Experiment 10A

WBH, MEB 10-27-2022

MOLAR MASS OF A LIQUID FROM THE DENSITY OF ITS VAPOR

MATERIALS: Dry 250 mL Erlenmeyer flask, piece of aluminum foil (~3" x 3"), rubber band, 800 mL beaker, 100 mL graduated cylinder, iron ring (2), ring stand, wire gauze, Bunsen burner, test tube clamp, rubber gripper for handling hot glassware.

PURPOSE: The purpose of this experiment is to determine the molar mass of an unknown liquid by measuring properties of its vapor phase after heating.

LEARNING OBJECTIVES: By the end of this experiment, the student should be able to demonstrate the following proficiencies:

1. Given the properties of a gas, calculate its molar mass by using the Ideal Gas Law.
2. Recognize potential sources of error and suggest reasons why this type of determination may not give an exact value for the molar mass.

DISCUSSION: In this experiment, the molar mass of an unknown volatile liquid compound will be determined by heating the liquid in a flask until it is completely converted to its vapor form, filling the flask. Because the volume, temperature, and pressure of the vapor will be known, we can apply applying the Ideal Gas Law, $PV = nRT$ to solve for the number of moles of vapor in the flask. This, together with the measured mass of the condensed vapor, will allow us to calculate the molar mass of the unknown compound.

PROCEDURE:

(CAUTION! Because all of the unknowns are flammable, this experiment must be performed in a fume hood, taking care to prevent direct contact between the liquid unknown and/or its vapor with open flame)

1. Assemble the ring stand with two iron rings, wire gauze, and clamp as shown in Figure 1 (Do not attach the Erlenmeyer flask to the clamp yet). With the Bunsen burner resting on the benchtop, adjust the height of the iron ring/wire gauze so that there is a ca. 1.5-inch gap between the wire gauze and the top of the burner. Place the beaker on the wire gauze, and adjust the clamp so that it is right at the top of the beaker as shown.

2. Place 300 mL of deionized water in the 800 mL beaker. Light the Bunsen burner and adjust to get a moderate flame with top of the flame just touching the wire gauze. Turn off the burner.

3. Obtain a *dry* 250 mL Erlenmeyer flask from the bin at the front of the room. Weigh the dry flask on an *analytical balance* to the nearest 0.0001 g. Record this value in the Data section.

4. Obtain a sample (ca. 5 mL) of unknown liquid from your instructor and pour the whole sample into the flask. **Record the unknown number** in the Data Section. Recap the vial and return the empty vial to your instructor.

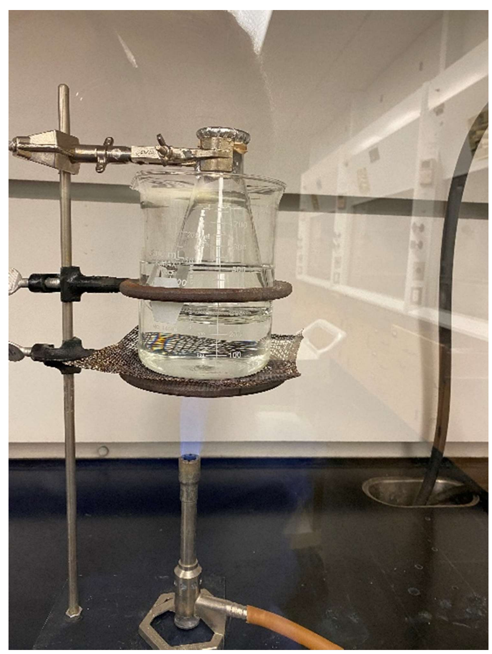

Figure 1. Ring stand setup.

5. Place a piece of foil over the opening of the Erlenmeyer flask, crimp the edges of the foil tightly around the opening of the flask, and secure with a rubber band. Poke 2-3 *small* pinholes into the foil using a thumb tack to let the excess vapor escape (Figure 2).

6. Carefully secure the top of the Erlenmeyer flask in the clamp and push the flask down into the water until the clamp is at the lip of the beaker. If necessary, add more water to the beaker using the plastic wash bottle to raise the water level up to around one inch below the top of the beaker; the goal is to immerse as much of the flask as possible in the boiling water so that the vapor in the flask reaches a uniform temperature of 100°C.

7. Light the burner and heat the water in the beaker to a **gentle boil**, then allow the flask to remain in the boiling water for at least **10 minutes**. There may be some minor splashing of the water as it boils so lower the hood sash. After 10 minutes of continuous heating, all of the unknown liquid should be boiled away and the flask should be completely filled with vapor. To ensure that all air is flushed out by the expanding vapor, **heating must be done without interruption.** Do not remove the flask from the bath and then return it to the bath for further heating.

Figure 2. Flask with foil and small pin holes.

✍ Answer In-lab Questions #1 and #2 on page E10A-5.

8. While the flask is boiling, prepare a small ice bath. Use the small bin available to you and scoop 1 to 2 scoops of ice into the bin. Add water to the bin with ice (do not add a lot of water; the goal is a slush.) This will be used in step 9 to briefly cool your flask.

9. When the 10-minute heating period is done, turn off the burner. Carefully loosen the clamp where it attaches to the ring stand and slide the clamp upwards to remove the flask from the water bath. Remove the clamp from the flask, ensure that the foil cap is still securely in place, and hold the flask in a water-ice slush bath for 30 seconds, taking care to **keep the foil dry** so that no water can enter the flask. After cooling, allow the covered flask to sit on the benchtop for 5 minutes until it has warmed back to near room temperature.

10. Carefully dry the outside of the flask with a paper towel, and take it back to the same analytical balance used to weigh the empty flask. Zero the balance, remove the rubber band and foil, and then promptly weigh the flask and its contents (condensed liquid). Record this value (to ±0.0001 g) in the Data Section.

Note: If you obtain more than 1 gram of condensed liquid then you probably did not heat long enough or water entered your flask. You will need to repeat the procedure with a new sample.

✍ Answer In-lab Question #3 on page E10A-6.

11. Dispose of the condensed liquid in the flask into the proper waste container in the instructor hood.

12. Determine the volume of the flask by filling it *completely* (to the brim) with water and then carefully transferring the water (in portions) into the 100 mL graduated cylinder. To avoid spills, use a disposable pipet to empty the first few mL of water out of the flask before you try to pour. Record the total volume in the Data Section.

13. Measure the atmospheric pressure using the barometer in the room. Ask your instructor for help if you do not know how to use the barometer.

Clean-up:

1. When finished, place your wet Erlenmeyer flask in the appropriately labeled bin at the front of the room.

2. Return the capped unknown vial to your instructor, without washing.

3. Arrange the equipment neatly in your hood, make sure the main gas valve is closed, and close your hood sash.

Name ______________________________ Section ___________________________

Partner _____________________________ Date ______________________________

DATA SECTION – Experiment 10A

Record data with correct units and proper significant figures.

Unknown number: ____________

Mass of flask (dry):	
Mass of flask + condensed vapor:	
Mass of condensed vapor:	
Total volume of flask:	
Temperature of system at boiling (i.e., boiling point of water)	
Barometric pressure (include units)	

DATA TREATMENT

1. Based on your experimental data, calculate the molar mass of the unknown liquid using the Ideal Gas Law. Show your work. Watch units!

R = 0.08206 L·atm/mol·K

Experimental Molar Mass = _________________________ Include units.

2. After you have determined the molar mass of your unknown, ask your instructor for the accepted chemical analysis (mass % of each element) for your unknown compound. Write this down below.

% C ______________ % H ______________ % O ______________ % N ______________

3. From the chemical analysis data in Question 2, determine the *empirical formula* for your unknown and calculate the corresponding *empirical formula mass*.

Empirical formula: ______________________

Empirical formula mass: ______________________

4. Determine the *molecular formula* of your unknown using this empirical formula and the experimentally-determined molar mass (from Question 1) for your unknown.

Molecular formula: ______________________

5. Based upon the <u>molecular formula</u> you just determined, calculate the <u>exact</u> molar mass (to two decimal places) of your unknown using atomic masses from a periodic table.

Exact Molar mass: ____________________

6. Calculate the % deviation between experimentally-determined the molar mass for your unknown (Question 1), and the exact molar mass calculated in Question 5 above.

_________________________ %

7. Considering the of the procedure used to determine the molar mass, suggest at least one reasonable explanation for this % deviation (other than simply poor technique or human error).

✍ IN-LAB QUESTIONS ✍

1. What would happen if you heated your flask for a few minutes, allowed it to cool briefly and then began heating again? Would this introduce error?

2. Why is it not necessary to weigh the flask and the liquid unknown before the initial heating?

3. A. After heating your unknown liquid for 10 minutes, what is present in the flask? Be specific.

B. What physical change occurs when the outside of the flask is cooled? What is/are present inside the flask after the flask has cooled?

C. Is the mass of the condensed liquid the same as the mass of the gas that filled the flask?

Name ______________________________ Section ____________________ Date __________________

PRE-LAB QUESTIONS

Experiment 10A

1. A small volume of a volatile liquid, such as hexane (C_6H_{14}), is added to an Erlenmeyer flask, which is then covered loosely with aluminum foil. The Erlenmeyer flask is placed in a beaker of water, which is heated to boiling.

a. What does it mean to be a *volatile* liquid? What does volatile refer to?

b. What is the temperature of boiling water (at 1 atm pressure)? ___________ °C

c. What is the boiling point of hexane (at 1 atm pressure)? ___________ °C

d. When the water starts boiling, what happens to the volatile liquid in the flask? Circle all that apply.

i. The liquid remains in the flask since its boiling point is less than the boiling point of water.

ii. The liquid solidifies due to the higher pressure in the flask.

iii. The liquid evaporates.

iv. The liquid is converted to a gas and it pushes air out of the flask.

2. The ideal gas law can be used to determine the molar mass of an ideal gas.

a. Starting with PV = nRT, *replace* n (moles of gas) with g/MM where g is the mass of the gas and MM is the molar mass of the gas. Then, solve for MM and write the resulting gas law expression below:

MM =

b. A flask contains 1000 mL of a pure diatomic gas at a pressure of 646 mm Hg and temperature of 20.0°C. Given that the mass of the gas in the flask is 1.13 g, determine the molar mass of the gas. R = 0.08206 L·atm/mol·K (Watch units!)

MM =	g/mol

c. Based on molar mass, what is the identity of the diatomic gas? Provide the molecular formula.