Experiment 10A

10-16-2020

MOLAR MASS OF A LIQUID FROM THE DENSITY OF ITS VAPOR

MATERIALS: Dry 250 mL erlenmeyer flask, piece of foil (~3” x 3”), rubber band, 800 mL beaker, 500 mL graduated cylinder, iron ring, 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. 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 will be determined by heating it until the liquid is completely converted to its vapor form, filling the flask. Because the mass, volume, temperature, and pressure of the vapor will be known, we can apply applying the Ideal Gas Law, PV = nRT to solve for the molar mass.

PROCEDURE:

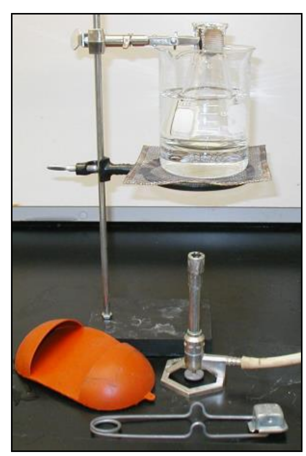
(CAUTION! Some of the unknowns are highly flammable!)

Flask with foil

1. Place an empty 800 mL beaker on a wire gauze on an iron ring attached to a ring stand. Light your Bunsen burner and adjust the flame to height of about one inch. Carefully raise or lower the beaker on the ring stand so that the flame will be at the proper height for heating the beaker. Turn off the burner for now.

2. Fill the 800 mL beaker with 300 mL of distilled water and place it on the wire gauze.

3. Obtain a dry 250 mL Erlenmeyer flask from the front of the room. Weigh the dry flask (no cap) on a top-loading balance to the nearest 0.01 g. Record this value in the Data section.



Setup

4. Obtain a sample of an unknown liquid from your instructor and pour the liquid into the flask. **Record the unknown number** in the Data Section. Return the vial to your instructor <u>without washing it</u>.

5. Place a piece of foil over the opening of the Erlenmeyer flask and crimp the

edges of the foil tightly around the opening of the flask. Place a rubber band over the foil to secure it to the flask. Poke 3-4 pinholes into the foil to let the excess gas escape (you can use a pencil or pen but make sure the holes are <u>small</u>).

6. Carefully attach a clamp to the Erlenmeyer flask and force the flask down into the water in the beaker until the clamp is at the lip of the beaker. Secure the clamp to the ring stand as shown in the picture.

7. Begin heating the water with the burner. <u>After</u> the water begins to boil, allow the flask to remain in it for **10 minutes**. There may be some minor splashing of the water as it boils so lower the hood sash. After 10 minutes of boiling, all of the liquid in the flask should be converted to its vapor completely filling the flask. **It is important that after this point, the heating process be done without interruption. Do not remove the flask from the bath and then return it to the bath for further heating**.

✍ Answer In-lab Questions #1 and #2 on page E10A-4.

8. After 10 minutes in the boiling water bath, turn off the burner. Carefully remove the flask from the water bath by holding the top of the flask with hot hands (rubber gripper) and loosening the clamp. Be careful handling the hot flask and clamp. Cool the <u>outside</u> of the flask by running cold water over the bottom portion of the flask. Do <u>not</u> allow water to enter the flask. Once the clamp is cool enough, you can remove it and continue cooling the outside of the flask. Once the flask is cool, dry it with a paper towel. Remove the foil cap and dry again if necessary. Immediately weigh the flask and its contents (condensed liquid) on the top-loading balance. Record this value in the Data Section.

<u>Note</u>: 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 entire procedure with a new sample.

✍ Answer In-lab Question #3 on page E10A-4.

9. Dispose of the condensed liquid in the flask in the proper waste container in the instructor's hood.

10. Determine the volume of the flask by filling completely with water and measuring this volume of water with a 500 mL graduated cylinder. Read the graduations carefully. Record the total volume in the Data Section.

11. Obtain the atmospheric pressure from the barometer in the room. Ask your instructor for help if you do not know how to use the barometer.

12. Start working on the calculations on page E10A-3.

Clean-up:

1. When finished with the experiment, place wet erlenmeyer flasks in the appropriately labeled bin at the front of the room.

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

3. Return all equipment to their original locations. The only items that should be left at your station is an 800 mL beaker and a 500 mL graduated cylinder. All other equipment should be returned to your student drawers/cabinets.

DATA SECTION

Record data with correct units and proper significant figures.

Unknown number: ____________

Mass of dry flask	_______________
Mass of flask and 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. 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 MM = ________________________ 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 compound. Write this down below.

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

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

Empirical formula: ________________________

Empirical mass: ________________________

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

Molecular formula: ________________________

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

Exact Molar mass: ______________________

6. Using the molar mass for your unknown (as determined in Question 1), calculate the % deviation as compared to the exact molar mass (determined in Question 5).

________________________ %

7. By careful examination of the procedure used to determine the molar mass, suggest at least one 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 under running water? What is/are present in 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? _________________ (assume 1 atm pressure)

c. What is the boiling point of hexane? __________________

To find this information, search the Internet. Material Safety Data Sheets (MSDS) for various chemicals can be found at: http://hazard.com/msds/index.php and other similar websites.

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. Solve for MM and write that gas law expression below:

MM =

b. A flask contains 1000 mL of a pure diatomic gas at 646 mm Hg and 20.0°C. The mass of the gas 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.