Solubility of Ammonia

Indicator Color Show

Introduction

Ammonia gas is easily generated by heating a concentrated ammonium hydroxide solution. In this demonstration, ammonia gas will be collected in jumbo pipet bulbs and its water solubility and acid–base properties will be investigated. The result is a beautiful indicator color show.

Concepts

- Ammonia gas
- Acid–base reactions
- Gas solubility
- Indicators

Materials

Acid–base indicator solutions, approximately 2 mL each
- Bromthymol blue, 0.04%
- Phenolphthalein, 0.5%
- Phenol red, 0.02%

Ammonium hydroxide concentrated solution, NH_4OH, 14.8 M, 1 mL

Beakers, 100-mL, 4

Hot plate

Microtip pipet

Scissors

Super jumbo pipet bulbs, 3

Distilled water

Thermometer

Safety Precautions

Concentrated ammonium hydroxide solution is moderately toxic by ingestion and inhalation. It is a serious respiratory hazard; both the liquid and the vapor are extremely irritating, especially to the eyes. Dispense ammonium hydroxide in a hood and perform this demonstration in a well-ventilated lab only. Wear chemical splash goggles and chemical-resistant gloves and apron. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Preparation

1. Cut off the stems from four jumbo pipets, leaving about 1 cm of stem attached to the bulb of each pipet. The jumbo pipet bulbs will be used as gas collection vessels.
2. Fill four 100-mL beakers half-full with distilled water and add 2–3 mL of a different acid–base indicator (see the *Materials* section) to each beaker. Observe and record the initial color of each indicator solution in cold water.
3. Fill a 100-mL beaker about one-half full with tap water and heat the water to 70–80 °C using a hot plate set at a medium setting (6–8).
4. Squeeze the microtip pipet to push out the air and carefully place the pipet tip into the concentrated ammonium hydroxide solution. Draw up enough ammonium hydroxide solution to fill the bulb about one-half full. The microtip pipet will serve as the gas generator in this demonstration. *Note:* Remove the pipet from the ammonia solution before completely releasing the bulb. Air, not liquid, must be in the stem of the pipet (otherwise concentrated ammonium hydroxide solution may squirt out of the pipet when the solution is heated). Invert the pipet and tap the pipet bulb to remove any liquid, if necessary, from the pipet stem.

Procedure

5. Insert the microtip pipet containing ammonium hydroxide solution into the cut-off bulb of a jumbo pipet (see step 1).
6. Place the microtip pipet and the jumbo pipet bulb "assembly" into the hot water bath (Figure 1). Observe the vigorous bubbling of the ammonium hydroxide solution—warming the solution releases ammonia gas.

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7. Collect ammonia gas in the jumbo pipet bulb: Lift the jumbo pipet bulb slightly and squeeze the bulb to remove as much air as possible. Re-insert the jumbo pipet bulb onto the microtip pipet and *slowly* release the pressure on the bulb to allow ammonia vapor to fill the bulb.
8. Place the tip of the jumbo pipet bulb into one of the beakers filled with cold water and an acid–base indicator (see step 2). Gently squeeze the pipet bulb to push out one bubble of gas and allow a drop of water to enter the pipet bulb. *(Observe that the pipet bulb immediately fills about half-way with water—the solubility of ammonia gas in water is very high. As the ammonia gas pressure inside the bulb rapidly decreases, more water is drawn into the pipet bulb due to the pressure difference with the atmosphere.)*
9. Observe and record the final (basic) color of the acid–base indicator solution in the jumbo pipet bulb.
10. Repeat steps 6–8 with the remaining acid–base indicator solutions. Collect ammonia gas in a fresh jumbo pipet bulb each time. It should not be necessary to add more ammonium hydroxide solution to the gas-generating pipet. Observe and record the indicator color in each pipet bulb. *(See the table in the Discussion section.)*

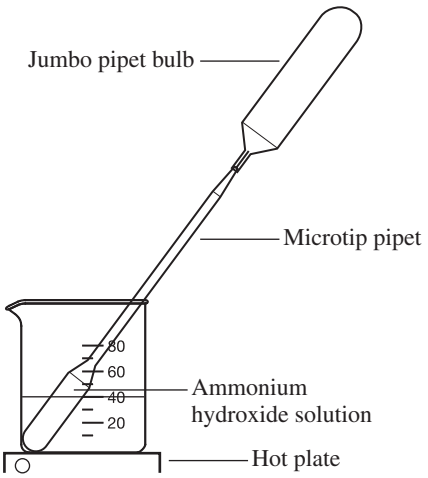

Figure 1.

11. Write the equation for ammonia gas dissolving in water and the resulting ionization of water to produce "NH_4OH." Discuss the evidence from this demonstration that this is a reversible reaction and that ammonia is a weak base.
12. *(Optional)* Read the warning on a container of a commercial ammonia cleaner. Discuss the significance of the hazard warning. *(The label will probably say do not breathe the vapors and keep off the skin. Ammonia cleaners will release enough ammonia gas at room temperature that breathing the vapors is hazardous—the gas dissolves in the moisture of the mucous membranes and the lungs. Ammonia is also a skin irritant.)*
13. *(Optional)* Show students a chart with the pH range of different indicators and their color changes. Ask students to predict, based on the observations from this activity, other indicators that could be used in this demonstration.

Disposal

Consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. The indicator solutions may be disposed of down the drain with plenty of excess water according to Flinn Suggested Disposal Method #26b.

Tips

- Other acid–base indicators that may give suitable color changes include alizarin, alizarin red, cresol red, and universal indicator. Rinse all glassware before use to obtain reproducible color changes.
- In step 7, wait a few seconds until you feel some pressure on the walls of the bulb before slowly releasing the bulb.
- If ammonia leaks into a beaker containing an indicator solution and causes a color change, add one drop of vinegar to change the indicator back to its acidic form.
- Vary the amount of indicator added in step 2 depending on the concentration of the indicator solution. Add enough indicator to produce vivid color changes. Phenol red indicator is a very dilute solution—use about 10 mL of this indicator.
- The solubility of ammonia gas in water is about 90 g per 100 mL at 0 °C and about 32 g per 100 mL at 25 °C. The room temperature solubility corresponds to a volume of 460 L ammonia gas dissolving in 1 L of water.
- The term "ammonium hydroxide" raises consternation among many chemists. It is the name given to a concentrated solution of ammonia in water, which is about 14.8 Molar. The solution is highly basic, hence the designation as ammonium hydroxide. There is no pure compound corresponding to that composition.

Discussion

A dual equilibrium comes into play when ammonia gas dissolves in water. The fact that ammonia gas is easily driven off when the concentrated ammonia solution is heated suggests a simple solubility equilibrium (Equation 1) to give hydrated ammonia molecules, $NH_3(aq)$.

$$NH_3(g) \rightleftarrows NH_3(aq) \qquad \textit{Equation 1}$$

The indicator color changes, however, reveal that the resulting aqueous ammonia solution is basic. The acid–base reaction of ammonia with water is shown in Equation 2.

$$NH_3(aq) + H_2O(l) \rightleftarrows NH_4^+(aq) + OH^-(aq) \qquad \textit{Equation 2}$$

The solubility of ammonia gas in water is extremely high—approximately 460 liters of ammonia gas will dissolve in one liter of water at room temperature! As with any gas, the solubility of ammonia gas in water decreases as the temperature increases.

The following table summarizes the pH ranges for the indicators used in this demonstration and their corresponding color changes. Notice that the initial colors of many of the indicators in this demonstration are in the acidic range (pH <7). The pH of water is usually slightly acidic due to the presence of dissolved carbon dioxide.

Indicator	pH range	Initial Color (Acidic)	Final Color (Basic)
Bromthymol blue	6.0–7.6	Yellow-green	Blue
Phenol Red	6.8–8.4	Yellow-orange	Red
Phenolphthalein	8.2–10.0	Colorless	Red-violet

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, structure and properties of matter, chemical reactions, interactions of energy and matter
Content Standard F: Science in Personal and Social Perspectives, natural and human-induced hazards

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Reference

This activity was adapted from *Chemistry of Gases*, Vol. 8 in the *Flinn ChemTopic™ Labs* series; Cesa, I., Editor; Flinn Scientific: Batavia IL (2003).

Materials for *Solubility of Ammonia—Indicator Color Show* are available from Flinn Scientific, Inc.

Catalog No.	Description
A0174	Ammonium Hydroxide, 14.8 Molar, 100 mL
B0173	Bromthymol Blue Indicator Solution, 0.04%, 100 mL
P0115	Phenolphthalein Indicator Solution, 0.5%, 100 mL
P0100	Phenol Red Indicator Solution, 0.02%, 100 mL

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