Lab # 9: Molecular Weight of a Volatile Liquid

INTRODUCTION

One of the important applications of the Ideal Gas Law is found in the experimental determination of the molecular weight of gases and vapors. In order to measure the molecular weight of a gas or vapor, we need simply to determine the mass of a given sample of the gas under known conditions of temperature and pressure. The gas obeys the Ideal Gas Law.

$$PV = nRT \qquad (1)$$

Since the number of moles, n, is equal to the mass, g, of the gas divided by its gram-molecular weight, M, after substituting we have:

$$PV = \frac{gRT}{M} \qquad (2) \qquad\qquad M = \frac{gRT}{PV} \qquad (3)$$

This experiment involves measuring the gram-molecular weight of a volatile liquid by using the above equation. A small amount of the liquid is introduced into a weighed flask. The flask is then placed in boiling water, where the liquid will vaporize completely, driving out the air and filling the flask with vapor at atmospheric pressure and the temperature of the boiling water. If we cool the flask so that the vapor condenses, we can measure the weight of the vapor and calculate a value for M. **Remember that in all gas law problems, temperature must be in K.**

PROCEDURE

1. Obtain a round bottom flask, a stopper, tube and small cork, a cork ring, an unknown liquid and a 1000 mL beaker. Support the flask on the cork ring at all times. With the stopper loosely inserted in the neck of the flask, weigh the empty dry flask on the balance. Pour about 5 mL of the unknown liquid into the flask. Assemble the apparatus as shown in figure 1. Drape the entire assembly with aluminum foil but be careful that there is no possibility for condensed water to drip into the flask. (Why?) Poke a hole in the foil near the lip of the beaker so that the steam will escape as far from the neck of the flask as possible. Make sure there is sufficient water in the 1000 mL beaker to cover most of the round bottom flask.

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2. Add a few boiling chips to the water in the 1000 mL beaker and heat the water to boiling. **Make sure that the cork is not inserted in the tubing in the neck of the flask.** Watch the liquid level in your flask; the level should gradually drop as vapor escapes through the cap. After all the liquid has disappeared and no more vapor comes out of the cap, continue to boil the water gently for 1 to 2 minutes. Measure the temperature of the boiling water. Shut off the burner and wait until the water has stopped boiling (about ½ minute). Being careful not to burn yourself, remove the aluminum foil and then loosen the clamp holding the flask in place. Slide out the flask, and immediately insert the small cork into the tubing to seal the flask.

3. Immerse the flask in a beaker of cool water to a depth of about 4 cm. Alternatively, you may hold the flask under running water. Do not allow water to enter the flask. After holding the flask in the water for about 2 minutes to allow it to cool, carefully remove the cork for not more than a second or two to allow air to enter, and again insert the cork. (As the flask cools, the vapor inside condenses and the pressure drops, which explains why air rushes in when the stopper is removed.)

4. Dry the flask with a towel to remove the surface water. Loosen the cork momentarily to equalize any pressure differences, and reweigh the flask.

5. Read the atmospheric pressure from the barometer.

6. Repeat the procedure using another 5 mL of your unknown sample. It is not necessary to wash or dry the flask at this point, simply put another 5 mL of your sample into the flask. Remove the cork from the flask before placing it in the beaker of hot water. Repeat steps 2, 3, 4 and 5.

7. Empty any excess unknown liquid from the flask into the Organic Waste. Rinse the flask well with tap water and then distilled water. Do not dry it. Fill the flask with distilled water, insert the stopper and glass tube without the small cork. Wipe off any overflow water from the outside of the flask and then insert the small cork into the glass tube. Weigh the flask on a balance capable of measuring this size mass. Measure the temperature of the water inside the flask. Look up the density of the water (use Table 2: Absolute Density of Water from the Densities of Solids and Liquids Lab). Calculate the volume of the flask using the density formula.

8. Calculate the gram-molecular weight of the unknown liquid.

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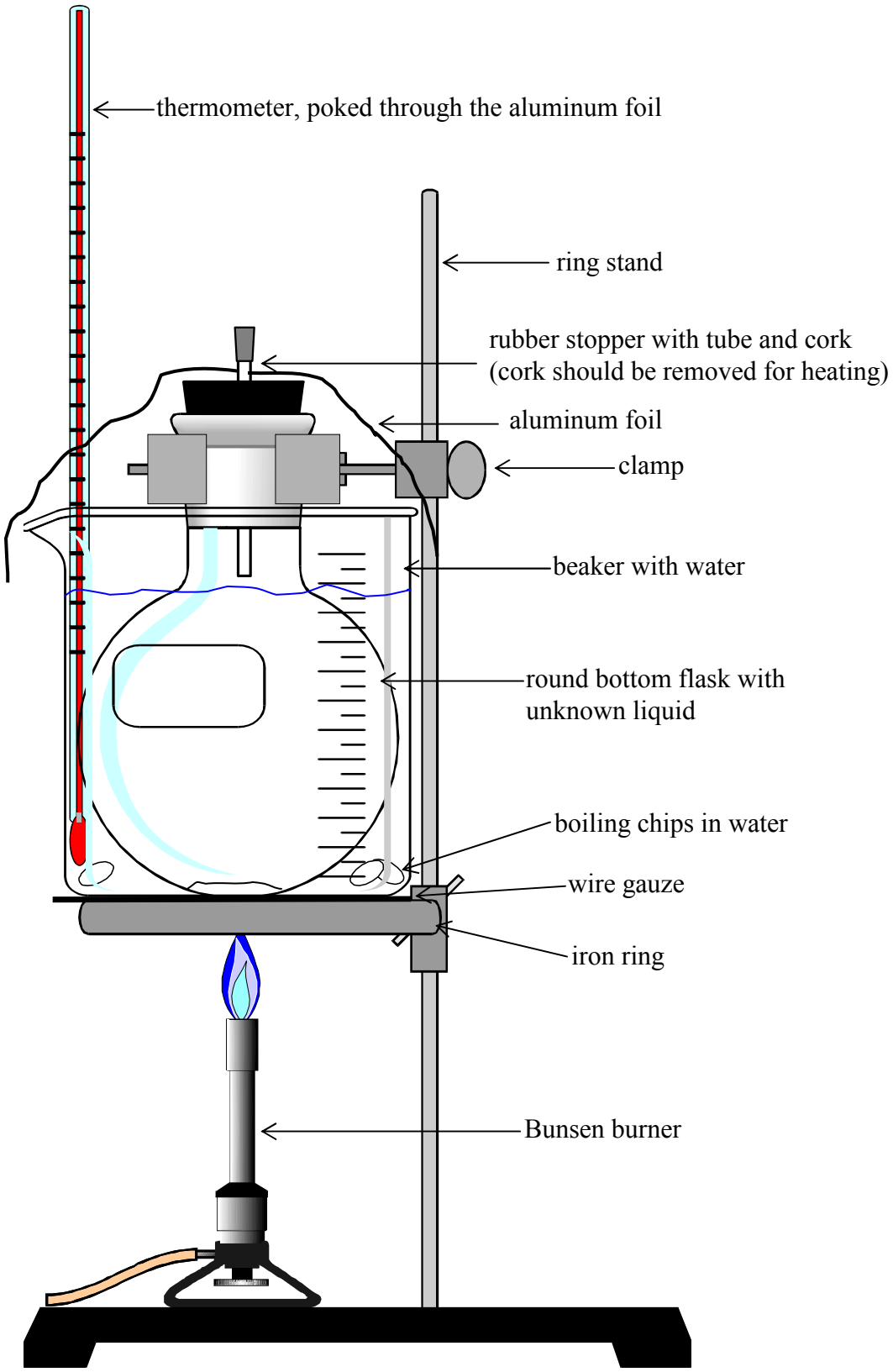
Figure 1: Experimental Set-up (not to scale)



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DATA	Trial 1	Trial 2
Unknown Number		
Mass of flask, stopper and cork (g)		
Mass of flask, stopper, cork and condensed vapor (g)		
Temperature of boiling water bath (°C)		
Barometric pressure (inches Hg)		
Mass of flask, stopper, cork and water (g)		
Temperature of water in flask (°C)		

CALCULATIONS AND RESULTS

Density of water at above temperature (g/mL)		
Mass of water in flask (g)		
Volume of flask (volume of vapor) (**L**)		
Pressure of vapor (mm Hg)		
Temperature of vapor (K)		
Mass of vapor (g)		
Molecular weight of unknown liquid (g/mol)		
Average molecular weight (g/mol)		

Instructor's Initials_____

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PRESTUDY

1. (3) a. Convert 754.6 torr to atm.

b. Convert 0.843 atm to mm Hg.

c. Convert 698.6 mm Hg to in Hg (inches Hg).

2. (5) A sample of an unknown liquid is vaporized in a flask having a volume of 521.9 mL at 105.9°C. The vapor has a mass of 0.613 g and the barometric pressure is 761.8 torr. Calculate the molecular weight of the unknown liquid. (Show all your work and use equation 3.)

_____ g/mol

3. (2) Suggest **two** possible sources of experimental error in this experiment. (Math errors and errors with significant figures are not acceptable sources of error.)

1. _____

_____

2. _____

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