EXERCISE 11

Gas Laws

OBJECTIVES:

1. To verify Graham's law of diffusion.
2. To verify Charles' law.
3. To determine absolute zero by applying Charles' law.
4. To perform some mathematical data analysis.

Equipment

1. 30-35 cm length of glass tubing
2. Q-tips
3. Centimeter ruler
4. 250 ml flask
5. 1 hole rubber stopper
6. 2-3 cm glass tube
7. large beaker
8. bunsen burner, iron ring, and stand
9. ice bath
10. thermometer

I. Graham's Law of Diffusion:

Graham's law is most commonly stated as:

$$\frac{r_1}{r_2} = \frac{\sqrt{MW_2}}{\sqrt{MW_1}}$$ equation 11-1

where r1 = rate of diffusion of gas 1

r2 = rate of diffusion of gas 2

MW_1 = molecular weight of gas 1

MW_2 = molecular weight of gas 2

In this experiment we will measure distance of diffusion instead of rate, so

$$\frac{d_1}{d_2} = \sqrt{\frac{MW_2}{MW_1}}$$ equation 11-2

Procedure

1. Assemble dry glass tubing (tube must be dry) as shown in figure 11-1. Hold the tube in middle by a clamp. Place a Q-tip saturated with concentrated HCl in one end of the tube and a Q-tip saturated with concentrated NH_4OH in the other end. Be careful to insert these Q-tips simultaneously. A band of solid white NH_4Cl should form in the tube in less than 5 minutes. (If ring does not form within 5 minutes, start again). Measure the distance from each Q-tip to ammonium chloride band.

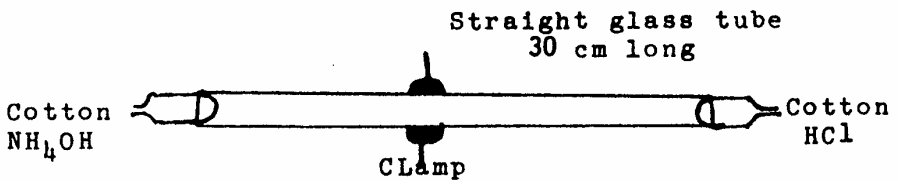

Figure 11-1

2. Let the distance from the surface of the NH_4OH be d_1 . From the measured distances, calculate the ratio d_1 / d_2.

3. From the known molecular weights, calculate the ratio $\sqrt{MW_2} / \sqrt{MW_1}$ (remember the gases which are actually diffusing are NH_3 and HCl). Calculate the percentage error for your measured ratio.

II. Charles' Law

Charles' Law may be stated as:

$V = kT$ equation 11-3

This statement implies that at some zero temperature (on an absolute scale) the volume of an ideal gas must be zero. We will determine the Celsius scale temperature corresponding to absolute zero.

Procedure

4. Fit a 250 ml Erlenmeyer flask with a 1 hole rubber stopper. Place a short length of fire-polished, glass tubing in the stopper. Place this assembly in a boiling water bath so that it is almost totally submerged. Heat the flask in this way for 5 minutes. During last minute use a thermometer to determine the temperature of the water. Record this temperature. The air occupying the flask's volume now has a temperature of the boiling point of water.

5. Quickly carry out the following sequence of steps: Place your thumb or forefinger over the glass tube so as to make an air tight seal. Remove the flask from the boiling water bath. Turn the flask upside-down and completely immerse the flask in an ice water bath. Remove your finger, but keep the flask submerged upside-down for at least 5 minutes in order to cool the trapped air. Read and record the temperature of the ice bath.

6. Raise the flask until the water levels inside and outside are equal. While in this position, place your finger over the glass tube. Remove the flask from the cold water bath and turn it right-side-up. Use a graduated cylinder to determine the volume of water in the flask.

7. Determine the total volume which the flask will hold, with the stopper in place, by filling the flask with water and measuring the water with a graduated cylinder.

8. Calculate the volume of air at the boiling water temperature and the volume of air at the ice water temperature.

9. To graphically determine absolute zero, plot your data using paper as in Figure 11-2 and extrapolate to zero volume.

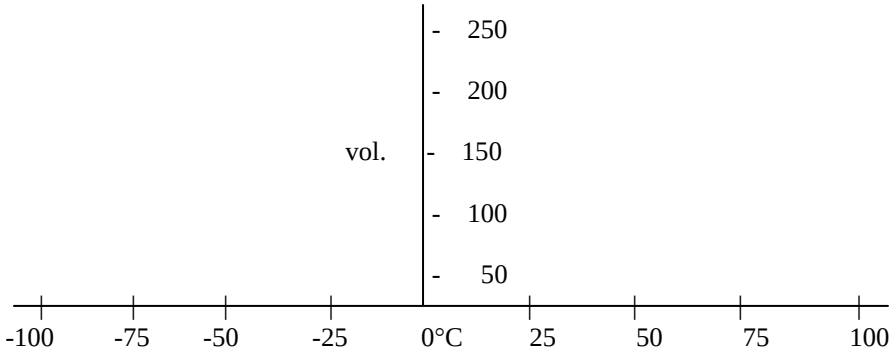

Figure 11-2

10. The value of absolute zero can be determined mathematically, also from some knowledge of the behavior of straight lines. Find the slope of the line from equation 11-4.

$$\text{slope} = \frac{\Delta V}{\Delta T} \qquad \text{equation 11-4}$$

11. Calculate the y intercept, called b, by using the pair of V and T values for the ice water bath and solving equation 12-5 for b.

$$V = (\text{slope}) \times (T)\ ^\circ C + b \qquad \text{equation 11-5}$$

Repeat the calculation using the V and T pair for the boiling water measurement. Average these 2 values for use in equation 11-6.

12. Since we are trying to find the temperature at which the volume is zero, we need to solve equation 11-6 for T using the values of slope and intercept from equation 11-5.

$$0 = (\text{slope}) \times (T) + b \qquad \text{equation 11-6}$$

13. Look up the accepted value for absolute zero and calculate your percent error and show all your calculations.

EXERCISE 11

ANSWER SHEET – Page 1

NAME _____ SECTION _____ DATE_____

1. Graham's Law of Diffusion..... _____

   a. Distance NH_3 traveled..... _____

   b. Distance HCl traveled..... _____

2. $\frac{d_1}{d_2}$ =..... _____

3. $\frac{\sqrt{MW_2}}{\sqrt{MW_1}}$ = ... _____

Percent error

EXERCISE 11

ANSWER SHEET - Page 2

4. Temperature of boiling water..... _____

5. Temperature of ice bath..... _____

6. Volume of water in flask..... _____

7. Total volume of flask..... _____

8. a. Volume of air in boiling water bath..... _____

   b. Volume of air in ice water bath..... _____

9. Absolute zero by extrapolation (use graph paper)..... _____

10. Slope..... _____

11. Intercept
    a. ice bath..... _____

    b. boiling water bath..... _____

    c. average..... _____

12. Calculated value of absolute zero..... _____

13. Accepted value of absolute zero..... _____

14. Percent error