution, 1%, 100 mL
S0148	Sodium Hydroxide Solution, 1 M, 500 mL

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