KINETIC MOLECULAR (K-M) THEORY OF MATTER NOTES

- based on the idea that particles of matter are always in motion
- assumptions of the K-M Theory

1.) Gases consist of large numbers of tiny particles that are far apart relative to their size. This means that ____

2.) Collisions between gas particles and between particles and container walls are elastic collisions. This means that ____

3.) Gas particles are in constant, rapid, random motion. This can be inferred because ____

4.) There are no forces of attraction or repulsion between gas particles. This means that ____

5.) The average kinetic energy of gas particles depends on the temperature of the gas. This means that ____

An ideal gas conforms to all points of the K-M Theory.

- GASES BEHAVE NEARLY IDEALLY UNDER CONDITIONS of _________ temperature, _________ pressure, & _________ molar mass.

PROPERTIES OF GASES NOTES

- In order to fully describe a gas, four measurable quantities must be stated.

* PRESSURE: ____

units: 1 atm ("atmosphere") = _______ mm Hg ("millimeters mercury")
= _______ torr
= _______ kPa ("kilopascals")
= _________ Pa ("pascals")

EX. 1: 455 mm Hg = ? atm

EX. 2: 2.252 atm = ? torr

EX. 3: 150. kPa = ? mm Hg

measured with a ___________________

* TEMPERATURE: ____

units: degrees Celsius (^oC), Kelvins (K), or ^oF (^oF not usually used in class)
how to convert from ^oC to K?___________________________________

** "STP" stands for "Standard Temperature and Pressure". The conditions at STP are exactly 1 atm pressure and exactly 0 ^oC. **

* VOLUME: ____

units: 1 Liter (L) = _______ mL = _______ cm^3 = _______ dm^3

* QUANTITY: ____

units: moles how to convert from grams to moles?

Temperature & Pressure Conversions WKSHT

1.) 2.00 atm to mm Hg
2.) 115 kPa to atm
3.) 500. mm Hg to atm
4.) 3.5×10^4 torr to mm Hg
5.) 35 ^oC to Kelvin
6.) 120 ^oC to Kelvin
7.) -25 ^oC to Kelvin
8.) -227 ^oC to Kelvin
9.) 1800. mm Hg to kPa
10.) 93,500 Pa to atm
11.) 950. torr to atm
12.) 0.490 atm to kPa
13.) standard temperature in Kelvin & Celsius
14.) 298 K to ^oC
15.) 100. K to ^oC
16.) 5 Kelvin to ^oC

IDEAL GAS EQUATION NOTES

P V = n R T

"P" stands for ____________________, must be in units of ____________________

"V" stands for ____________________, must be in units of ____________________

"n" stands for ____________________, must be in units of ____________________

"T" stands for ____________________, must be in units of ____________________

"R" stands for the Ideal Gas Constant, has a value of 0.0821 with units of $\frac{L \cdot atm}{mole \cdot K}$

EXAMPLE 1:

Q: What pressure is exerted by 0.325 moles of hydrogen gas in a 4.08 L container at 35 ^oC?

A: P V = n R T solving for P ... $P = \frac{n\,R\,T}{V}$

n = 0.325 moles (correct unit)

T = 35 ^oC (need to convert to K) T = 35 ^oC + 273 = 308 K

V = 4.08 L (correct unit)

$$P = \frac{(0.325\ \cancel{moles})\ (0.0821\ \cancel{L}\ atm/\cancel{mole}\ \cancel{K})\ (308\ \cancel{K})}{(4.08\ \cancel{L})} = 2.01\ atm$$

EXAMPLE 2:

Q: What mass of chlorine gas, Cl_2, in grams, is contained in a 10.0 L tank at 27 ^oC and 3.50 atm of pressure? (Answer: 101 grams)

EXAMPLE 3:

Q: A gas at 20.0 ^oC and 3.98 atm contains 1.45 moles of gas particles. What volume does the gas occupy? (Answer: 8.77 L)

Ideal Gas Equation 1 WKSHT

1.) What is the pressure exerted by 2.0 moles of an ideal gas when it occupies a volume of 12.0 L at 373 K?
2.) A flashbulb of volume 2.6 cm^3 contains O_2 gas at a pressure of 2.3 atm and a temperature of 26^oC. How many moles of O_2 does the flashbulb contain?
3.) If 0.20 moles of helium occupies a volume of 64.0 liters at a pressure of 0.15 atm, what is the temperature of the gas?
4.) What is the volume of 0.35 moles of gas at 1.7 atm of pressure and a temperature of 100 K?
5.) What is the pressure of 1.5 moles of an ideal gas at a temperature of 150 K and occupies a volume of 20.0 liters?
6.) How many moles of gas occupy 16.2 liters at a pressure of 1.05 atm and a temperature of 37^oC?

Ideal Gas Equation 2 WKSHT

1.) Calculate the volume of exactly 1.00 mole of a gas at STP.
2.) How many moles of nitrogen are present in 17.8 liters at 27 ^oC and 1.3 atm pressure?
3.) What is the pressure of 2.3 moles of carbon dioxide at 235 K occupying 23.7 liters of space?
4.) If there are 4.02 x 10^{23} molecules of N_2O in a sample, how many moles are there?
5.) Using answer from #4, calculate the pressure of the gas if it occupies 27,025 cm^3 of space at 38.0 ^oC.
6.) How many grams of NH_3 are present in 35.0 dm^3 of space at 78.3 K and 0.853 atm of pressure?
7.) What is the temperature of 34.2 grams of sulfur dioxide occupying 30.0 liters of space and having a pressure of 800. torr?

8.) What is the pressure (in mm Hg) of 79.4 grams of boron trifluoride in a 20.0 L container at a temperature of 245 K?

9.) How many grams are in a sample of arsenic trifluoride that has a volume of 17,600 mL and a temperature of 92 ^{o}C and a pressure of 108,732 Pa?

10.) How many kilopascals of pressure are exerted by 23.8 liters of oxygen with a mass of 175 grams at a temperature of 58 ^{o}C?

11.) How many moles of argon are in 30.6 liters at 28 K and 658 mm Hg of pressure?

12.) How many grams of argon are found in # 11?

GAS LAWS NOTES

* Unlike Ideal Gas Equation, the "Gas Laws" describe one gas undergoing a change in conditions. The Gas Laws are also different from the Ideal Gas Equation because you do not have to convert any units except temperature that has to be in Kelvins.

Combined Gas Law: $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$

* All of the other gas laws can be derived from the combined gas law. *

~ Boyle's Law

- describes relationship between pressure & volume when temperature is constant
- because temperature is constant, it can be excluded from the equation

- so, equation for Boyle's Law is ______________________________
- pressure & volume are ___________________ proportional
- graph of pressure vs. volume would have the general shape of

EXAMPLE: A sample of gas occupies 15 liters under 2.1 atm of pressure. What would the volume of the gas be if the pressure were decreased to 1.2 atm? (Assume that temperature is constant.)

~ Charles' Law

- describes relationship between volume & temperature when pressure is constant
- because pressure is constant, it can be excluded from the equation

- so, equation for Charles' Law is ______________________________
- volume & temperature are _________________ proportional
- graph of volume vs. temperature would have the general shape of

EXAMPLE: When I purchase a helium balloon at the store (where the temperature is 25 ^{o}C) for my friend's birthday, the clerk fills the balloon to a volume of 20.0 liters. When I go outside, the balloon shrinks to a volume of 17.9 liters. What is the temperature outside?

~ Gay-Lussac's Law
- describes relationship between pressure & temperature when volume is constant
- because volume is constant, it can be excluded from the equation

- so, equation for Gay-Lussac's Law is ___________________________
- pressure & temperature are ________________ proportional
- graph of pressure vs. temperature would have the general shape of

EXAMPLE: An aerosol can has an internal pressure of 2.75 atm at room temperature (25 °C). What is the pressure in the can if I leave it outside in the sun and the temperature goes up to 35 °C?

Gas Law Problems WKSHT

1.) The gas pressure in an aerosol can is 1.5 atm at 25 °C. Assuming that the gas inside obeys the ideal gas equation, what would the pressure be if the can were heated to 450 °C?
2.) A pocket of gas is discovered in a deep drilling operation. The gas has a temperature of 480 °C and is at a pressure of 12.8 atm. Assume ideal behavior. What volume of the gas is required to provide 18.0 L at the surface at 1.00 atm and 22 °C?
3.) A fixed quantity of gas is compressed at constant temperature from a volume of 368 mL to 108 mL. If the initial pressure was 5.22 atm, what is the final pressure?
4.) A gas originally at 15 °C and having a volume of 182 mL is reduced in volume to 82.0 mL while its pressure is held constant. What is its final temperature?
5.) At 36 °C and 1.00 atm pressure, a gas occupies a volume of 0.600 L. How many liters will it occupy at 0.0 °C and 0.205 atm?
6.) What is the temperature at which 9.87×10^{-2} moles occupies 164 mL at 0.645 atm?
7.) Chlorine is widely used to purify municipal water supplies and to treat swimming pool waters. Suppose that the volume of a particular sample of Cl_2 is 6.18 L at 0.90 atm and 33 °C. What volume will the Cl_2 occupy at 107 °C and 0.75 atm?
8.) A gas exerts a pressure of 1.5 atm at 27 °C. The temperature is increased to 108 °C with no volume change. What is the gas pressure at the higher temperature?

GAS STOICHIOMETRY NOTES

* chemical reaction is happening
* deals with two different substances (at least 1 is a gas)
* given chemical equation
* assume reaction occurs at STP unless otherwise noted

To solve stoichiometry problems... ALWAYS!!!!!!!!!!!

**** WRITE THE BALANCED EQN & GIVEN AND UNKNOWN INFORMATION! ****

If given...	**Problem asks for...**	**Use step(s)**
Moles	moles	**2**
Moles	grams, molecules, or liters	**2** & **3**
Grams, molecules, or liters	moles	**1** & **2**
Grams, molecules, or liters	grams, molecules, or liters	**1**, **2**, & **3**

1.) Find moles of given element or compound. (Set up a "T chart".)

and unit given in problem | 1 mole = answer to step 1
| *## unit given

~If unit given is grams, the *#* used should be molar mass from P.T.
~If unit given is molecules, the *#* used should be 6.022 x 10^{23}
~If unit given is liters, the *#* used should be 22.4

2.) Use mole ratio (coefficients) from balanced equation. (Set up below.)

$$\frac{\text{**\#** moles given substance}}{\text{coefficient of given substance}} = \frac{\text{x moles unknown substance}}{\text{coefficient of unknown subst.}}$$

Then, solve for x.
should be your answer from step 1 or the number of moles given in the problem.

3.) Find answer. (Set up a "T chart".)

x moles unknown subst	***#*** unknown unit	= final answer
	1 mole	

"x" should be your answer from step 2

~If the unknown unit is grams, the ***#*** should be molar mass from PT
~If the unknown unit is molecules, the ***#*** should be 6.022 x 10^{23}
~If the unknown unit is liters, the ***#*** should be 22.4

Example # 1
How many Liters of carbon dioxide gas can be produced from the decomposition of 4.50 grams of sodium carbonate? $Na_2CO_3 \rightarrow Na_2O + CO_2$ (Note: Equation is already balanced.)

4.50 g Na_2CO_3	1 mole Na_2CO_3	= 0.0425 moles Na_2CO_3
	106 g Na_2CO_3	

Na: 2 x 23.0 = 46.0
C: 1 x 12.0 = 12.0
O: 3 x 16.0 = 48.0

$\left.\begin{matrix}46.0\\12.0\\48.0\end{matrix}\right\}$ 106.0

$$\frac{0.0425 \text{ moles } Na_2CO_3}{1} = \frac{x \text{ moles } CO_2}{1} \qquad x = 0.0425 \text{ moles } CO_2$$

0.0425 moles CO_2	22.4 L CO_2	= **0.951 L CO_2**
	1 mole CO_2	

Example # 2
How many liters of H_2 are needed to react completely with 15.0 L of N_2?
$N_2 + H_2 \rightarrow NH_3$

Example # 3
How many grams of aluminum are needed to completely react with 16.0 L of oxygen?
$Al + O_2 \rightarrow Al_2O_3$ (Ans: 25.7 g)

GAS STOICHIOMETRY (standard conditions) WKSHT.

**** assume all reactions in this section occur at STP ****

1.) How many liters of oxygen can be formed from the decomposition of 2.00 grams of $KClO_3$.

__ $KClO_3 \rightarrow$ __ KCl + __ O_2

2.) How many grams of $CaCO_3$ are required to produce 6.00 L of CO_2?

__ $CaCO_3 \rightarrow$ __ CaO + __ CO_2

3.) Determine the volume of hydrogen gas produced when 0.250 moles of zinc react with excess HCl.

__ Zn + __ $HCl \rightarrow$ __ $ZnCl_2$ + __ H_2

4.) How many liters of nitrogen are required to combine with 3.0 L of hydrogen in the following reaction:

__ N_2 + __ $H_2 \rightarrow$ __ NH_3

5.) How many liters of oxygen are needed to combine with 7.0 liters of propane in the following reaction:

__ C_3H_8 + __ $O_2 \rightarrow$ __ CO_2 + __ H_2O

6.) From the following reaction: __ CH_4 + __ $O_2 \rightarrow$ __ CO_2 + __ H_2O

How many liters of CO_2 are formed from 32.0 grams of CH_4?

7.) How many grams of Na are needed to produce 5.0 L of hydrogen?

__ Na + __ $H_2O \rightarrow$ __ $NaOH$ + __ H_2

8.) Determine the volume of CO_2 produced from burning 0.750 moles of C.

__ C + __ $O_2 \rightarrow$ __ CO_2

DALTON'S LAW OF PARTIAL PRESSURES NOTES

* DEALS WITH A MIXTURE OF DIFFERENT GASES *

1.) The sum of the pressures of the individual gases equals the total pressure exerted by the mixture of gases.

$$P_{TOTAL} = P_{gas1} + P_{gas2} + \ldots$$

EXAMPLE: A mixture of oxygen and nitrogen exerts 1.1 atm of pressure. What is oxygen's partial pressure if the pressure of the nitrogen gas is 0.8 atm?

2.) The pressure of a gas "collected over water" is equal to the atmospheric pressure minus the vapor pressure of the water. $P_{gas} = P_{atm} - P_{water}$

EXAMPLE: A 44.6 mL sample of carbon dioxide is collected over water at 765 mm Hg pressure and 25 ^oC. What is the vapor pressure of the "dry" gas? (The vapor pressure of water at 25 ^oC is 23.76 mm Hg. You will have to look up this value on a table or this value must be given to you.)

3.) The partial pressure of a gas is equal to the "mole fraction" multiplied by the total pressure.

$P_x = \frac{\text{(moles x)}}{\text{(total moles)}} \cdot P_{total}$ "P_x" = partial pressure of certain gas

* "mole fraction" = $\frac{\text{(moles x)}}{\text{(total moles)}}$

EXAMPLE: A mixture of gases contains 2.0 moles of He and 4.0 moles of oxygen. If the mixture exerts a pressure of 801 torr, what is the partial pressure of the oxygen?

GRAHAM'S LAW OF EFFUSION NOTES

* compares the rates of effusion of different gases

* lighter gases (lower molar masses) effuse faster than heavier gases (higher molar masses)

$$\frac{\text{rate A}}{\text{rate B}} = \sqrt{\frac{\text{MM B}}{\text{MM A}}}$$

the rate of gas A compared to the rate of gas B is equal to the square root of the inverse of the molar masses of the gases

EXAMPLE 1: Compare the rates of effusion for oxygen gas and hydrogen gas.

EXAMPLE 2: An unknown gas effuses 1.18 times faster than SO_2. What is the molar mass of the unknown gas?

DALTON'S LAW & GRAHAM'S LAW WKSHT.

1.) Determine the partial pressure of each gas in a container with 2.0 moles of N_2, 3.0 moles of O_2, and 7.0 moles of H_2 that has a total pressure of 850 mm Hg. (You will have 3 separate answers for this question.)
2.) A mixture of nitrogen and oxygen has a total pressure of 730 mm Hg. If the nitrogen has a partial pressure of 420 mm Hg, find the pressure of the oxygen.
3.) At an altitude of 30,000 ft., the total air pressure is only about 450. mm Hg. If the air is 21.0 % oxygen, what is the partial pressure of oxygen at this altitude?
4.) A mixture of 3 gases have the following pressures: oxygen = 355 mm Hg, helium = 468 mm Hg, & nitrogen = 560 mm Hg. Find the % of each gas in the mixture.
5.) Compare the rate of effusion of CH_4 and CO_2. (Give answers to # 5, 6, & 7 to 3 SF's.) (Your answers for # 5, 6, &, 7 should read " ___ effuses ___ times faster than ___.")
6.) Compare the rate of effusion of helium and nitrogen.
7.) How much faster does ammonia (NH_3) effuse than HCl?
8.) An unknown gas effuses 4.0 times faster than O_2. Find the molar mass of the unknown gas.

UNIT 10 REVIEW & PRACTICE WORKSHEET

1.) Convert 122.3 kPa to atm.
2.) Convert 94 ^oC to Kelvins.
3.) The volume of a gas at 725 torr is 275 mL. What is the volume of the sample at 950.0 torr?
4.) At STP, how many liters of hydrogen gas can be produced from the complete reaction of 27.45 grams of iron with excess H_2O?

$$\_\_\_ \ Fe + \_\_\_ \ H_2O \rightarrow \_\_\_ \ Fe_3O_4 + \_\_\_ \ H_2$$

5.) What is the temperature (in ^oC) of a 1.37 mole sample of carbon monoxide in a 18.3 liter container at 805 mm Hg?
6.) A mixture of gases contains 2.50 moles of hydrogen, 3.25 moles of nitrogen, and 1.75 moles of oxygen and the total pressure is 775 torr. What is the partial pressure of the nitrogen?
7.) A gas at 47.6 ^oC has a volume of 125 mL. What is the temperature of this sample of gas when its volume is 362 mL?
8.) Some rockets are fueled by the reaction of hydrazine (N_2H_2) and hydrogen peroxide (H_2O_2). How many liters of H_2O can be produced from the complete reaction of 37.7 liters of N_2H_2?

$$\_\_\_ \ N_2H_2 + \_\_\_ \ H_2O_2 \rightarrow \_\_\_ \ N_2 + \_\_\_ \ H_2O$$

9.) An unknown gas effuses 1.57 times faster than N_2O_3. What is the molar mass of the unknown gas?
10.) The pressure of a gas at 35.6 ^oC is 114.3 kPa. What is the pressure when the temperature drops to 17.3 ^oC?
11.) A mixture of three gases (helium, neon, and argon) has a total pressure of 950. torr. If the helium and neon exert a pressure of 255 torr each, what is the partial pressure of the argon?
12.) A 21.5 liter sample of gas at 107 kPa of pressure has a temperature of 27.2 ^oC. What is the pressure of the gas if it is transferred to a 32.6 liter container at 44.1 ^oC?

GASES - A FANTASTIC SUMMARY & REVIEW!

Law	Ideal Gas Equation	Combined Gas Law
equation	P V = n R T	$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$
explanation	one gas at one set of conditions	one gas that is changing conditions
when to use it	when the problem gives 3 of these: P, V, n, T	more than one temperature, pressure, and/or volume in the problem
specific units req'd?	pressure = atm, volume = liters, quantity (n) = moles, temperature = Kelvins	temperature = Kelvins, pressure & volume can be any unit, but must be the same unit on both sides of the equation

Law	Boyle's Law	Charles' Law	Gay-Lussac's Law
equation	$P_1 V_1 = P_2 V_2$	$\frac{V_1}{T_1} = \frac{V_2}{T_2}$	$\frac{P_1}{T_1} = \frac{P_2}{T_2}$
explanation	pressure & volume are inversely proportional; temperature is constant	volume & Kelvin temp of a gas are directly proportional; P is constant	pressure & Kelvin temp of a gas are directly proportional; V is constant
when to use it	given 2 difft pressures & 1 volume or given 2 difft volumes & 1 pressure	given 2 difft volumes & 1 temperature or given 2 difft temperatures & 1 volume	given 2 difft pressures & 1 temperature or given 2 difft temperatures & 1 pressure
specific units req'd?	any - but must be the same on both sides of equation	any unit for volume (same on both sides), Kelvin temperature	any unit for pressure (same on both sides), Kelvin temperature

Law	Dalton's Law	Dalton's Law	Graham's Law
equation	$P_{total} = P_{gas1} + P_{gas2} + ...$	$P_x = \frac{\text{(moles x)}}{\text{(total moles)}} \cdot P_{total}$	$\frac{\text{rate A}}{\text{rate B}} = \sqrt{\frac{\text{MM B}}{\text{MM A}}}$
explanation	the sum of the pressures of the individual gases in a mixture equals the total pressure exerted by the mixture	amount of a gas in mixture is proportionate to the amount of its partial pressure	rate of gas A compared to the rate of gas B is equal to the square root of the inverse of their molar masses
when to use it	mixture of gases; only pressures given	mixture of gases; moles & total pressure given	when any form of the word "effusion" or "diffusion" is in the problem
specific units req'd?	any- all must have same unit	any- all must have same unit	no

EXTRA UNIT 10 REVIEW WORKSHEET

1.) Convert the following pressure measurements to atmospheres.

(A) 151.98 kPa (B) 456 mm Hg (C) 912 torr

2.) What are the conditions for gas measurement at STP?

3.) The volume of a sample of methane gas measures 350. mL at 27.0 °C and 810. mm Hg. What is the volume (in liters) at -3.0 ^oC and 650. mm Hg pressure?

4.) How many grams of nitrogen gas are contained in a 32.6 liter container at 34.4 ^oC and 579 torr?

5.) A mixture of four gases in a container exerts a total pressure of 955 mm Hg. In this container, there are 4.50 moles of N_2, 4.25 moles of CO_2, 2.75 moles of H_2, and 2.00 moles of O_2. What is the partial pressure of H_2?

6.) Compare the rates of effusion of carbon dioxide gas and carbon monoxide gas.

7.) An unknown gas effuses 1.37 times faster than Cl_2 gas. What is the molar mass of the unknown gas?

8.) Given the following unbalanced reaction: ___ C_5H_{12} + ___ O_2 $\rightarrow$ ___ CO_2 + ___ H_2O
How many liters of oxygen are needed to produce 45.7 liters of CO_2?

9.) Given the unbalanced equation: ___ Mg + ___ O_2 $\rightarrow$ ___ MgO
How many liters of oxygen gas are required to produce 45.8 grams of magnesium oxide?

10.) An aerosol can contains gases under a pressure of 4.50 atm at 20.0 ^oC. If the can is left on a hot, sandy beach, the pressure of the gases increases to 4.80 atm. What is the temperature on the beach (in ^oC)?

Ideal Gas Eqn. 1 wksht.
1.) 5.1 atm; 2.) 2.4 x 10^{-4} moles; 3.) 580 K; 4.) 1.7 L; 5.) 0.92 atm; 6.) 0.668 moles

Ideal Gas Eqn. 2 wksht.
1.) 22.4 L; 2.) 0.94 moles; 3.) 1.9 atm; 4.) 0.668 moles; 5.) 0.631 atm;
6.) 78.9 g; 7.) 720. K; 8.) 897 mm Hg; 9.) 83 g; 10.) 632 kPa; 11.) 12 moles;
12.) 480 g

Gas Law Problems wksht.
1.) 3.6 atm; 2.) 3.59 L or 3.6 L; 3.) 17.8 atm; 4.) 130 K or 130. K; 5.) 2.59 L or 2.6 L;
6.) 13.1 K 7.) 9.2 L; 8.) 1.9 atm

Gas Stoichiometry wksht.
1.) 0.551 L; 2.) 26.8 g; 3.) 5.60 L; 4.) 1.0 L; 5.) 35 L; 6.) 44.8 L;
7.) 10. g; 8.) 16.8 L

Dalton's Law & Graham's Law wksht.
1.) N_2 = 142 mm Hg, O_2 = 213 mm Hg, H_2 = 496 mm Hg 2.) 310 mm Hg 3.) 94.5 mm Hg
4.) O_2 = 25.7%, He = 33.8 %, N_2 = 40.5 % 5.) CH_4 effuses 1.66 times faster than CO_2.
6.) He effuses 2.65 times faster than N_2. 7.) NH_3 effuses 1.46 times faster than HCl 8.) 2.0 g/mole

Unit 10 Review & Practice wksht.
1.) 1.207 atm 2.) 367 K 3.) 210. mL 4.) 14.7 L 5.) -101 ^oC 6.) 336 torr
7.) 928 K 8.) 75.3 L 9.) 30.8 g/mole 10.) 108 kPa 11.) 440 torr 12.) 74.5 kPa

Extra Unit 10 Review wksht.
1.) (A) 1.5003 atm (B) 0.600 atm (C) 1.20 atm 2.) 0 ^oC (or 273 K) & 1 atm 3.) 0.393 L
4.) 27.6 g 5.) H_2 = 195 mm Hg 6.) CO effuses 1.25 times faster than CO_2.
7.) 37.8 g/mole 8.) 73.1 L 9.) 12.8 L 10.) 40.0 ^oC

DETERMINING MOLAR MASS USING THE IDEAL GAS EQUATION LAB

DISCUSSION & OBJECTIVE

Gases are one of the major products and/or reactants in many chemical reactions. Of all the states of matter, gases are the most affected by changes in temperature and pressure. The method of collecting the gas also affects the pressure of the gas. The relationship between the density of a gas and the pressure and temperature at which it is collected can be used to determine the molecular weight of the gas.

This lab activity will use the Ideal Gas Equation to experimentally determine the molar mass of a common gas - butane. Since real gases do not behave ideally at room temperature, the results will be expected to vary from the calculated molar mass. The idea of a dry gas versus one collected over water will also be involved.

MATERIALS

- butane lighter, large container, large graduated cylinder, thermometer, balance

SAFETY PRECAUTIONS

- basic safety precautions apply; **Do not try to ignite the gas after collecting it!**

PROCEDURE

1. Immerse the lighter completely in water. Then use a paper towel to dry the lighter as best as possible. Then weigh the butane lighter to the nearest hundredth of a gram. Record this value in the data table.
2. Fill the container about two-thirds to three-fourths full with water.
3. Place the graduated cylinder in the container and fill it with water also. Invert the cylinder and keep the opening of the cylinder under the surface of the water to prevent any water from leaving the cylinder. (You should not have any air bubbles at the top of the graduated cylinder.)
4. Check the lighter to be certain it is open as much as possible to allow gas to escape rapidly.
5. Place the top of the lighter up into the opening of the cylinder and depress the striker to allow the gas to bubble up into the cylinder. (Butane is not very flammable under water!)
6. Allow the gas to escape until about 250 mL of gas are collected. Quickly read the volume of the gas because butane is more soluble in water than most hydrocarbons. Record this volume.
7. Dry the lighter **completely** and weigh it again. Record this value.
8. Read the temperature of the water to the nearest tenth of a degree. Record this temperature.
9. Your instructor will provide you with the barometric pressure reading.

DATA TABLE

Mass of the lighter before collecting gas	________________ g
Mass of the lighter after collecting gas	________________ g
Mass of gas collected	**________________ g**
Volume of gas collected	________________ mL
Volume measurement in Liters	**________________ L**
Temperature of the water (and gas)	________________ ^oC
Temperature measurement in Kelvins	**________________ K**
Barometric pressure	________________ inches Hg
Barometric pressure conversion (1 inch = 25.4 mm)	________________ mm Hg
Vapor pressure of water at certain temperature *	________________ mm Hg
Pressure of the "dry" gas	________________ mm Hg
Dry gas pressure measurement in atm	**________________ atm**

* See table of water vapor pressures on next page.

CALCULATIONS

The ideal gas equation is $P V = n R T$

where P = pressure, V = volume, n = moles, R = ideal gas constant, and T = temperature.

Make sure that your calculations are clearly shown in #3 below! (Please note that clearly implies not only legibility, but also a logical progression of calculations. Numbers written haphazardly all over your paper is not a logical progression.)

Experimental molar mass = _________________g/mole

The formula for butane is C_4H_{10}. Calculate the theoretical molar mass based on this formula.

Theoretical molar mass = _________________ g/mole

Calculate the % error: $\frac{|\text{theoretical value} - \text{experimental value}|}{\text{theoretical value}} \times 100$

LAB QUESTIONS

1.) Identify at least three (3) possible sources of experimental error. (The errors you include should stem from either an assumption that was made about the gas or lab conditions or something that you did or did not do during the lab. Remember, I know that you're intelligent young adults. "We read the insert name of measuring device here wrong." is not an acceptable source of experimental error. Think about your answers!)

2.) Read Step 6 in the PROCEDURE. What effect would leaving the gas in contact with the water for an excessive amount of time have on the experimental molar mass? (Would the experimental molar mass be higher or lower if you did this? Why? Think about your calculations.)

3.) Show **in detail** how you determined the experimental molar mass of butane, the theoretical molar mass of butane, and your percent error.

Temperature (^oC)	**Water Vapor Pressure (mm Hg)**
17.0	14.5
17.5	15.0
18.0	15.5
18.5	16.0
19.0	16.5
19.5	17.0
20.0	17.5
20.5	18.1
21.0	18.6
21.5	19.2
22.0	19.8
22.5	20.4
23.0	21.1
23.5	21.7
24.0	22.4