

Diffusion of Gases

A Kinetic Energy Demonstration



Introduction

The temperature of a gas is a measure of the average kinetic energy of the gas particles. The kinetic energy of any object depends on the mass of the object and on its velocity. The effect of molar mass on the rate of diffusion of gases illustrates this principle.

Concepts

- Diffusion
- Kinetic-molecular theory

Materials

Ammonium hydroxide, concentrated (14.7 M), NH_4OH , 4 mL	Glass tubes, 14 mm wide by 30 cm long, 2
Hydrochloric acid, concentrated (12.1 M), HCl , 2 mL	Forceps
Phenolphthalein solution, 1%, 5 mL	Latex gloves, disposable
Thymol blue solution, 0.04%, 2 mL	Pasteur pipets, glass, 2
Water, distilled and wash bottle	Ring stands and clamps, 2
Cotton balls, 12	Rubber stoppers, size 2, 4

Safety Precautions

Concentrated ammonium hydroxide and hydrochloric acid are corrosive and will cause severe burns. Their vapors are extremely irritating, especially to the eyes and respiratory tract. Always wear gloves when working with these reagents and dispense in a hood using caution. Phenolphthalein indicator solution contains alcohol and is flammable. 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

Part A. Diffusion of Ammonia Gas

1. Set up a ring stand and clamp a glass tube in place horizontally.
2. Using a Beral-type pipet, add about 1 mL of phenolphthalein indicator solution to a cotton ball. Set the cotton ball aside to allow the alcohol solvent to evaporate.
3. Hold the "indicator" cotton ball with a pair of forceps and add 10–20 drops of water. Immediately place the cotton ball into one end of the glass tube and seal the end of the tube with a rubber stopper.
4. Using a glass Pasteur pipet, add 10–20 drops of concentrated ammonium hydroxide solution to a clean cotton ball. Immediately place the cotton ball into the other end of the diffusion tube and seal the end of the tube with a rubber stopper.
5. Observe how long it takes for ammonia gas to diffuse through the tube and reach the phenolphthalein-soaked cotton ball. *(The front end of the cotton ball will begin to turn pink within about 90 sec. It takes 3–5 minutes for the entire cotton ball to turn bright pink due to the reaction of ammonia with water to form a basic solution.)*

Part B. Comparing the Rate of Diffusion for Ammonia and Hydrochloric Acid

6. Set up two same-sized, clean glass tubes in the horizontal position.
7. Prepare two thymol blue-soaked cotton balls by adding about 20 drops of water, followed by 10–20 drops of thymol blue indicator solution, to each ball. The indicator balls will be dark gold in color. *(Thymol blue is red at $\text{pH} < 1$, blue at $\text{pH} > 9$, and yellow-gold in the pH range 2.8–8.0.)*

8. Stopper one indicator ball in place in each of the two glass tubes.
9. Using a clean Pasteur pipet for each solution, add 12 drops of concentrated ammonium hydroxide solution to one cotton ball and 10 drops of concentrated hydrochloric acid to a second cotton ball. (*Adding unequal amounts of the two solutions compensates for the fact that the ammonium hydroxide solution is more concentrated than the hydrochloric acid solution.*)
10. Immediately place one cotton ball in each glass tube and stopper the tubes.
11. Compare how long it takes for ammonia versus hydrochloric acid to diffuse the length of the tube in each case. (*Within about 90 sec, the indicator cotton ball in the NH_3 tube will turn blue. It will take about 5 minutes for the indicator cotton ball in the HCl tube to turn red.*)

Part C. Gas-Phase Reaction of Ammonia and Hydrochloric Acid

12. Set up a clean glass tube in the horizontal position.
13. Repeat step 9 to prepare ammonia and hydrochloric acid-soaked cotton balls and stopper one ball in place in each of the two ends of the glass tube.
14. Observe any changes along the length of the glass tube. (*In less than one minute a white ring of solid NH_4Cl will be visible about two thirds of the way down from the NH_3 source in the diffusion tube. The reaction takes place closer to the HCl source rather than in the middle of the tube because the lighter NH_3 gas molecules travel farther than the heavier HCl gas molecules in the same length of time.*)

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures, and review all federal, state and local regulations that may apply, before proceeding. The cotton balls should be placed in a fume hood to thoroughly degas and may be disposed of according to Flinn Suggested Disposal Method #26b.

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 A: Science as Inquiry
- Content Standard B: Physical Science, properties and changes of properties in matter, motions and forces

Content Standards: Grades 9–12

- Content Standard A: Science as Inquiry
- Content Standard B: Physical Science, structure and properties of matter, motions and forces, conservation of energy and increase in disorder

Tips

- Always wear gloves when working with concentrated ammonia and hydrochloric acid. To avoid cross contamination of the indicator-soaked cotton balls and either reagent, always wear clean gloves and hold the cotton balls with forceps.
- The time required for the gases to diffuse the length of the tube depends on the tube length. To avoid excessively long diffusion times, use tubes about 30 cm (12 inches) long. The Glass Demonstration Tube, Catalog No. GP9146, available from Flinn Scientific is 24" long. To cut glass tubing, we recommend using the Glass Tubing Cutter, Catalog No. AP5418. Always fire-polish the ends of cut glass.
- The phenolphthalein-soaked indicator balls must be wet with water in order to observe the color change due to ammonia gas. Ammonia is extremely soluble in water.
- The concentration of ammonium hydroxide and hydrochloric acid will affect the time needed for the indicator color changes to be observed. It took more than 5 minutes for any color change to be observed for ammonia when the concentration of ammonia was 1 M.

Discussion

Gas diffusion refers to the mixing of different gases throughout an enclosed space due to the random molecular motion of the gas particles. When ammonia molecules are introduced into the diffusion tube, they mix with the existing oxygen, nitrogen and other gas particles in the tube. The ammonia molecules will collide with other air molecules and the side of the tube and slowly diffuse down the tube until they dissolve in the water solvent in the cotton ball. The resulting acid–base reaction with the phenolphthalein indicator causes a color change from colorless to pink.

The rate of diffusion is controlled by the root mean square speed of the gas molecules. If two different gas molecules have the same average kinetic energy but have different masses, then the lighter molecules will move faster. This is shown in Parts B and C where ammonia molecules (17 g/mole) diffuse faster than hydrochloric acid molecules (molar mass 36.5 g/mole).

The kinetic-molecular theory (KMT) assumes that the particles in a gas are in constant motion and therefore predicts that a gas will eventually fill its container. The KMT also predicts that if two gases are added to a container, they will quickly mix and form a homogeneous solution. The mixing of gases is called diffusion.

Materials for the *Diffusion of Gases* are available from Flinn Scientific, Inc.

Catalog No.	Description
GP9146	Glass Demonstration Tube
AP5418	Glass Tubing Cutter
A0174	Ammonium Hydroxide, 14.8 M, 100 mL
H0031	Hydrochloric Acid, 12 Molar, 100 mL
P0019	Phenolphthalein Indicator Solution, 1%, 100 mL
T0045	Thymol Blue Indicator Solution, 0.04%, 100 mL

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