

Unit 10 – Chapter 5: Gas Laws

Name _____

Lab: Determination of the Molar Mass of Volatile Liquids

Period _____

Introduction:

The molar masses of compounds are used daily in the chemistry profession. The molar mass is defined as the mass, in grams, of 1 mole of any element or compound. How is molar mass determined and how is the molar mass of an unknown found? In this experiment, the molar masses of several volatile liquids will be calculated based on measurements of their vapor density.

Background:

The ideal gas law relates the four measurable properties of a gas (P, V, n, T). In this experiment, the ideal gas law will be used to determine the molar mass of volatile liquids.

$$PV = nRT \quad \text{Equation 1}$$

The number of moles (n) of any pure substance is equal to its mass divided by its molar mass.

$$n = \text{mass/molar mass} \quad \text{Equation 2}$$

Substituting for n in Equation 1 and then rearranging produces the equation for the molar mass of a gas.

$$\text{molar mass (g/mol)} = \frac{\text{mass (g)} \times RT(\text{K})}{P(\text{atm}) \times V(\text{L})} \quad \text{Equation 3}$$

In this lab, the molar masses of several volatile liquids with boiling points well below the boiling point of water are determined. A small sample of the liquid is placed in a tared 15-mL plastic pipet and the pipet is then heated in boiling water to vaporize the liquid. The air and excess vapor escape, leaving the pipet filled only with the volatile liquid vapor at atmospheric pressure and at the temperature of boiling water. The pipet is then removed and cooled to condense the vapor.

Once cooled the pipet is weighed. By massing the same pipet filled with deionized water, the volume of the pipet is calculated. **The molar mass of the volatile liquid is then determined from Equation 3 using the mass of the condensed vapor, the volume of the pipet, the atmospheric pressure, and the temperature of the boiling water.**

Pre-lab Questions:

A determination of the molar mass of methyl alcohol (CH_3OH) yielded the following data.

Temperature of boiling water bath:	99.5°C
Barometric pressure:	738 mm Hg
Temperature of room temp. water bath:	24.0°C
Density of water at room temperature:	0.9973 g/mL

	Trial 1
Mass of empty pipet	1.557 g
Mass of pipet and condensed methyl alcohol	1.571 g
Mass of pipet and water	16.001 g
Mass of condensed methyl alcohol	
Mass of water in filled pipet	
Volume of pipet	
Molar mass of methyl alcohol (experimental)	
Molar mass of methyl alcohol (theoretical)	

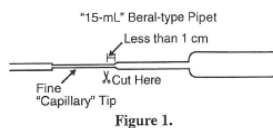
Using the data, fill in the rest of the table. Calculate the molar mass of methyl alcohol using Equation 3 and compare this value to the actual molar mass of methyl alcohol. The volume of the pipet is equal to the volume of water in the pipet. Use the relationship of mass and density to determine this volume. Once the volume of the pipet is determined, equation 3 in the *Background* section can be used to calculate the molar mass of methyl alcohol.

Materials:

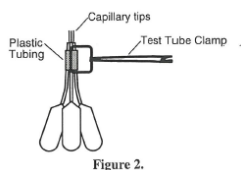
Acetone, CH_3COCH_3 , 2 mL	Beral-type pipets, super jumbo, narrow stem, 15-mL, 3
Ethyl alcohol, $\text{CH}_3\text{CH}_2\text{OH}$, 2 mL	Balance, milligram (0.001-g precision)
Isopropyl alcohol, $(\text{CH}_3)_2\text{CHOH}$, 2 mL	Barometer
600 mL beaker, 2	Pliers
Hot Plate	Permanent marker
Plastic tubing pipet holder	Test tube clamp
Thermometer	Deionized water
250 mL beaker, 1	Timer

Procedure:

1. Place a 600-mL beaker on the hot plate and add about 400 mL of tap water to the beaker. Turn on the hot plate to boil the water.
2. Obtain three 15-mL jumbo Beral-type pipets. With pliers, pull the thin stems of each so that a very fine “capillary” tip is formed where the stem has been pulled (Figure 1).



3. Cut the pipet as shown in Figure 1 so that the capillary tip is less than 1-cm long.
4. Label the pipets #1, #2, and #3 with a permanent marker.
5. Mass each pipet to the nearest 0.001 g and record this mass in the Data Table.
6. Draw 2-3 mL of the ethyl alcohol from the labeled bottle into pipet #1. Repeat with acetone in pipet #2, then isopropyl alcohol in pipet #3.
7. Insert the tips of the pipets containing the three alcohols into the short piece of plastic tubing, then secure the tubing with a test tube clamp (Figure 2).



8. Lower the pipets into the boiling water bath. Make sure the entire bulb of each pipet is below the water line.
9. Heat for at least five minutes.
10. Carefully remove the pipets from the water. Inspect each pipet. If any liquid remains in a pipet bulb, heat the entire assembly for another minute.
11. Cool the pipets by lower the pipet assembly into a bath of room temperature water in a 600-mL beaker.
12. Record the temperature of the boiling water bath and the barometric pressure of the room in the Data Table.
13. Dry the pipets with paper towels and mass each pipet, which now contains only the condensed vapor, to the nearest 0.001 g. Record these values in the Data Table.
14. Fill a 250-mL beaker with room temperature deionized water.
15. Fill pipet #1 with the deionized water, then expel the water into the sink to flush the remaining ethyl alcohol from the pipet. Repeat this process several times.
16. To determine the volume of pipet #1: Fill the pipet completely with deionized water, dry the outside, and mass the pipet and water. Record the mass in the Data Table.
17. Repeat step 16 for pipets #2 and #3.
18. Repeat steps 2 through 13 for acetone and isopropyl alcohol.

Data Tables:

Temperature of boiling water bath: _____ °C

Barometric pressure: _____ mm Hg

Temperature of room temp. water bath: _____ °C

Density of water at room temperature: _____ g/mL

Jumbo Pipets

	Jumbo Pipet #1	Jumbo Pipet #2	Jumbo Pipet #3
Mass of empty pipet			
Mass of pipet and water			
Mass of water in filled pipet			
Volume of pipet			

Volatile Liquids

	Trial 1	Theoretical MM	% Yield
Ethyl Alcohol [CH₃CH₂OH]			
Mass of pipet and condensed ethyl alcohol			
Mass of condensed ethyl alcohol			
Molar mass of ethyl alcohol			
Acetone [CH₃COCH₃]			
Mass of pipet and condensed acetone			
Mass of condensed acetone			
Molar mass of acetone			
Isopropyl Alcohol [(CH₃)₂CHOH]			
Mass of pipet and condensed isopropyl alcohol			
Mass of condensed isopropyl alcohol			
Molar mass of isopropyl alcohol			

Post-Lab Calculations

1. Determine the mass of condensed, volatile vapor for each pipet and enter these values in the Data Table.
2. Determine the density of water at the temperature of the room temperature water bath used in this experiment. Enter this density value in the Data Table. Use this value and mass of water in each filled pipet to calculate the volume of each pipet.
3. Determine the mass of the condensed volatile liquid and enter these values in the Data Table.
4. **Calculate the experimental molar mass** of each volatile liquid by using the values of the barometric pressure, the temperature of the boiling water, the mass of the volatile liquid, and the volume of the pipet. Enter these values in the Data Table.
5. **Calculate the theoretical molar mass** of each volatile liquid based off of the stated chemical formula. Enter these values in the Data Table.
6. **Based off the experimental molar mass and theoretical molar mass calculations, determine the % yield for each volatile liquid in this experiment.** Enter these values in the Data Table.

Post-Lab Questions

1. Volatile liquids with lower boiling points often give better results than those with higher boiling points. Suggest a reason for this using the concept of IMFs.
2. What effect would vapor condensation in the neck of the jumbo pipets have on the reported molar mass? How large of an error might this produce?
3. Some liquids have enough attractions between molecules to form **dimers**. (Dimers are molecules formed from the combination of the identical molecules (which in class we have referred to as the Cl I F H O Br N's). What effect would this have on the experimental molar mass?