CH 222 Winter 2026:

"Molar Mass of a Volatile Liquid" *Lab Instructions*

Step One:

Get a printed copy of this lab! You will need a printed (hard copy) version of pages I-2-2 through I-2-10 to complete this lab. If you do not turn in a printed copy of the lab, there will be a 2-point deduction.

Step Two:

Watch the **video introduction** for this lab **here: http://mhchem.org/y/2.htm**
The video introduction will help prepare you for the lab and assist you in completing the work before turning it in to the instructor.
Also **complete the PreLab questions** before starting the lab.

Step Three:

Bring the printed copy of the lab with you on Monday, January 12 (section L1), Wednesday, January 14 (section L2) *or* **Friday, January 16 (section L3).** During lab in room AC 2507, you will use these sheets (with the valuable instructions!) to gather data, all of which will be recorded in the printed pages below.

Step Four:

Complete the lab work and calculations on your own, then **turn it in** (pages I-2-5 through I-2-10 *only* to avoid a point penalty) **at the beginning of lab or recitation to the instructor on Wednesday, January 21 (*MLK!* AC 1303 at 9 AM, section L1), Wednesday, January 21 (section L2)** *or* **Friday, January 23 (section L3).** The graded lab will be returned to you the following week during recitation.

If you have any questions regarding this assignment, please email (mike.russell@mhcc.edu) the instructor! Good luck on this assignment!

Molar Mass of a Volatile Liquid

The experimental determination of the molar mass of gases and vapors is one important application of the Ideal Gas Law. To determine the molar mass of a gas or vapor, we need to determine the mass (g, below) of the gas sample under known conditions of temperature (**T**), Volume (**V**) and pressure (**P**). Assuming the gas obeys the Ideal Gas Law:

$$\mathbf{PV = nRT}$$

and if pressure, temperature and volume are determined experimentally and **R** is a constant (**0.082057 L atm mol^{-1} K^{-1}**), we can solve the equation for moles (**n**) of gas. The molar mass (grams/mole, or **MM**) of the gas or vapor can be determined based on the mass of the liquid remaining (**g**) in the flask and the number of moles calculated from the ideal gas law; or you can use:

$$\mathbf{MM = gRT/PV}$$

In this experiment, the molar mass of a volatile liquid will be determined using the ideal gas law. A small amount of the liquid is introduced into a weighed flask. The flask is then placed in boiling water where the liquid will completely vaporize, driving out any air and filling the flask with vapor at barometric pressure and the temperature of the boiling water. The mass of the vapor can be determined by cooling the flask to condense the vapor. (Note: ***the thermometer does not need a separate clamp*** (as shown in Figure One, below); you can place the thermometer directly in the boiling water when a reading is required.)

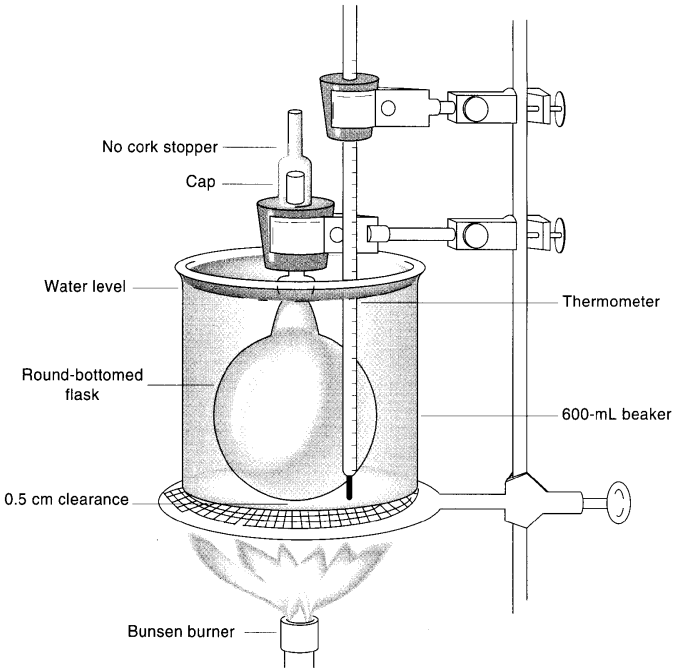

Figure One

PROCEDURE:
Obtain a round bottom flask fitted with a glass cap with a capillary opening, and a cork ring should support the entire apparatus at all times. If necessary, wash the flask with a touch of acetone, then dry the flask and cap and record the mass of the empty, dry flask and cap to the nearest 0.001g using the cork ring for support.

Obtain an unknown liquid and record the identification number. Pour approximately 5 mL of your unknown sample into the flask. (Note: the exact volume is not important; the mass of the final condensed vapor will be determined.) Assemble the apparatus as shown in Figure 1. It is important to have the round bottom flask immersed as deeply as possible in the 1000 mL water bath for uniform heating. Heat the water to the boiling point. Watch the liquid level in your flask; the level should gradually disappear as vapor expands and pushes first air from the flask, then as excess unknown vapor. Once all the liquid has disappeared, continue to heat the flask for 5 minutes to allow the vapor to reach the temperature of the boiling water. Measure and record the temperature of the boiling water. Also record the barometric pressure.

Turn off the burner and wait for the water to stop boiling (about 30 seconds). Remove the flask from the beaker of water and allow the flask to cool to room temperature and the vapor to condense. (You can speed up this process by running tap water over the stoppered flask.) Dry the outside of the flask and weigh the flask with the condensed vapor.

Repeat the procedure using another 5 mL sample of your liquid unknown. **Do not empty or clean the flask between trials**; just pour another 5 mL into the flask

Once the two trials are complete (**and not before**!), find the volume of the flask. Fill the flask and cap with water. Determine the mass of the flask filled with water, then determine the temperature of the water used to fill the flask. Using the *Handbook of Chemistry and Physics*, determine the density of the water to at least six sig figs. If the *Handbook* is difficult to read, use this link as an alternative: **http://mhchem.org/den**

Rinse the flask with a touch of acetone, then blow dry. Return the flask to the cart.

Using the density of water and the mass of water in the flask, calculate the volume of the flask. Be sure to subtract the empty mass of the flask first! When converting to atmospheres use **1013 mbar = 1 atm** (other conversions will not receive full credit); also, use **273.15** to convert to Kelvin temperatures, and **use the complete version of R** (listed on the previous page) for full credit.

Determine the **average molar mass** (in grams per mole) of your liquid sample and **parts per thousand (ppt).** Parts per thousand is a *unitless number* that measures the precision of your measurements (how close they are to each other) - it does not measure accuracy, or concentration (ppt can refer to 1 g of a solute in 1000 g of solvent, but our ppt will measure the precision of our measurements.

Smaller parts per thousand numbers indicate a better precision. To calculate parts per thousand, see this handout: **http://mhchem.org/ppt**

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Molar Mass of a Volatile Liquid

Record all masses to the milligram (0.001 g)

YOUR NAME: _____ ***LAB PARTNER(s):*** _____

*first **AND** last names*

Data: *Record during lab and use in Calculations section*

empty flask (g): _____ *Include flask, stopper and cork ring*

Unknown number: _____

Trial I		**Trial II**	
Boiling water temperature (°C):	_____	Boiling water temperature (°C):	_____
flask + condensed vapor (g):	_____	flask + condensed vapor (g):	_____
barometric pressure (mbar):	_____	barometric pressure (mbar):	_____

flask filled with water (g): _____

Density of water (g/mL): _____ *from Handbook of Chemistry & Physics* or link

Density temperature (°C): _____ *"cold" water temperature*

Part A Calculations: *Molar Mass Determination of a Volatile Liquid*

Show all work, use significant figures and circle the final answer for full credit.

1. Using your data, determine the temperature of the gas in Kelvin for both Trials.

Trial I Temperature (K): _____

Trial II Temperature (K): _____

2. Using your data, determine the pressure of the gas in atmospheres for both Trials.

Trial I Pressure (atm): _____

Trial II Pressure (atm): _____

3. Using your data, determine the mass of the unknown liquid remaining at the end of the experiment for both Trials.

Trial I mass of liquid (g): _____

Trial II mass of liquid (g): _____

4. Using your data, calculate the volume (L) that the gas occupies in the flask (*hint:* use only the **mass of water** in the flask; this will be the same for both Trial I and Trial II.)

Volume of flask (L): _____

5. What is the value of R for this lab? Report to five significant figures and include units.

Value of R with units: _____

6. Using the previously recorded and calculated values, **determine the molar mass** of the gas **for Trial I and Trial II**. **Calculate** the **average molar mass** for both trials. **Determine** the **average deviation** and the **parts per thousand** using your molar mass values. *Hint:* do not average any values until you have calculated the molar mass values for the unknown liquid. *Show all work!*
   Parts per thousand (ppt) guide: **http://mhchem.org/ppt**

molar mass (Trial I) (g/mol): _____ molar mass (Trial II) (g/mol): _____

average molar mass (g/mol): _____ average deviation: _____

Parts per thousand: _____

Postlab Questions:

Show all work, use significant figures and circle the final answer for full credit.

1. Use the data below to find the moles of unknown and the molar mass of the unknown. *Show all work!*
   - mass of an empty flask and stopper = 55.441 g
   - 5 mL of unknown added and heated; boiling water bath at 100.˚C, all unknown liquid vaporized
   - mass of the flask, stopper and condensed vapor = 56.039 g.
   - volume of the flask = 215.9 mL
   - barometric pressure = 1003 mbar

moles unknown: _____ **Molar mass of unknown (g/mol)**: _____

2. Determine if each of the following procedural errors would **increase**, **decrease**, or have **no effect** (use these terms in your answer) on the molar mass calculations in this experiment. **Explain** your reasoning.

i. The flask was not dried before the final weighing with the condensed vapor inside.

Effect on molar mass:

Explain:

ii. The flask was removed from the boiling water before the vapor had reached the temperature of the boiling water. All the liquid had vaporized.

Effect on molar mass:

Explain:

iii. The volume of the cap was not measured with the volume of the flask.

Effect on molar mass:

Explain:

iv. The student uses 7.5 mL of liquid sample.

Effect on molar mass:

Explain:

Molar Mass of a Volatile Liquid PreLab Questions

Ideally you will complete these before performing the lab.
Include the completed PreLab Questions when you turn in your lab report.

1. What is the **mathematical value of R**, the gas constant, to five significant figures? (*Note:* this is the only version you should use with the gas laws!) What are the **units of R** for this lab?

2. What quantity does **n** stand for in the ideal gas equation?

3. How many torr in 1 mm Hg? *Answer*: _____ torr

4. How many mm Hg in 1 atm? *Answer*: _____ mm Hg

5. How many mbar in 1 atm? *Answer*: _____ mbar

6. What number (to the hundredths place) is used to convert Celsius to Kelvin, and Kelvin to Celsius? *Answer*: _____

7. When converting °C to K, one must _____ the number from question #6 to convert Celsius to Kelvin.

   add **subtract** **multiply** **divide** *(circle one)*

8. How many mL are in exactly 1 L? *Answer*: _____ mL

9. What are the units in chemistry for molar mass? *Answer*: _____

10. The density of liquid water is always equal to 1 g/mL **True** **False** *Circle one, and explain your answer below.*

11. We will use **Parts per thousand** (ppt) to measure the precision of our molar mass values. You can find a handout on how to calculate parts per thousand here: **http://mhchem.org/ppt** If you calculate molar mass values of 86.1 g/mol and 90.1 g/mol, calculate the **average molar mass**, the **average deviation** of the molar mass values, and the **parts per thousand** for these two values.