LAD D1 (pg 1 of 4) Determining the Molar Mass of a Gas

Name________________________Per___

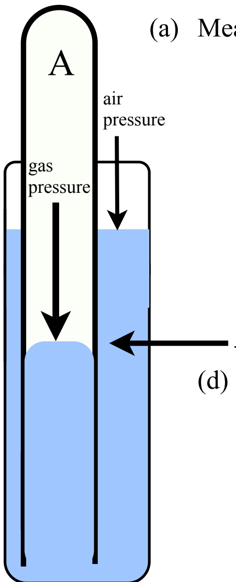
In this lab, as with any lab, you must show work to support any calculations.

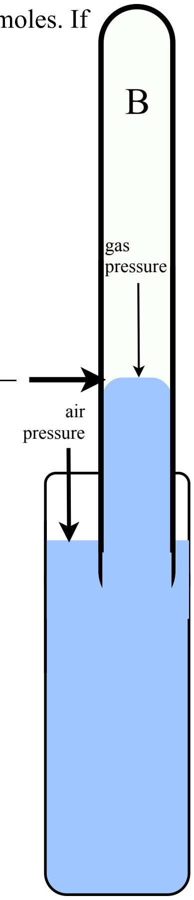
Introduction

Your objective in this lab is to determine the molar mass of a gas, using the ideal gas law. You will measure mass, and use volume and pressure and temperature to calculate moles, which of course will allow the calculation of mass per moles. If you measure the mass of a gas and its corresponding number of moles, you can calculate the gases' molar mass.

PreLab

1. Let's learn about pressure in a sealed container.





(a) Measure and record the volume of the gas in your gas tube on the line in diagram A.

(b) Then raise the gas tube up as far as possible without raising above the surface of the water in the cylinder as shown in diagram B. Read the volume of gas in the gas tube and record it on the line in the diagram B.

Vol gas in situation B________

(c) Is the volume of gas in the eudiometer B more or less than in diagram A?
circle one

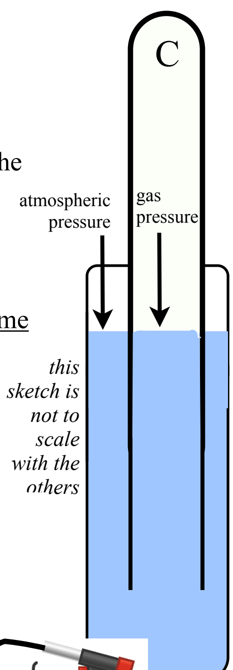
________Vol of gas in situation A

(d) Since you didn't let any air in or out between situation A and B, and the temperature has not changed from situation A to situation B, yet the volume HAS changed, the pressure of the gas in the eudiometer in diagram B **must** be different than in the eudiometer A. Would you predict that the **pressure** of the gas in diagram B is more or less than the **pressure** of the gas in diagram A?
circle one

(e) Put an (↑ or ↓) arrow on the equation below for the pressure in B to justify your response.

$$\overset{\#}{P_A}\ \overset{\#}{V_A} = P_B\ V_B$$

(f) In diagram A is the gas pressure inside the eudiometer, more or less than the air pressure outside the tube? How can you tell, or how did you decide?
circle one

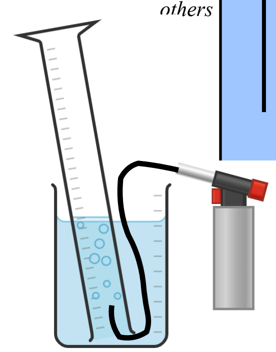


(g) In diagram B is the gas pressure inside the eudiometer, more or less than the air pressure outside the tube? How can you tell, or how did you decide?
circle one

(h) Now, consider diagram C, is the gas pressure inside the eudiometer more than, less than, or the same as the air pressure outside the tube? How can you tell, or how did you decide?
circle one

Voila! If we want to know the pressure of gas in a closed container, we can know what the pressure is only if we move the eudiometer so the water level is the same inside and out. Of course this requires that we know what the atmospheric pressure is, but we can get atmospheric barometer pressure from the weather app on our phones.

2. Consider the diagram below in which gas from the canister is collected over water. The graduated cylinder collecting the gas actually contains two gases. What is the other gas and how does that gas get into the container?



Some facts to help you understand *vapor pressure* of gas over a liquid in a sealed container.

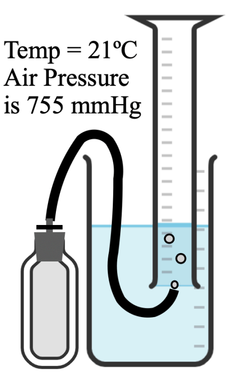
- When a liquid evaporates to a gas (vapor) in a closed container, and the gaseous molecules cannot escape, some of the vaporized molecules will strike the liquid phase or sides of container and condense back into liquid.
- When the rate of condensation of the vapor becomes equal to the rate of evaporation of the liquid, the amount of vapor will have reached a *maximum* and the vapor pressure will no longer change. The gas in the sealed container is said to be in ***equilibrium*** with the liquid.
- The pressure exerted by the water vapor in equilibrium with liquid water in a closed container at a given temperature is called the ***equilibrium water vapor pressure***, and if the temp is constant, equilibrium will be achieved very quickly.
- ***Equilibrium vapor pressure is dependent only on temperature***: at a higher temperature, more molecules have enough energy to escape from the liquid or solid. At a lower temperature, fewer molecules have sufficient energy to escape from the liquid or solid. The vapor pressure of a liquid is independent of any other gas molecules in the space above the liquid.

3. You know that water evaporates, and thus some of the water will evaporate into the eudiometer tube in which we collected the gas, meaning there are actually two gases in the eudiometer, the gas from the canister **and** H_2O vapor. Sometimes a chemist would say that the gas is not "dry." Fortunately, the amount of water that will evaporate is caused only by the temperature of the water, this allows the pressure of the water vapor to be looked up in a chart.
   (a) So if our lab room today was at 21.0ºC, what will be the equilibrium vapor pressure of water in a closed eudiometer?

   (b) So if the pressure of the space containing gases over water was 755 torr, what is the pressure of the "dry" gas collected in the eudiometer.

Equilibrium Water Vapor Pressure

Temp (ºC)	Pressure (mm Hg)	Temp (ºC)	Pressure (mm Hg)
0	4.6	27	26.7
5	6.5	28	28.4
10	9.2	29	30.0
11	9.8	30	31.8
12	10.5	35	42.2
13	11.2	40	55.3
14	12.0	45	71.9
15	12.8	50	92.5
16	13.6	55	118.0
17	14.5	60	149.4
18	15.5	65	187.5
19	16.5	70	233.7
20	17.5	80	355.1
21	18.6	90	525.8
22	19.8	92	567.0
23	21.1	94	610.9
24	22.4	96	657.6
25	23.8	98	707.3
26	25.2	100	760.0



4. Write the Ideal Gas Law in the space below,
   - and then substitute for moles: n = mass/molar mass
   - and then manipulate the variables and isolate for molar mass.
   - (This literal equation isolated for molar mass will be used in PostLab Q's 1-4.)

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5. Make a data/results table in your Google Sheets Lab Document. Use the same spreadsheet, just make a new sheet in a new tab at the bottom. Be sure and LABEL that new tab D1, and pull all the way to the LEFT of all your tabs. Be sure and make a row for each measurement and processing the data item. Be sure a title at the top which includes the Lab number and a descriptive title.

Materials – on trays per lab group

- 100 ml glass graduated cylinder
- gas containers
  (lighter, butane canister, and/or Dust-Off)
- matches
- thermometer
- "hot hands" grippers
- sink drain stop or large tub
- bucket and sponges for bench clean-up

 Determining the Molar Mass of a Gas

Procedure

A. Weigh the gas container. (In separate trials, you will test both butane and a the gas in a Dust-Off canister.).

B. Prepare the graduated cylinder to collect gas by filling the cylinder with water and inverting the cylinder mouth down into the sink or tub. Try not to allow any air bubbles in the cylinder. Place the hose under water and allow gas to flow out of the canister (using dry hands and keeping the canister dry) until you have collected an *almost full* graduated cylinder of gas (DO NOT GO BEYOND FULL, or you will not have any markings to read the volume).

C. Measure the volume of gas when you have raised or lowered the graduated cylinder so that the level of water inside the tube and the surface of water in the sink are the same. At that moment, read the volume of gas inside the graduated cylinder.

D. ____

Fill in the missing procedural item.

E. Use the thermometer to record the temperature of water in the sink and the temperature of the air in the room - we hope that they are close to the same. (If they are not, take an average, since you can use only one value in your calculation.)

F. Using the vapor pressure chart, record the equilibrium vapor pressure of water for the temperature of water/air in the room on your data table.

G. On your phone look up and record the air pressure in the room. ALERT! The air pressure on your phone is in inches.

Process the Data – ***Be sure and record your data and embedded formulas to calculate these results on your Google sheet. Your second gas should be a second trial in your Google sheet.***

(a) Calculate & correct the air pressure in mmHg from the inches value recorded from your phone. (25.4 mm = 1 inch) (Look up the elevation, divide by 1000 then multiply by 26 and subtract that from the air pressure on the phone.)

(b) Convert the temperature of the air / water (average if necessary) into Kelvin.

(c) Calculate the mass of gas that was released into the cylinder.

(d) Calculate the partial pressure of the gas in the cylinder. Use the water vapor pressure table given in the PreLab.

(e) Using your literal equation in which you solved for molar mass in the preLab, calculate the molar mass of butane.

(f) The chemical formula for butane is C_4H_{10}, The primary common component in Dust Off is difluoroethane, $C_2H_4F_2$ Calculate the theoretical molar mass for each gas.

(g) Calculate the percent error for your experimental molar mass calculations.

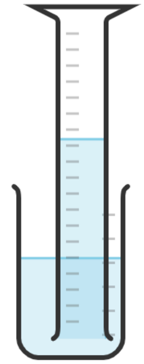
Post-Lab Questions - ***to be answered on this sheet in the spaces provided. Calculations must be shown.***

You may want to rewrite and refer to your literal equation from PreLab #3 to help justify your responses.

1. Shrek suggested that the molar mass of the gas turned out too large because when he measured the canister's mass after letting out the gas, the canister was wet from the lab procedure. Do you agree or disagree? Justify your response.

2. If you had a goofy lab partner like Donkey who decided to open the gas canister's valve and let out some gas on the way to the balance before the final weighing of the canister, would the calculated molar mass be larger, smaller, or no change?

 Determining the Molar Mass of a Gas



3. Fiona measured the volume of the butane when the graduated cylinder looked like the diagram to the right, would the calculated molar mass be larger, smaller, or no change?

4. Muffin Man said that some gases are more soluble than others, and he suggested that if the gas used in this lab procedure were quite soluble, the calculated molar mass would be smaller than the theoretical molar mass? Do you agree or disagree with Muffin Man? Justify your response.

5. I hope you remember the combined gas law, PV/T = PV/T . Calculate the volume of a mole of gas at today's room conditions, (___ºC and ___ torr) *Show your work. Use this calculated number in the next three problems.*

6. Most *Bic* lighters hold 5.0 ml of liquified butane (density = 0.60 g/ml) Calculate the minimum size container you would need to "catch" all of the butane (from a lighter) at today's room conditions (___ºC and ___ torr), if you released all of the butane from the lighter. *Show your work. Do NOT use the ideal gas law in this problem. Since the pressure and temperature are constant, you can just work the stoichiometric ratios with the molar volume you calculated in the problem #5.*

7. Write a balanced equation for the combustion of butane.

8. What volume of air at today's room conditions (___ºC and ___ torr) would be required to combust a full lighter of butane. Remember that air is only ~20% oxygen. *Show your work. Again, do NOT use the ideal gas law in this problem. Since the pressure and temperature in the room are constant today, you can just work the stoichiometric ratios with the volume you calculated in the problem problem #6.*

9. What would be the total volume of gases produced at today's room conditions (___ºC and ___ torr) by the combustion described in the previous question. *Again, do NOT use the ideal gas law in this problem. Since the pressure and temperature are constant, you can just work the stoichiometric ratios with the volume you calculated in the problem #8.*