Acids, Bases and Buffers

A Colorful Dry-Ice Demonstration

Introduction

The color of universal indicator in acidic, basic and neutral solutions is demonstrated. Dry ice is added to a portion of each solution and the color changes are observed. The effect of mixing solutions of different colors (different pH values) is also seen.

Concepts

- Acids and bases
- pH scale
- Indicators
- Buffers

Materials

Beakers, 1-L, 3
Hydrochloric acid solution, HCl, 0.1 M, 750 mL
Sodium hydroxide solution, NaOH, 0.1 M, 750 mL
Distilled water
Dry ice
Universal indicator solution, 10 mL
Color chart for universal indicator
Test tube rack
Test tubes, large, 3
Tongs

Safety Precautions

Dilute hydrochloric acid solution is toxic by ingestion and is irritating to skin and eyes. Sodium hydroxide solution is a skin irritant and very dangerous to eyes. Handle dry ice using tongs or while wearing appropriate gloves. Dry ice can cause frostbite. Universal indicator solution is an alcohol-based solution and is a flammable liquid. 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.

Procedure

1. Fill one 1-L beaker about ¾ full with distilled water. Fill a second 1-L beaker to the same level with 0.1 M HCl, and a third beaker with 0.1 M NaOH. Label the beakers as neutral, acid, and base, respectively.
2. Add sufficient universal indicator solution (2–3 mL) to each beaker to produce a bright, rich color. Observe the color of each solution and identify the pH using the universal indicator color chart.
3. Remove a portion of solution from each beaker. Place each solution into a separate large test tube in a test tube rack. Label the test tubes as to their contents. Set these tubes aside.
4. Carefully add several chunks of dry ice to each of the solutions in the beakers. Note the indicator color changes that occur and discuss the changes.
5. When the colors of the solutions in the beakers no longer appear to be changing, add a small amount of the set-aside acid solution from the appropriate test tube to the beaker that originally contained the neutral solution. Observe the changes. Add a similar amount of the set-aside acid solution from the test tube to the beaker that originally contained the basic solution. Observe the color changes and compare and contrast the effect of adding more acid to each solution.
6. Repeat step 5, adding a small amount of the set-aside basic solution from the appropriate test tube to both the original "neutral" beaker and the "basic" beaker. Discuss the results.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures govern-

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ing the disposal of laboratory wastes. Acidic solutions should be disposed of according to Flinn Suggested Disposal Method #24b. Basic solutions should be disposed of according to Flinn Suggested Disposal Method #10. Allow dry ice to sublime in a well-ventilated area.

Discussion

Universal indicator solution is red in acidic solutions having pH ≤4, green in neutral solution (pH = 7), and purple in basic solutions having pH ≥10. Adding carbon dioxide in the form of dry ice to the water in each solution produces a weak acid, carbonic acid, H_2CO_3 (Equations 1 and 2).

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

$$H_2CO_3(aq) \rightleftarrows H^+(aq) + HCO_3^-(aq) \qquad \textit{Equation 2}$$

The acid solution remains acidic even after dry ice has been added, and the red color does not change. The neutral green solution turns orange (pH = 5) when dry ice is added, due to the presence of H^+ ions from the dissociation of H_2CO_3. Since carbonic acid is a weak acid, the pH of the carbonic acid solution will be higher than that for hydrochloric acid, which is a strong acid. Thus, the green neutral solution turns orange rather than red. The basic purple solution turns yellow (pH = 6) when dry ice is added. Carbonic acid reacts with the sodium hydroxide in the basic solution to produce sodium bicarbonate, a salt. A solution containing a weak acid and the salt of that weak acid is a buffer. Buffers resist changes in pH, thus explaining the persisting yellow color in this solution when additional acid or base is added. The pH of the buffer solution produced in beaker 3 does not change when more strong acid or strong base is added.

Beaker	**1**	**2**	**3**
Initial Composition	Water "Neutral"	0.1 *M* HCl "Acid"	0.1 *M* NaOH "Base"
Initial Indicator Color (pH)	Green (pH = 7)	Red (pH ≤4)	Purple (pH ≥10)
Color (pH) after Adding Dry Ice	Orange (pH = 5)	Red (pH ≤4)	Yellow (pH = 6)
Color Change after Adding More Acid	Red (pH ≥4)	N/A	Yellow (pH = 6)
Color Change after Adding More Base	Yellow (pH = 6)	N/A	Yellow (pH = 6)

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 B: Physical Science, properties and changes of properties in matter
Content Standards: Grades 9–12
Content Standard B: Physical Science, structure and properties of matter, chemical reactions

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Chemicals for *Acids, Bases and Buffers* are available from Flinn Scientific, Inc.

Catalog No.	**Description**
U0001	Universal Indicator Solution, 100 mL
H0014	Hydrochloric acid solution, 0.1 M, 500 mL
S0149	Sodium hydroxide solution, 0.1 Mr, 500 mL
W0001	Water, distilled, 1 gallon

Consult the Flinn Scientific website for current prices.