Chemistry 101 **Experiment 5 - DIFFUSION OF GASES AND GRAHAM'S LAW**

In this experiment, the relative rates of diffusion of two gases will be determined. Rates of diffusion yield information that can lead to calculation of the molecular weights of gases.

Gases consist of particles that are in constant rapid motion. This motion causes gases to travel across space (diffuse) and completely mix with each other. It is this diffusion that eventually causes one to notice smells such as perfume, fish, ammonia, etc.

In this experiment, the rates of diffusion of two gases, ammonia (NH_3) and hydrogen chloride (HCl), will be investigated. These gases are convenient to use for such an experiment because, when they meet and react, they form a white smoke consisting of ammonium chloride (NH_4Cl):

$$NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$$

Therefore, if ammonia gas and hydrogen chloride gas are released simultaneously at opposite ends of a glass tube, a white ring of smoke will form at the location where they meet.

This experiment will demonstrate rates of diffusion, a property of gases investigated by Thomas Graham. In 1829, he proposed his law of diffusion which states that the rate of diffusion of a gas is inversely proportional to the square root of its density:

$$R \propto \frac{1}{\sqrt{d}}$$

However, since the ideal gas law indicates that the density of a gas and its molecular weight are proportional, we can write:

$$R \propto \frac{1}{\sqrt{MW}}$$

If the rates of diffusion of two gases are compared, this yields the following equations:

$$\frac{R1}{R2} = \frac{\frac{1}{\sqrt{MW1}}}{\frac{1}{\sqrt{MW2}}} \quad \text{or} \quad \frac{R1}{R2} = \frac{\sqrt{MW2}}{\sqrt{MW1}}$$

Thus, if the rates of diffusion of two gases are known and the molecular weight of one of them is known, the molecular weight of the other gas can be calculated:

$$MW2 = \frac{R_1^2 (MW1)}{R_2^2}$$

In this experiment, the distance each gas travels will be measured as well as the time it takes for them to meet and react (D = distance, t = time):

$$\frac{R_{NH3}}{R_{HCl}} = \frac{\frac{D_{NH3}}{t}}{\frac{D_{HCl}}{t}} = \frac{\sqrt{MW_{HCl}}}{\sqrt{MW_{NH3}}}$$

This can be rearranged to:

$$MW_{HCl} = \frac{R^2_{NH3}\ MW_{NH3}}{R^2_{HCl}}$$

PROCEDURE

Wear your **safety glasses** while doing this experiment.

You will carry out the experiment with a partner.

Obtain a gas diffusion apparatus from the stockroom, consisting of a glass tube and two corks which have holes drilled in them and a stopwatch. Clamp the glass tube horizontally on a ring stand (See Figure 5). Loosely place a wad of cotton into each cork and in the hood saturate one wad of cotton with drops of concentrated NH_3 solution and the other wad of cotton with drops of concentrated HCl solution. Be sure to keep the corks far apart to avoid a premature reaction.

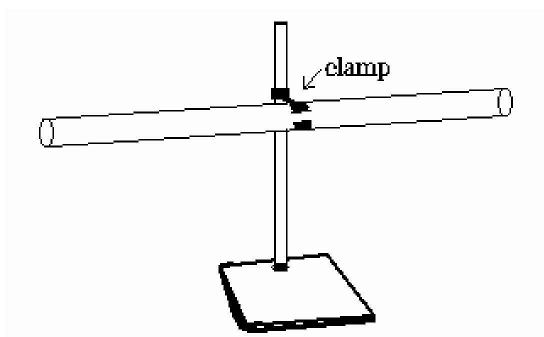

Figure 5: Gas Diffusion Apparatus

Once the corks are ready, return to your lab bench and insert the corks simultaneously into the opposite ends of the glass tube. One partner will begin to measure the time. Now, very carefully observe the glass tube and at the time of the first appearance of a white ring of ammonium chloride, record the time and mark the location of the ring on the tube.

Measure and record the distance each gas traveled.

To repeat the experiment, clean the glass tube with tap water. Rinse with deionized water and then with alcohol. Dry the tube completely, then clamp the tube horizontally, once again.

Discard the cotton wads in the waste beaker in the hood and then place clean cotton in the corks and saturate as before, then repeat the experiment.

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Pre-Laboratory Assignment

1. A gas of unknown molecular weight is found to diffuse at a rate of 0.19 cm/s compared to 0.59 cm/s for helium gas. Calculate the molecular weight of the unknown gas.

2. Which of all of the possible gases should have the highest rate of diffusion?

3. A balloon inflated with helium gas will rise to the ceiling of a room. However, after a certain period of time, the balloon will descend to the floor. Why does the balloon eventually descend?

4. If the cork containing the concentrated NH_3 solution were inserted into the glass tube several seconds after the insertion of the cork containing HCl, what effect would this have on the calculated value of the molecular weight of HCl?

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Report Sheet

	TRIAL		
	First	Second	Third
Time of insertion of stoppers	______	______	______
Time of appearance of smoke	______	______	______
Total time elapsed (seconds)	______	______	______
Distance travelled by NH_3(cm)	______	______	______
Distance travelled by HCl(cm)	______	______	______
Rate of diffusion of NH_3(cm/s)	______	______	______
Rate of diffusion of HCl(cm/s)	______	______	______
MW of NH_3	17.0	17.0	17.0
Calculated MW of HCl	______	______	______
Mean MW of HCl		______	
True value of the MW of HCl		36.5	
Percent error of mean value		______	

Show your calculations below:

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Post-Laboratory Questions

1. How many times faster will CH_4 gas diffuse compared to C_4H_8 gas?

2. If CH_4 gas and C_4H_8 gas are released simultaneously at the left and right ends respectively of a 50.0 cm long glass tube, at what distance from the left end of the tube will they meet?

3. Methane gas, CH_4, diffuses 2.3 times faster than an unknown gas at the same temperature and pressure. What is the molecular weight of the unknown gas?

4. Does the first appearance of the white smoke indicate the first contact of the NH_3 and HCl molecules? Explain your answer. If the answer is "no", how will this affect the calculated value of the molecular weight of HCl?