# Graham's Law of Diffusion

Molecules are constantly in motion, and their kinetic energy depends on their mass and velocity. At the same temperature and pressure, the average kinetic energy of the molecules in any gas is the same. For this to be true, more massive molecules must move more slowly. One way to observe this difference is in the rate of diffusion of gases. A gas of lower molar mass diffuses faster than a gas of higher molar mass. The purpose of this activity is to discover the relationship between the mass and velocity of two different gases.

**Objectives**

- **Observe** the color change of universal acid base indicator exposed to hydrochloric acid and ammonia (a base).
- **Determine** the relative velocities of ammonia and hydrogen chloride molecules.
- **Identify** the mathematical relationship between the mass and velocity of two different gases.

**Procedure**

1. **Hypothesize** which will move faster, NH3 molecules or HCl molecules.
2. Fill all the wells in a 96-well microplate with water by placing the plate under a tap of slowly running water.
3. Place the filled microplate on a flat surface with the numbered columns away from you and the lettered rows to the left.
4. Remove the water from wells D1 and D12 with a plastic pipette.
5. Add a single drop of universal indicator to each of the wells in the microplate except wells D1 and D12. Note the color of the indicator in a data table like the one shown.
6. Cut 6 pieces of soda straw, each approximately 3 cm long.
7. Place the soda straws in wells D1, D12, A1, A12, H1 and H12, as shown in the diagram. The straws will prevent a plastic bag from coming in contact with the surface of the liquid in the plate.
8. Hold the plate horizontally, slip it into a sandwich bag, and seal the bag.
9. Puncture the plastic bag with a pencil or pen point just above wells D1 and D12.
10. One partner should obtain a few drops of ammonia solution in a plastic pipette.
11. The other partner will obtain a few drops of hydrochloric acid in a separate plastic pipette. **CAUTION:** *Do not inhale fumes of ammonia or hydrochloric acid. Avoid contact with skin or eyes. Be sure no ammonia or hydrochloric acid remains in the stem of the pipette before you carry it back to your work area.*
12. While one partner places the ammonia pipette into the hole above well D1, the other partner should place the hydrochloric acid pipette into the hole above well D12.
13. Simultaneously add the acid and ammonia to wells D1 and D12. Wait for 30 seconds.

## DATA Table

| | |
|---|---|
| A. Initial color of universal indicator in water | |
| B. Wells with red or yellow color from exposure to HCl | |
| C. Wells with blue or violet color from exposure to $NH_3$ | |
| D. $NH_3$/HCl velocity ratio (C/B) | |
| E. Molar mass of $NH_3$ (g/mol) | |
| F. Molar mass of HCl (g/mol) | |

## CALCULATIONS:

1. Find the ratio of blue or violet wells to red or yellow wells. This is the velocity ratio.

$$\frac{\text{Blue or violet wells}}{\text{Red or yellow wells}} = \frac{\text{ammonia velocity}}{\text{HCl velocity}}$$

2. Calculate the molar masses of ammonia and hydrogen chloride and record them in the data table. (gmm)

3. Calculate the 4 molar mass ratios for ammonia and HCl listed below:

$$\text{Mass ratio 1} = \frac{\text{molar mass NH3}}{\text{molar mass HCl}}$$

$$\text{Mass ratio 2} = \frac{\text{molar mass HCl}}{\text{molar mass NH3}}$$

$$\text{Mass ratio 3} = \frac{\sqrt{\text{molar mass NH3}}}{\sqrt{\text{molar mass HCl}}}$$

$$\text{Mass ratio 4} = \frac{\sqrt{\text{molar mass HCl}}}{\sqrt{\text{molar mass NH3}}}$$

## DISCUSSION:

1. Which gas moved faster? Why?

2. Why do indicators change the color of a solution? (refer to acid/base chapter)

3. Compare each of the molar mass ratios with the velocity ratio. Which mass ratio is most like the estimated velocity ratio?

## Conclusion