Nonadditivity of Volumes

Neutralization Reactions

FLINN SCIENTIFIC CHEM FAX!

Introduction

Everyone knows that if you add a half-gallon of water to a half-gallon of water you get . . . a gallon of water. Here's a demonstration that seems to defy an intuitive rule—the additivity of liquids.

Chemical Concepts

- Acids and bases
- Stoichiometry
- Volume

Materials

Hydrochloric acid, HCl, 2 *M*, 500 mL	Graduated cylinder, 25-mL
Sodium hydroxide, NaOH, 2 *M*, 500 mL	Volumetric flasks, 500-mL, 2
Water, distilled or deionized, 1 L	Volumetric flask, 1000-mL

Safety Precautions

Sodium hydroxide solutions are corrosive to all body tissue, especially to the eyes. Much heat is evolved when preparing sodium hydroxide solution—use borosilicate glass beakers and have an ice bath available. Hydrochloric acid is toxic by ingestion or inhalation and severely corrosive to all body tissues. Handle both solutions with care. 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. Prepare 500 mL of 2 *M* sodium hydroxide solution by measuring out and adding 40 g of sodium hydroxide to a 500-mL volumetric flask.
2. Add approximately 100 mL of distilled or deionized water to the flask. Mix to dissolve the solid.
3. Fill to the 500 mL mark with water. Cap securely and invert to mix.
4. Prepare 500 mL of 2 *M* hydrochloric acid by adding approximately 200 mL of distilled or deionized water to a 500-mL flask.
5. Add 83 mL of concentrated hydrochloric acid, 12.1 M, to the volumetric flask. Fill up to the 500-mL mark with water. Cap securely and invert to mix
6. Alternatively, 2 M hydrochloric acid solution may be prepared from 6 M HCl by adding 167 mL 6 M HCl to 333 mL water.

Procedure

1. Ask students to predict what the final volume of liquid will be when exactly 500 mL of 2 *M* sodium hydroxide is added to exactly 500 mL of 2 *M* hydrochloric acid.
2. Using a funnel, pour 500 mL of 2 *M* sodium hydroxide solution into a 1000-mL volumetric flask. Then, with constant swirling, add 500 mL of 2 *M* hydrochloric acid solution.
3. To their surprise, students will clearly see that the volume of the resulting solution is more than 1 liter!
4. Direct the students to write the balanced chemical equation for the reaction.
5. Cap the 1000-mL volumetric flask and completely mix the solution by inverting several times. Uncap the flask, and use a pipet to transfer excess liquid above the 1 L mark to a 25-mL graduate. The volume transferred should be close to 18 mL, which is the approximate volume of one mole of water.

Publication No. 91255
061616

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. The resulting solution may be disposed of according to Flinn Suggested Disposal Method #26b.

Tips

- The reaction between sodium hydroxide and hydrochloric acid is exothermic. A small percentage of the increased volume is due to the heat created in the reaction. To obtain an accurate measurement of the volume of water produced, wait until the flask has cooled back to room temperature.
- This is a great demo to perform twice—once when teaching stoichiometry and again when teaching acids and bases.

Discussion

Many reactions that are commonly done in chemistry labs include water as a reactant. However, since most reactions are done in solution, water is often overlooked. This demonstration will prove to students that water can be a product and will remind them that not all products of a reaction are readily visible. The balanced chemical equation for this reaction is:

$$OH^-(aq) + H^+(aq) \rightarrow H_2O(l)$$

In this demonstration there is one mole of hydroxide ions and one mole of hydrogen ions, therefore, one mole of water must be produced. If the mass of one mole of water is 18 g, and the density 1 g/mL, then 18 mL will "magically" appear.

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 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, chemical reactions

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Nonadditivity of Volumes* activity, presented by George Gross, is available in *Neutralization Reactions*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Nonadditivity of Volumes* are available from Flinn Scientific, Inc.

Catalog No.	Description
S0074	Sodium hydroxide, NaOH, 100 g
H0005	Hydrochloric acid, HCl,12 M, 2.5 L
GP4040	Volumetric flask, 500-mL
GP4045	Volumetric flask, 1000-mL

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