Gas Solubility: The Fountain Effect[1]

A small amount *of* water is injected into an inverted round-bottomed flask connected by a glass tube to a reservoir *of* water below it. Soon after the injection, the water from the reservoir rushes into the flask, turning red as it enters and forming a fountain inside the flask. Other color changes are also described [*1*,*2*].

MATERIALS FOR PROCEDURE A

source of dry ammonia gas (cylinder with valve)

10 mL phenolphthalein indicator solution (To prepare 100 mL of solution, dissolve 0.05 g of phenolphthalein in 50 mL of 95% ethanol, and dilute the solution to 100 mL with distilled water.)

2-liter round-bottomed flask

2-holed rubber stopper to fit 2-liter flask

100-cm length glass tubing, with outside diameter of 8 mm

3-liter round-bottomed flask

2 ring stands

2 rings to support 2-liter flask

cork ring to support 3-liter flask

dropper

10-cm length rubber tubing to fit over dropper's open end

15-cm length copper wire, 16 gauge

gloves, plastic or rubber

90-cm length plastic or rubber tubing

solid rubber stopper to fit 2-liter flask

pressure bulb

PROCEDURE A

Preparation

Assemble the glassware as illustrated in **Figure 1**. The glass tube should extend to within 10 cm of the bottom of the inverted upper, 2-liter flask and to within 1 cm of the bottom of the lower, 3-liter flask. When the dropper is inserted through the stopper, the constricted end of the dropper should be inside the 2-liter flask. Tighten the rubber tubing to the dropper with wire.

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[1] B.Z. Shakhashiri, *Chemical Demonstrations: A Handbook for Teachers of Chemistry,* Vol. 2, University of Wisconsin Press, Madison, WI (1985), pp. 205-210.

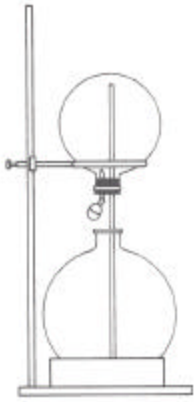

Figure 1.

Unstopper and remove the 2-liter flask from the apparatus. Support it inverted on the second ring stand in a well-ventilated hood. Wearing gloves, attach the 90-cm length of plastic or rubber tubing to the valve of the cylinder of dry ammonia and insert the other end into the inverted flask. Fill the flask with ammonia gas by the downward displacement of air. Stopper the flask with the solid rubber stopper.

Place 6-10 mL of phenolphthalein indicator solution in the 3-liter flask and fill the flask with water. Fill the pressure bulb with water and wire its exhaust valve to the rubber tubing attached to the dropper. Holding the ammonia-filled 2-liter flask inverted over the apparatus, remove its solid stopper and reassemble the apparatus.

Presentation

Squeeze the pressure bulb to deliver several milliliters of water into the ammonia - filled flask. As ammonia dissolves in the water, the level of water in the long glass tube will rise until it overflows into the upper flask. When the water begins to flow from the tube into the flask, more ammonia will dissolve, and the rate at which the water rises in the tube will increase dramatically, producing a fountain effect within the flask. As the ammonia dissolves in the water, it forms a basic solution, causing the phenolphthalein in the water to turn magenta.

HAZARDS

Only round-bottomed flasks should be used as the upper flask in this demonstration. Erlenmeyer and other flat-bottomed flasks may implode under the stress of the vacuum created during this procedure.

Ammonia gas irritates all parts of the respiratory system and is severely irritating to the eyes. Ammonia gas also causes burns to the skin and is toxic by inhalation. Mixtures of ammonia gas and air can be explosive and should be kept away from sparks or open flame.

Hydrogen chloride gas is severely irritating to the eyes and the respiratory system and can cause bums to the skin. Inhalation must be prevented.

Sodium hydroxide can cause severe burns of the skin and eyes. Dust from solid sodium hydroxide is very caustic.

DISPOSAL

The contents of the flasks should be flushed down the drain with water.

DISCUSSION

Ammonia and hydrogen chloride are among the most water-soluble gases known. The volume of ammonia that will dissolve in water at 0°C and a partial pressure of 1 atm is 1130 liters [*3*], while 506 liters of hydrogen chloride dissolve under the same conditions [*4*]. These gases are highly soluble in water because they react with water. Hydrogen chloride gas forms hydronium ions and chloride ions when it dissolves in water.

$$HCl(g) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$$

After ammonia gas has dissolved in water, the solution contains an equilibrium mixture of aquated ammonia molecules, ammonium ions, and hydroxide ions.

$$NH_3(aq) + H_2O(1) \rightarrow NH_4^+(aq) + OH^-(aq)$$

The difference in the solubilities of these two gases can be seen when Procedures A and B are presented together. The ammonia dissolves more rapidly, and its fountain is more vigorous. Because the ammonia fountain is more spectacular, it is recommended that the hydrogen chloride fountain be presented first when the two are presented together.

The pH indicators specified in these procedures are just two of the many that can be used. Quite a variety of color changes are possible with other indicators. Any indicator which changes color in the pH range of 9 through 11 can be used with the ammonia fountain, while one that changes in the range of 2 through 5 can be used with the hydrogen chloride fountain.

REFERENCES

1. G. S. Newth, *Chemical Lecture Experiments,* Longmans, Green and Co.: London (1928).
2. H. N. Alyea and F. B. Dutton, Eds., *Tested Demonstrations in Chemistry,* 6th ed., Journal of Chemical Education: Easton, Pennsylvania (1965).
3. J. A. Dean, Ed., *Lange's Handbook of Chemistry,* 12th ed., McGraw-Hill: New York (1978).
4. P. Arthur, *Lecture Demonstrations in General Chemistry,* McGraw-Hill: New York (1939).