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, Hot Hands.

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. Use the Dumas method to determine the molar mass of a liquid.
2. Given the properties of a gas, calculate its molar mass by using the Ideal Gas Law.
3. Suggest reasons why this type of determination may not give an exact value for the molar mass.

DISCUSSION: In this experiment, the Dumas method will be used to determine the molar mass of a volatile liquid. In this method, the liquid is heated to completely convert it to its vapor (filling the flask). The properties of the gas are measured. The molar mass is determined by applying the Ideal Gas Law, PV = nRT, where P is the pressure (in atm), V is the volume (in L), n is the number of moles of gas, R is the universal gas constant (0.08206 L atm/mol K), and T is the temperature (in K).

PROCEDURE: (work with a partner)

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

1. Fill an 800 mL beaker with 300 mL of distilled water and place it on a wire gauze on an iron ring attached to a ring stand. Light your Bunsen burner and adjust the flame. Carefully raise or lower the beaker on the ring stand so that the flame will be at the proper height for heating the beaker (don’t burn yourself). Turn off the burner for now.

2. 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.

3. 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 without washing it.

4. 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 small).

5. 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
6. Begin heating the water with the burner. After 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-5.

7. 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 and loosening the clamp. Be careful handling the hot flask and clamp. Cool the outside of the flask by running cold water over the bottom portion of the flask. Do not 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 enough, you can remove it and continue cooling the outside of the flask. Immediately weigh the flask and its contents (condensed liquid) on the top-loading balance. Record this value 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 entire procedure with a new sample.

Answer In-lab Question #3 on page E10A-5.

8. Dispose of the condensed liquid in the flask in the proper waste container in the instructor’s hood.

9. 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.

10. 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.


**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.

Name ________________________________
Section ______________________________

Partner ______________________________ Date _____________________________
DATA SECTION
Experiment 10A

Unknown number: ____________  Include units!

Mass of dry flask  ____________
Mass of flask and condensed vapor  ____________
Mass of condensed vapor  ____________
Total volume of flask  ____________
Temperature of system at boiling (no need to measure this, BP 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!
   \[ R = 0.08206 \text{ L atm/mol K} \]
   
   \[ \text{Experimental MM} = \frac{pV}{nT} \]

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.

   \[ \% \text{ C } \text{ } \% \text{ H } \text{ } \% \text{ O } \text{ } \% \text{ N } \]
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 % error 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 % error (other than simply poor technique or human error).
IN-LAB QUESTIONS

Experiment 10A

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? YES NO
**PRE-LAB QUESTIONS**

**Experiment 10A**
**Complete this before lab.**

1. About 5 mL of a volatile liquid, such as hexane (C\(_6\)H\(_{14}\)), is added to an Erlenmeyer flask. A foil cap is placed over the opening of the flask and a few small holes are punched through the foil. The Erlenmeyer flask is placed in a beaker of water. The water 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)

   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](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 \( P \cdot V = n \cdot R \cdot T \)

      *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:

      \[
      MM = \frac{g}{R \cdot T}
      \]

   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. \( R = 0.08206 \text{ L-atm/mol-K} \) (Watch units!)

      \[
      MM = \frac{1.13 \text{ g}}{0.08206 \text{ L-atm/mol-K} \cdot 273.15 \text{ K}}
      \]

   c. What do you think this diatomic gas is? Give its chemical formula. ________________