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")

EX. 1: 455 mm Hg = ? atm

EX. 2: 2.252 atm = ? torr

measured with a ________________

* TEMPERATURE: ____

units: degrees Celsius (^{o}C), Kelvins (K), or ^{o}F (^{o}F not usually used in class)
how to convert from ^{o}C to K?______________________________

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

* VOLUME: ____

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

*QUANTITY: ____

units: moles how to convert from grams to moles?

IDEAL GAS EQUATION – describes one gas at one set of conditions

$$P V = n R T$$

"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 - What pressure is exerted by 0.325 moles of hydrogen gas in a 4.08 L container at 35^{o}C?
n = 0.325 moles (correct unit)
T = 35 ^{o}C (need to convert to K) T = 35 ^{o}C + 273 = 308 K
V = 4.08 L (correct unit)
P · 4.08 ~~L~~ = 0.325 ~~moles~~ · 0.0821 ~~L~~atm/~~mole K~~ · 308 ~~K~~
P = 2.01 atm

EXAMPLE 2 - A gas at 20.0^{o}C and 3.98 atm contains 1.45 moles of gas particles. What volume does the gas occupy? (Answer: 8.77 L)

EXAMPLE 3 - What mass of Cl_2 gas, in grams, is contained in a 10.0 L tank at 27^{o}C and 3.50 atm of pressure? (Answer: 101 grams)

<u>Ideal Gas Equation 1 WKSHT</u>

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^{o}C. 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^{o}C?

<u>Ideal Gas Equation 2 WKSHT</u>

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^{o}C 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^{o}C.
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 kPa?
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?

APPLICATIONS OF THE IDEAL GAS EQUATION NOTES

Start with: PV = nRT End with: MM = ____________

EXAMPLE 1 - At 28°C and 0.974 atm, 1.00 L of gas has a mass of 5.16 grams. What is the molar mass of this gas?

EXAMPLE 2 - What is the molar mass of a gas if 0.427 grams of the gas occupies a volume of 125 mL at 20.0°C and 0.980 atm? (A: 83.8 g/mole)

Start with: PV = nRT End with: D = ______________

EXAMPLE 3 - What is the density of argon gas, Ar, at a pressure of 551 torr and a temperature of 25°C?

EXAMPLE 4 - The density of a gas was found to be 2.0 g/L at 1.50 atm and 27°C. What is the molar mass of the gas? (A: 33 g/mole)

Applications of Ideal Gas Equation WKSHT

1.) What pressure is exerted by 1.0 mole of an ideal gas contained in a 1.0 L vessel at 0.0°C?

*2.) What is the density of a sample of ammonia gas, NH_3, if the pressure is 0.928 atm and the temperature is 63.0°C?

*3.) Calculate the molar mass of a gas if 4.5 L of the gas at 785 torr and 23.5°C has a mass of 13.5 grams.

4.) 0.453 moles of a gas confined to a 15.0 L container exerts a pressure of 1.24 atm on the walls of the container. What is the temperature of the gas (in °C)?

5.) 5.4 grams of carbon dioxide are confined to a 20.0 L container at a temperature of 32.5°C. What pressure does the gas exert?

*6.) 2.125 grams of a gas in a 1.25 L container exert a pressure of 0.838 atm at 40.0°C. What is the molar mass of the gas?

7.) To what temperature must 10.0 grams of NH_3 have to be heated in a 15.0 L container in order for it to exert a pressure of 3.50 atm?

8.) 2.0 x 10^{-5} grams of hydrogen gas at 155°C exert a pressure of 322.5 torr on the walls of a small cylindrical tube. What is the volume of the tube?

GAS LAWS – describe one gas undergoing a change in conditions

The "Gas Laws" differ from the Ideal Gas Equation because pressure & volume can be in any unit.

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°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 INFORMATION! **

1.) Find moles of given element or compound.
  * Use molar mass of given substance, if problem gives you grams.
  * Use 22.4 L = 1 mole of gas at STP, if problem gives you liters.
  * Use 6.022×10^{23} atoms (or molecules) = 1 mole, if problem gives you atoms/molecules.

2.) Use mole ratio (coefficients) from balanced equation. (Same as before!)

3.) Find answer.
  * Use molar mass of unknown substance, if question asks for grams.
  * Use 22.4 L = 1 mole of gas at STP, if problem asks for liters.
  * Use 6.022×10^{23} atoms (or molecules) = 1 mole, if problem asks for atoms/molecules.

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.)

$\frac{4.50 \text{ g } Na_2CO_3 \mid 1 \text{ mole } Na_2CO_3}{\mid 106 \text{ g } Na_2CO_3} = 0.0425 \text{ moles } Na_2CO_3$

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

$\frac{0.0425 \text{ moles } CO_2 \mid 22.4 \text{ L } CO_2}{\mid 1 \text{ mole } CO_2} = 0.951 \text{ L } CO_2$

Example # 2

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)

Example # 3

How many liters of H_2 are needed to react completely with 15.0 L of N_2?

$N_2 + H_2 \rightarrow NH_3$

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 $KClO_3$.

   __ $KClO_3$ → __ KCl + __ O_2

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

   __ $CaCO_3$ → __ CaO + __ CO_2

3.) What volume of hydrogen gas is produced when 0.250 moles of zinc react with excess HCl?

   __ Zn + __ HCl → __ $ZnCl_2$ + __ 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 → __ NH_3

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

   __ C_3H_8 + __ O_2 → __ CO_2 + __ H_2O

6.) From the following reaction: __ CH_4 + __ O_2 → __ 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 → __ $NaOH$ + __ H_2

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

   __ C + __ O_2 → __ 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 partial pressure of a gas in a mixture is directly proportional to the percentage of the mixture that is that gas. In other words, the partial pressure of a gas (in a mixture) is proportional to the amount of that gas in the mixture.

$$P_x = \frac{(\text{moles } x)}{(\text{total moles})} \cdot P_{total}$$

"P_x" = partial pressure of certain gas

EXAMPLE: A mixture of gases contains 2.00 moles of He and 4.00 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)

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

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?

EXAMPLE 3: Oxygen gas effuses 1.49 times faster than an unknown, diatomic gas. What is the gas?

DALTON'S LAW & GRAHAM'S LAW WKSHT.

1.) Determine the partial pressure of oxygen 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.

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 helium 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 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°C and 650. mm Hg pressure?
4.) How many grams of nitrogen gas are contained in a 32.6 liter container at 34.4°C 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 chlorine gas. What is the molar mass of the unknown gas?
8.) Given the following unbalanced reaction:
___ C_5H_{12} + ___ O_2 → ___ 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 → ___ 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°C. 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 °C)?

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 different pressures & 1 volume or given 2 different volumes & 1 pressure	given 2 different volumes & 1 temperature or given 2 different temperatures & 1 volume	given 2 different pressures & 1 temperature or given 2 different 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	$P_{total} = P_{gas1} + P_{gas2} + \ldots$	$P_x = \frac{\text{(moles x)}}{\text{(total moles)}} \cdot P_{total}$	$\frac{\text{rate } A}{\text{rate } B} = \sqrt{\frac{MM\ B}{MM\ A}}$
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	"effusion" or "diffusion" is in the problem
specific units req'd?	any - but all values must have same unit	any - but all values must have same unit of pressure	no

Law	Molar Mass (from Ideal Gas Equation)	Density (from Ideal Gas Equation)
equation	$MM = \frac{g\,R\,T}{P\,V}$	$D = \frac{P\,MM}{R\,T}$
explanation	one gas at one set of conditions, asking about molar mass (no information about density given)	one gas at one set of conditions (involves density)
when to use it	when the problem gives: mass (grams), P, V, T	when density is mentioned (given or asked for in problem)
specific units req'd?	pressure = atm, volume = liters, temperature = Kelvins, molar mass = g/mole	pressure = atm, volume = liters, temperature = Kelvins, molar mass = g/mole, density = g/L

UNIT 10 SUMMARY & PRACTICE WORKSHEET

1. Convert the following temperatures.
   (A) 104°C to K (B) -3°C to K (C) 67 K to °C (D) 1671 K to °C
2. Convert the following pressures.
   (A) 635 torr to atm (B) 104.2 kPa to mm Hg (C) 1.45 atm to kPa
3. Nitrogen effuses 1.19 times faster than an unknown gas that is added to light bulbs. What is the molecular mass of this unknown gas?
4. (A) What is the molecular mass of a 0.2500 g sample of a gas at 99.8°C and 0.9131 atm in a 100.0 cm^3 container? (B) What is the gas in the container?
5. A small 2.00 L fire extinguisher has an internal pressure of 506.6 kPa at 25°C. What volume of methyl bromide, the fire extinguisher's main ingredient , is needed to fill an empty fire extinguisher at standard pressure if the temperature remains constant?
6. If 45.0 g of propane gas burns completely in the following reaction:
   $C_3H_{8(g)} + 5\ O_{2(g)} \rightarrow 3\ CO_{2(g)} + 4\ H_2O_{(g)}$
   then how many liters of carbon dioxide gas will be released if the system is at STP?
7. Air in a closed cylinder is heated from 25°C to 36°C. If the initial pressure is 3.80 atm, what is the final pressure?
8. At what temperature Celsius will 19.4 g of molecular oxygen, O_2, exert a pressure of 1820 mm Hg in a 5.12 L cylinder?
9. To what temperature must 32.0 ft^3 of a gas at 2.0°C be heated for it to occupy 1.00 x 10^2 ft^3 at the same pressure? (ft^3 is a unit of volume)
10. Determine the molar mass of a gas that has a density of 2.18 g/L at 66°C and 720 mm Hg.
11. A 3.10 mL bubble of methane gas forms at the bottom of a bog where the temperature is 12°C and the pressure is 8.5 atm. The bubble rises to the surface where the temperature is 35°C and the pressure is 1.18 atm. What is the new volume of the methane bubble?
12. A mixture of 2.00 moles of H_2, 2.00 moles of NH_3, 4.00 moles of CO_2 and 5.00 moles of N_2 exerts a total pressure of 800. torr. What is the partial pressure of the carbon dioxide gas?
13. For the reaction $2\ H_{2(g)} + O_{2(g)} \rightarrow 2\ H_2O_{(g)}$, how many liters of water can be made from 5.0 L of oxygen gas and an excess of hydrogen?

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

Applications of the Ideal Gas Eqn. wksht.
1.) 22 atm; 2.) 0.572 g/L; 3.) 71 g/mole; 4.) 227 °C; 5.) 0.15 atm; 6.) 52.1 g/mole;
7.) 1090 K; 8.) 8.3 x 10^{-4} L

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.) O_2 = 213 mm Hg 2.) 310 mm Hg 3.) 94.5 mm Hg 4.) He = 33.8 %
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 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

UNIT 10 SUMMARY & PRACTICE wksht.
1. (A) 377 K (B) 270 K (C) -206^oC (D) 1398^oC
2. (A) 0.836 atm (B) 781.8 mm Hg (C) 147,000 Pa 3. 39.7 g/mole
4. (A) 83.8 g/mole (B) Kr 5. 10.0 L 6. 68.5 L 7. 3.94 atm 8. -27^oC
9. 859 K 10. 64.1 g/mole 11. 24 mL 12. 246 torr 13. 10. L

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)	____________ ^{o}C
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!) Explain how your calculated molar mass would be affected by these errors.

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 (°C)	**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