Name ______________________________ Class______ Date__________

Activity 2-2
Pressure of Gases

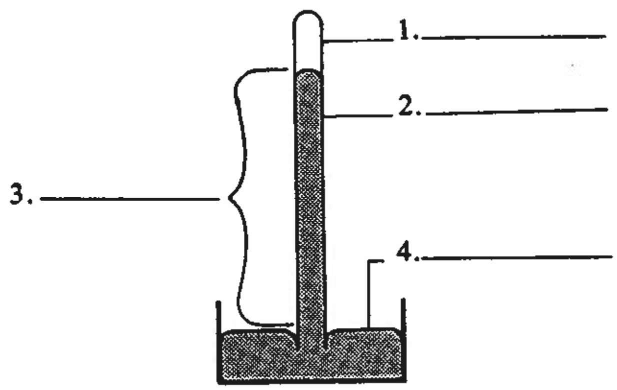
Measuring air pressure

Samples of matter in the gas phase have variable shape and volume because the particles of the gas can freely move throughout the container. As these particles move in rapid, random motion, they collide with the container walls to create pressure. Every sample of gas, including the atmosphere of the earth, exerts pressure.

The instrument used most often to measure air pressure is the mercury barometer. On each numbered line in the diagram of a mercury barometer, write the letter of the appropriate label from the list below.

Labels

A. reservoir dish of mercury
B. column of mercury
C. height of mercury column supported by atmospheric pressure
D. near total vacuum



5. The height of the mercury column that represents a pressure of 1 atmosphere, i.e., normal or standard pressure, is ________ centimeters, or ________ millimeters.

6. When atmospheric pressure increases, how does the height of the mercury column change?

____

7. If a mercury barometer were placed inside an evacuated container, how would the level of mercury in the tube compare to the level of mercury in the open dish? Explain your answer.

____

____

____

8. The SI unit of pressure is the pascal (Pa), defined as one newton per square meter. What is normal atmospheric pressure in pascals? ______________________

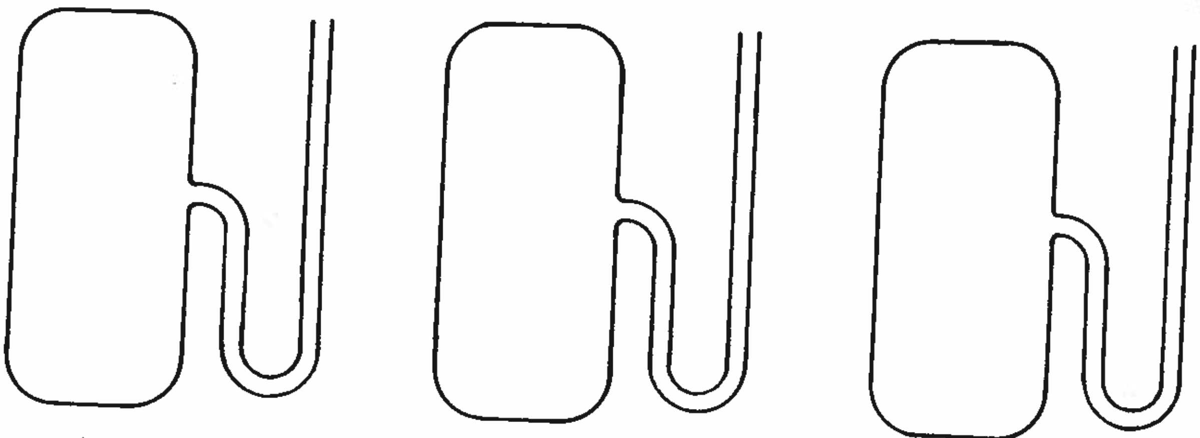
9. Find the section on Boyle's law in your textbook. Which unit of gas pressure is used most often?____________ What other units are used some of the time? ____________

____

Measuring pressure of confined gases

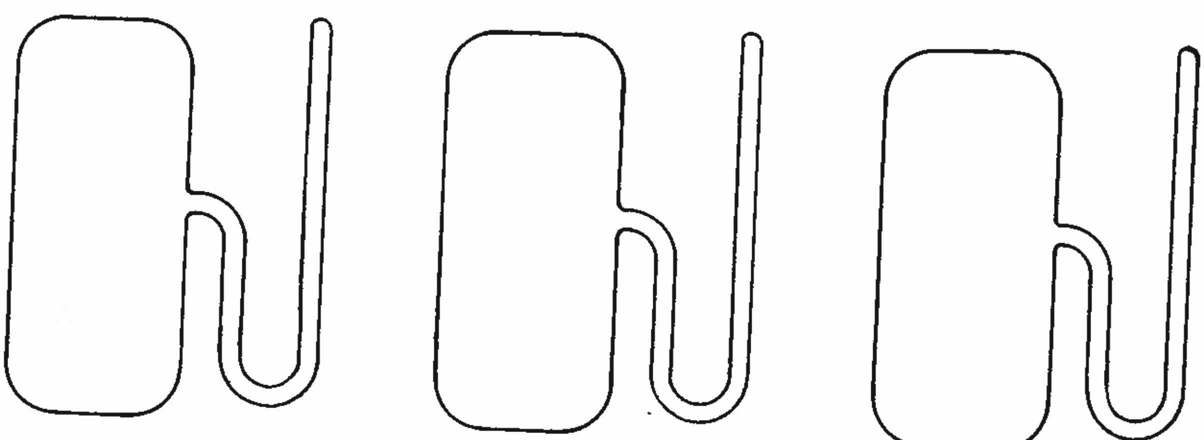
A manometer may be used to measure the pressure of a confined sample of gas. An open-end manometer is used to compare the pressure of a confined gas, P_{gas}, to the external pressure of the atmosphere, P_{atm}. Mercury (or other dense liquid) is placed in the manometer tube. The difference in the levels of the liquid permits comparison of the pressure of the confined gas to the external pressures.

10. Shade the tubes of the manometers in the diagram below to show mercury levels that indicate:
    A P_{gas} is less than P_{atm}
    B. P_{gas} is equal to P_{atm}
    C. P_{gas} is greater than P_{atm}



A B C

11. Closed-end manometers are used to read the actual pressure of a confined gas. Allowing 1 centimeter to represent 100 millimeters of mercury, shade the tubes of the manometers in the diagram below to show mercury levels that indicate:
    A. $P_{gas} = 250$ mm Hg
    B. $P_{gas} = 400$ mm Hg
    C. $P_{gas} = 340$ mm Hg

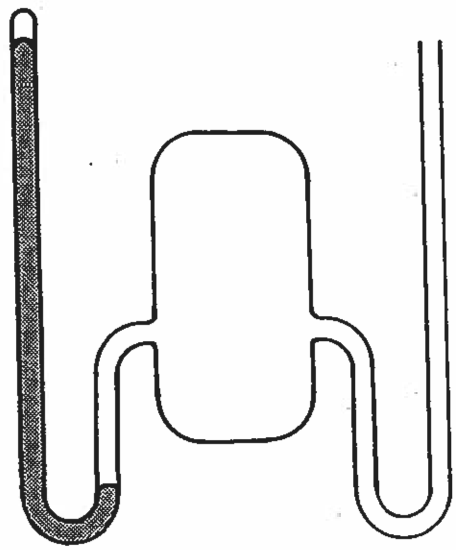


A B C

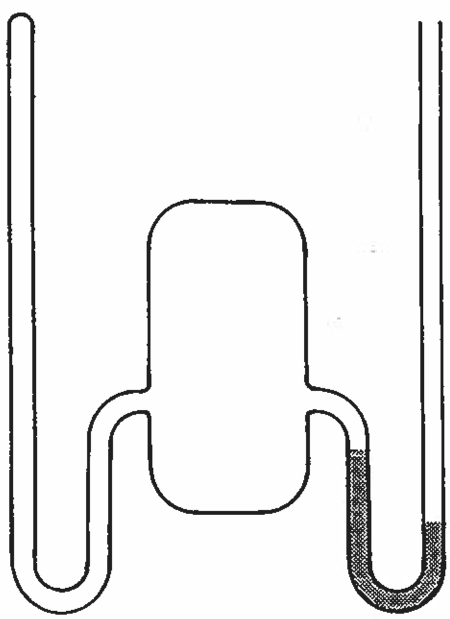
2

Name ______________________________ Class______ Date__________

12. The closed-end manometer in the diagram below shows a pressure of 600 mm for the confined gas. Shade the open-end manometer to show the same pressure when the external pressure equals 760 mm Hg. Use the scale 1 cm = 100 mm Hg.



13. If external pressure is 760 mm Hg, what is the pressure of the confined gas according to the open-end manometer?____________________
(Scale: 1 cm = 100 mm Hg.) Using the scale, shade the closed end manometer in the diagram below to show the same pressure.



Measuring Air Pressure—Kilopascals

Pressure is defined in physics as force per unit area. Gas pressures are usually expressed in millimeters of mercury, because this measurement can be made directly. However, pressure can also be expressed in *pascals* (Pa). The pascal, which is the standard SI unit of pressure, is defined as a pressure of 1 newton per square meter. The newton is a unit of force about equal to a weight of one-tenth of a kilogram. Thus, a pascal is a very small pressure. For practical purposes, the *kilopascal* (kPa)—1000 pascals—is the SI unit most often used to express pressure.

Standard atmospheric pressure (1 atm) is equivalent to 101.3 kPa or 760 mm Hg. Thus, the relationships $\frac{101.3\text{ kPa}}{1\text{ atm}}$ and $\frac{760\text{ mm Hg}}{1\text{ atm}}$ can be used to change from SI measurements to more convenient units and vice versa.

Practice problems

Solve each of the following problems. In the space below each problem, show a labeled setup. Do any necessary arithmetic on scrap paper. Write your answers in the spaces at the right.

14. What pressure in mm Hg is equal to 1 kPa? 14.____________

15. What pressure in kPa is equal to 725 mm Hg? 15.____________

16. What pressure in kPa is equal to 2.65 atm? 16.____________

Name ______________________ Class______ Date__________

Activity 2-4
Pressure/Volume Relationships in Gases

Boyle's law

Among the earliest systematic collections of facts about the physical world were the careful measurements by Robert Boyle (1627-1691) of the pressures and corresponding volumes of confined samples of gas. The mathematical relationship between these properties of pressure and volume is known as Boyle's law.

1. State Boyle's law in words as found in your textbook. ______________________
____
____

2. In this mathematical statement of Boyle's law,
$PV=K$
P represents ______________, V represents ______________, and K represents a ______________, which applies to a specific sample of gas maintained at constant ______________.

The following table gives pressure and volume readings for a confined sample of gas maintained at constant temperature. For each set of measurements, calculate K from the relationship $PV=K$. Your results should illustrate Boyle's law, within the limits of experimental uncertainty.

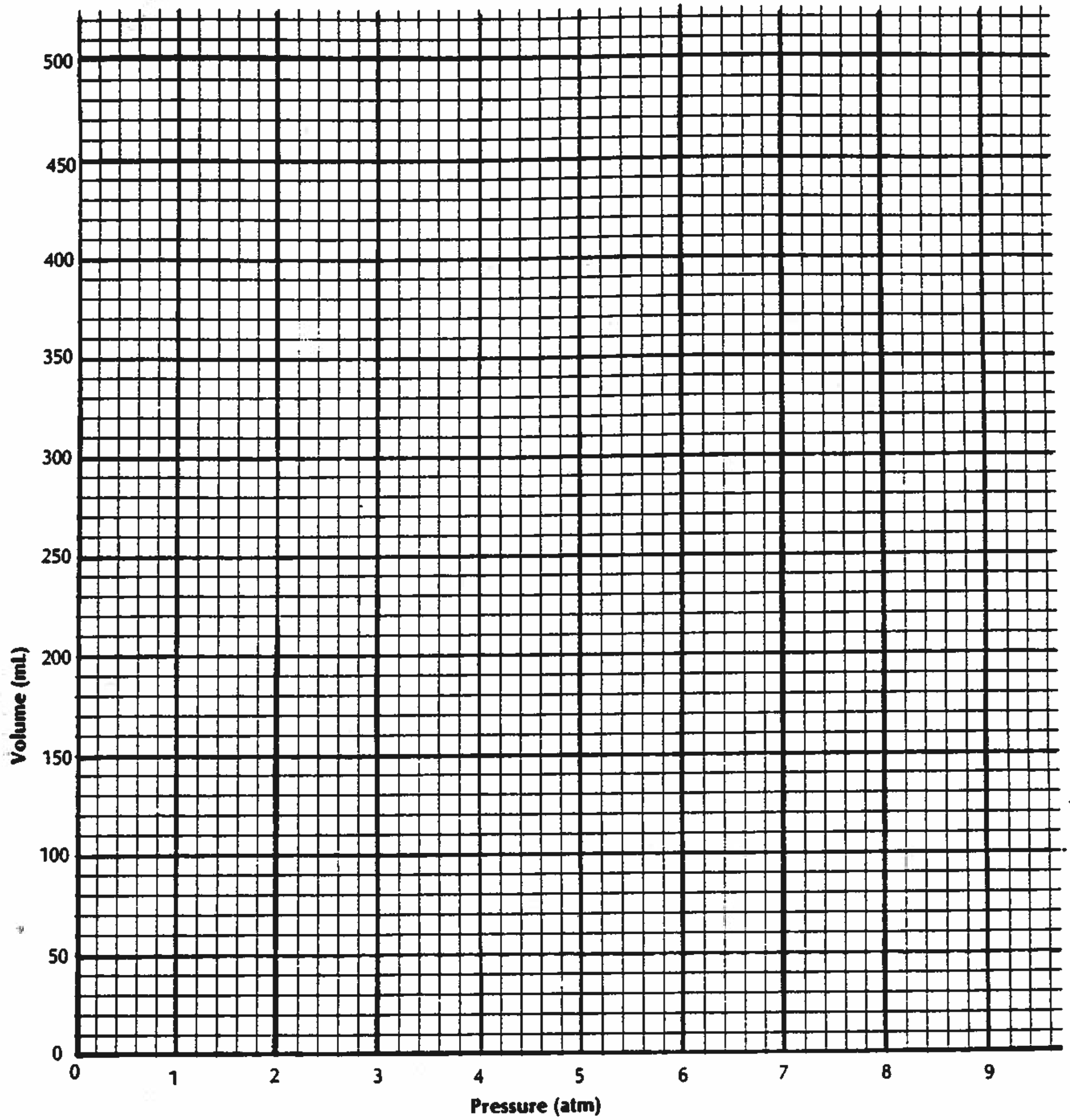
P (atm)	V (mL)	K (atm × mL)
0.20	500	
0.40	250	
0.60	167	
0.80	125	
1.00	100	
2.00	50.0	
3.00	33.3	
4.00	25.0	
5.00	20.0	
6.00	16.7	
7.00	14.3	
8.00	12.5	
9.00	11.1	

Questions 3-6 are based on the above information.

3. If the pressure of the sample were changed to 2.50 atmospheres, what volume would be expected? ______________ mL

4. If the pressure in the sample were changed to 0.50 atmosphere, what volume would be expected? ____________________ mL

5. On the following grid, plot the values in the table. Plot pressure on the *x*-axis and volume on the *y*-axis.



6. All pressure–volume readings for the same sample of gas at constant temperature should fit on the same line. Plot the points you predicted in questions 3 and 4 on the graph above. Circle these points in colored pencil. Do they fit the curve? ____________

BOYLE'S LAW

Name ______________

Boyle's Law states that the volume of a gas varies inversely with its pressure if temperature is held constant. (If one goes up, the other goes down.) We use the formula:

$$P_1 \times V_1 = P_2 \times V_2$$

Solve the following problems (assuming constant temperature).

1. A sample of oxygen gas occupies a volume of 250. mL at 740. torr pressure. What volume will it occupy at 800. torr pressure?

   ____

2. A sample of carbon dioxide occupies a volume of 3.50 liters at 125 kPa pressure. What pressure would the gas exert if the volume was decreased to 2.00 liters?

   ____

3. A 2.0 liter container of nitrogen had a pressure of 3.2 atm. What volume would be necessary to decrease the pressure to 1.0 atm?

   ____

4. Ammonia gas occupies a volume of 450. mL at a pressure of 720. mm Hg. What volume will it occupy at standard pressure?

   ____

5. A 175 mL sample of neon had its pressure changed from 75 kPa to 150 kPa. What is its new volume?

   ____

6. A sample of hydrogen at 1.5 atm had its pressure decreased to 0.50 atm producing a new volume of 750 mL. What was its original volume?

   ____

7. Chlorine gas occupies a volume of 1.2 liters at 720 torr pressure. What volume will it occupy at 1 atm pressure?

   ____

8. Fluorine gas exerts a pressure of 900. torr. When the pressure is changed to 1.50 atm, its volume is 250. mL. What was the original volume?

   ____

Boyles' Law

Use Boyles' Law to answer the following questions:

1) 1.00 L of a gas at standard temperature and pressure is compressed to 473 mL. What is the new pressure of the gas?

2) In a thermonuclear device, the pressure of 0.050 liters of gas within the bomb casing reaches 4.0×10^6 atm. When the bomb casing is destroyed by the explosion, the gas is released into the atmosphere where it reaches a pressure of 1.00 atm. What is the volume of the gas after the explosion?

3) Synthetic diamonds can be manufactured at pressures of 6.00×10^4 atm. If we took 2.00 liters of gas at 1.00 atm and compressed it to a pressure of 6.00×10^4 atm, what would the volume of that gas be?

4) The highest pressure ever produced in a laboratory setting was about 2.0×10^6 atm. If we have a 1.0×10^{-5} liter sample of a gas at that pressure, then release the pressure until it is equal to 0.275 atm, what would the new volume of that gas be?

5) Atmospheric pressure on the peak of Mt. Everest can be as low as 150 mm Hg, which is why climbers need to bring oxygen tanks for the last part of the climb. If the climbers carry 10.0 liter tanks with an internal gas pressure of 3.04×10^4 mm Hg, what will be the volume of the gas when it is released from the tanks?

6) Part of the reason that conventional explosives cause so much damage is that their detonation produces a strong shock wave that can knock things down. While using explosives to knock down a building, the shock wave can be so strong that 12 liters of gas will reach a pressure of 3.8×10^4 mm Hg. When the shock wave passes and the gas returns to a pressure of 760 mm Hg, what will the volume of that gas be?

7) Submarines need to be extremely strong to withstand the extremely high pressure of water pushing down on them. An experimental research submarine with a volume of 15,000 liters has an internal pressure of 1.2 atm. If the pressure of the ocean breaks the submarine forming a bubble with a pressure of 250 atm pushing on it, how big will that bubble be?

8) Divers get "the bends" if they come up too fast because gas in their blood expands, forming bubbles in their blood. If a diver has 0.05 L of gas in his blood under a pressure of 250 atm, then rises instantaneously to a depth where his blood has a pressure of 50.0 atm, what will the volume of gas in his blood be? Do you think this will harm the diver?

CHARLES' LAW

Name ____________

Charles' Law states that the volume of a gas varies directly with the Kelvin temperature, assuming that pressure is constant. We use the following formulas:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \quad \text{or} \quad V_1 \times T_2 = V_2 \times T_1$$

$$K = {}^\circ C + 273$$

Solve the following problems assuming a constant pressure.

1. A sample of nitrogen occupies a volume of 250 mL at 25° C. What volume will it occupy at 95° C?

   ____

2. Oxygen gas is at a temperature of 40° C when it occupies a volume of 2.3 liters. To what temperature should it be raised to occupy a volume of 6.5 liters?

   ____

3. Hydrogen gas was cooled from 1$\bar{5}$0° C to 5$\bar{0}$° C. Its new volume is 75 mL. What was its original volume?

   ____

4. Chlorine gas occupies a volume of 25 mL at 3$\bar{0}$0 K. What volume will it occupy at 600 K?

   ____

5. A sample of neon gas at 5$\bar{0}$° C and a volume of 2.5 liters is cooled to 25° C. What is the new volume?

   ____

6. Fluorine gas at 30$\bar{0}$ K occupies a volume of 50$\bar{0}$ mL. To what temperature should it be lowered to bring the volume to 30$\bar{0}$ mL?

   ____

7. Helium occupies a volume of 3.8 liters at -45° C. What volume will it occupy at 45° C?

   ____

8. A sample of argon gas is cooled and its volume went from 38$\bar{0}$ mL to 25$\bar{0}$ mL. If its final temperature was -55° C, what was its original temperature?

   ____

Charles' Law Worksheet

1) The temperature inside my refrigerator is about 4^0 Celsius. If I place a balloon in my fridge that initially has a temperature of 22^0 C and a volume of 0.5 liters, what will be the volume of the balloon when it is fully cooled by my refrigerator?

2) A man heats a balloon in the oven. If the balloon initially has a volume of 0.4 liters and a temperature of 20 ^{0}C, what will the volume of the balloon be after he heats it to a temperature of 250 ^{0}C?

3) On hot days, you may have noticed that potato chip bags seem to "inflate", even though they have not been opened. If I have a 250 mL bag at a temperature of 19 ^{0}C, and I leave it in my car which has a temperature of 60^0 C, what will the new volume of the bag be?

4) A soda bottle is flexible enough that the volume of the bottle can change even without opening it. If you have an empty soda bottle (volume of 2 L) at room temperature (25 ^{0}C), what will the new volume be if you put it in your freezer (-4 ^{0}C)?

5) Some students believe that teachers are full of hot air. If I inhale 2.2 liters of gas at a temperature of 18^0 C and it heats to a temperature of 38^0 C in my lungs, what is the new volume of the gas?

6) How hot will a 2.3 L balloon have to get to expand to a volume of 400 L? Assume that the initial temperature of the balloon is 25 ^{0}C.

7) I have made a thermometer which measures temperature by the compressing and expanding of gas in a piston. I have measured that at 100^0 C the volume of the piston is 20 L. What is the temperature outside if the piston has a volume of 15 L? What would be appropriate clothing for the weather?

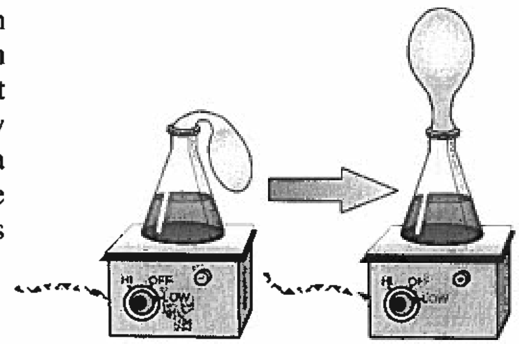
Chemistry: Form WS6.4.1A

PHASES OF MATTER

Name ______________________

Date ______________ Period ____

Using the Combined Gas Law

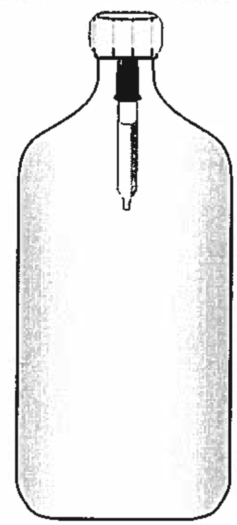


If a balloon is pulled over the neck of a flask, and the setup is placed on a hot plate, the balloon blows up as it heats up. This happens even though no additional air can get into the balloon. As the air heats up, it expands. The air can be squeezed back into a smaller space by increasing the pressure on it. This is what causes the diver in a Cartesian diver to sink when pressure is put on its container. The relationship between the temperature, pressure, and volume of a gas is known as the combined gas law.

THE LAW $$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Where:

- P_1 = initial pressure
- V_1 = initial volume
- T_1 = initial temperature (K)
- P_2 = final pressure
- V_2 = final volume
- T_2 = final temperature (K)



The equation has six variables. Generally, five variables must be provided in order to solve for the sixth. If either temperature, pressure, or volume is constant, they cancel out, making an equation of four variables.

Sample Problem

A gas with a volume of 250. mL at 35°C and 101.3 kPa is heated to 57°C and the pressure is increased to 151.3 kPa. What is its new volume?

- $T_1 = 35 + 273 = 308K;\ T_2 = 57 + 273 = 330K$
- $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$
- $V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{(101.3kPa)(250mL)(330K)}{(308K)(151.3kPa)} = 179mL$

(Continue ☞)

Fill in the blanks in the table below by using the combined gas law to find the unknown variable in each row.

	Initial			**Final**		
	volume	***pressure***	***temperature***	***volume***	***pressure***	***temperature***
1.	80.0 mL	96 kPa	27°C		99.0 kPa	0.0°C
2.	36 mL	SP*	ST*		96.6 kPa	35.0°C
3.	2.0 L	95.3 kPa	–45°C		SP*	ST*
4.	4.5 L	1.035 atm	375 K		1.100 atm	350. K
5.		0.980 atm	30.0°C	185 mL	0.900 atm	28.0°C
6.	16.5 mL	107.3 kPa	26.5°C	18.0 mL	104.4 kPa	
7.	14.8 mL	1.123 atm	75.5°C	16.5 mL		70.2°C
8.	5.322 L		100.0°C	4.895 L	104.2 kPa	98.5°C
9.	1.0 0L	SP	ST		SP	27.3 K
10.	2.50 L	SP	ST		111.4 kPa	87°C

*SP = Standard Pressure (101.3 kPa *or* 1.0 atm)
ST = Standard Temperature (0°C *or* 273 K)

Combined Gas Law Problems

Use the combined gas law to solve the following problems:

1) If I initially have a gas at a pressure of 12 atm, a volume of 23 liters, and a temperature of 200 K, and then I raise the pressure to 14 atm and increase the temperature to 300 K, what is the new volume of the gas?

2) A gas takes up a volume of 17 liters, has a pressure of 2.3 atm, and a temperature of 299 K. If I raise the temperature to 350 K and lower the pressure to 1.5 atm, what is the new volume of the gas?

3) A gas that has a volume of 28 liters, a temperature of 45 ^{0}C, and an unknown pressure has its volume increased to 34 liters and its temperature decreased to 35 ^{0}C. If I measure the pressure after the change to be 2.0 atm, what was the original pressure of the gas?

4) A gas has a temperature of 14 ^{0}C, and a volume of 4.5 liters. If the temperature is raised to 29 ^{0}C and the pressure is not changed, what is the new volume of the gas?

5) If I have 17 liters of gas at a temperature of 67 ^{0}C and a pressure of 88.89 atm, what will be the pressure of the gas if I raise the temperature to 94 ^{0}C and decrease the volume to 12 liters?

6) I have an unknown volume of gas at a pressure of 0.5 atm and a temperature of 325 K. If I raise the pressure to 1.2 atm, decrease the temperature to 320 K, and measure the final volume to be 48 liters, what was the initial volume of the gas?

7) If I have 21 liters of gas held at a pressure of 78 atm and a temperature of 900 K, what will be the volume of the gas if I decrease the pressure to 45 atm and decrease the temperature to 750 K?

8) If I have 2.9 L of gas at a pressure of 5 atm and a temperature of 50 ^{0}C, what will be the temperature of the gas if I decrease the volume of the gas to 2.4 L and decrease the pressure to 3 atm?

9) I have an unknown volume of gas held at a temperature of 115 K in a container with a pressure of 60 atm. If by increasing the temperature to 225 K and decreasing the pressure to 30 atm causes the volume of the gas to be 29 liters, how many liters of gas did I start with?

Name ______________________________

Date __________________ Period _____

Applying the Gas Laws

Calculate the answers to the problems below using the gas laws.

__________ **1.** What is the new volume of a gas if 50 mL at 81.0 kPa has its pressure increased to 101.3 kPa? (Temperature is constant.)

__________ **2.** 720 mL of H_2 gas at 0°C and 126.6 kPa is changed to S.T.P. What will be its new volume ?

__________ **3.** 440 mL of N_2 gas at 127°C is cooled to 27°C, while its pressure is kept constant. What is the new volume ?

__________ **4.** One thousand four hundred liters of N_2 gas at a pressure of 1.25 atmospheres has its pressure changed to 17.5 atmospheres. What will be its new volume at the new pressure? (Temperature is constant.)

__________ **5.** Hydrogen gas occupies a volume of 400 mL at 27°C. Find the volume it will occupy if the temperature is increased to 57°C? (Pressure is kept constant.)

__________ **6.** What is the pressure that must be exerted on 300 mL of a gas which has been collected at STP So that it may be confined to a volume of 190 mL? (Temperature is kept constant.)

__________ **7.** If 260 mL of O_2 gas is collected at 21°C and 101.3 kPa, what volume would this gas occupy at STP?

__________ **8.** 65 liters or a gas at 52°C is to be expanded to 72 liters. To what temperature must this gas be changed? (in degrees Celsius)

__________ **9.** A student collected 20 mL of a gas at 96 kPa. If the temperature remains constant, what volume will the gas occupy when the pressure is changed to 112 kPa?

__________ **10.** What is the volume do 482 liters of gas occupy if the temperature of the gas is changed from standard temperature to 27°C while the pressure is held at standard pressure?

BONUS

__________ **11.** A gas that was collected at 27°C and 52.0 kPa occupied 200 mL. What will its new volume be if its temperature is changed to 50°C and its pressure to 40.0 kPa? (Note: notice the changes that are taking place in this problem.)

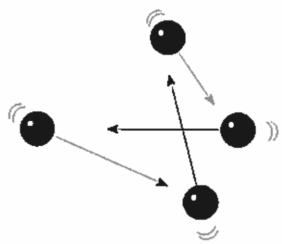
Chemistry: Form WS6.5.1A | Name ______________________

PHASES OF MATTER | Date ______________ Period ______

The Ideal Gas

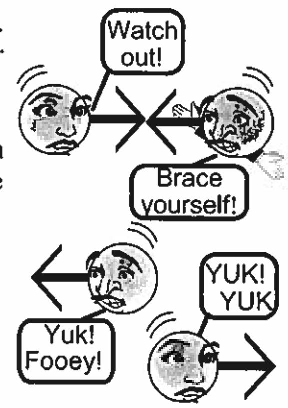
How do gases behave? In order to study gases, chemists have devised a model. The model is called an ideal gas (a gas which explains the behavior of all gases). This *Ideal Gas* model is based on the following assumptions, and can be applied only under conditions of **LOW PRESSURE AND HIGH TEMPERATURE**.

MOTION – gas molecules are continuously moving in a random, straight line motion.

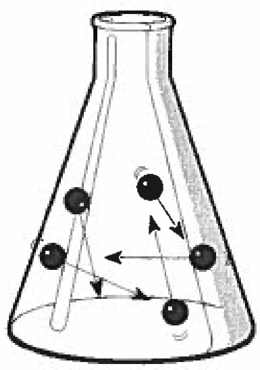


COLLISION – when gas molecules collide with each other or with the walls of the container there is no energy lost. Therefore, the total energy of the system never changes.

VOLUME – the actual volume of the molecules is insignificant when compared to the volume of the contained area (the container).



ATTRACTION – no attraction exists between molecules.



Deviations from the Ideal Gas Situation

☆ Gases deviate from the ideal conditions when conditions of **HIGH PRESSURE AND LOW TEMPERATURE** exist. These conditions lead to confinement and intermolecular attractions begin to act.

☆ VOLUME – gas molecules do have a volume of their own.

☆ ATTRACTION – there does exist a force of attraction between gas molecules. The above factors (deviations) allow for the existence of gases as either solids or liquids under certain conditions,

Answer the questions below based on your reading above and on your knowledge of chemistry.

1. Of the following: $H_2(g)$; $He(g)$; $CO_2(g)$; which would behave least like an ideal gas? Why? ______________________

____

2. Compared to other gases, why doesn't water vapor behave like an ideal gas? ______________________

____

3. Why do gases behave least like ideal gases at low temperature and high pressure? ______________________

____

4. The relationship between the Kelvin temperature and volume of a gas is linear until the temperature begins to approach 0 K. Why? ______________________

____

Chemistry: Form WS6.1.0A   Name ____________________

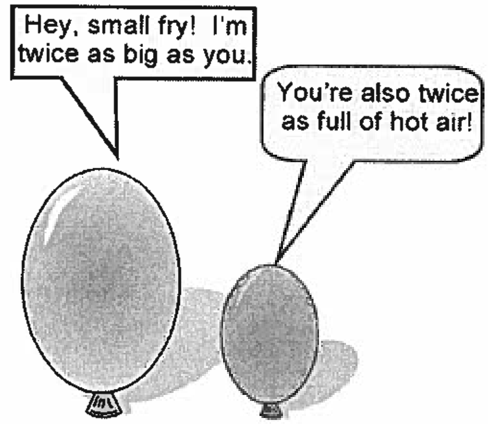
PHASES OF MATTER   Date ______________ Period _____

Applying Avogadro's Law

Avogadro's law says that under the same conditions of temperature and pressure, equal volumes of gases contain the same number of moles of particles. This makes sense. All other things being equal, a balloon that is twice as big as another contains twice as much air.

$$V = k\,n$$

V = volume; k = constant; n = number of moles



The insulting consequences of Avogadro's Law

This has useful consequences. The volume of 1 mole of gas at STP (Standard Temperature and Pressure) is always the same. It doesn't matter what the gas is. The volume of a mole is the same. At STP the molar volume of a gas is always 22.4 L. Using the standard molar volume, it is possible to solve several types of problems. See below.

Sample Problem 1: Moles to Volume
How many liters do 3.50 moles of oxygen occupy at STP?

$$3.50mol\left(\frac{22.4L}{1mol}\right) = 78.4L$$

Sample Problem 2: Volume to Moles
How many moles of nitrogen occupy 186 L at STP?

$$186L\left(\frac{1mol}{22.4L}\right) = 8.30mol$$

Sample Problem 3: Grams to Volume
What is the volume of 84.21 g of methane (CH_4) at STP?

$$84.21g\left(\frac{1mol}{16.04g}\right)\left(\frac{22.4L}{1mol}\right) = 118L$$

Sample Problem 4: Volume to Grams
What is the mass of 25.0 mL of dinitrogen trioxide (N_2O_3) at STP?

$$25.0mL\left(\frac{1L}{1000mL}\right)\left(\frac{1mol}{22.4L}\right)\left(\frac{76.02g}{1mol}\right) = 8.48 \times 10^{-2}\,g$$

Answer the following questions using the procedures illustrated above.

1. What is the volume of 7.15 *mol* of propane at STP?
2. What is the mass of 3.00 L of hydrogen gas at STP?
3. How many moles of sulfur dioxide occupy 56.0 mL at STP?
4. What is the volume of $6.60 \times 10^{-2}\,g$ of carbon dioxide at STP?
5. What is the mass of 112 mL of argon at STP?
6. What is the volume of 7.10 kg of chlorine at STP?
7. What is the volume of 0.0150 mol of hydrogen chloride at STP?
8. How many moles of neon occupy 3.36 L at STP?

Chemistry: Form WS6.5.3A

PHASES OF MATTER

Name ______________________

Date ______________ Period _____

Gas Stoichiometry

The gas laws make it clear that there is a relationship between the volume, the number of moles, and the mass of a gas. You learned how to determine the mass of any reactant or product in a chemical reaction from that of any other using the balanced equation. The relationship between the masses of the reagents involved in a reaction is:

$$m_1 \rightarrow mol_1 \rightarrow mol_2 \rightarrow m_2$$

When any of the reagents is a gas, a relationship exists between the volume and the number of moles as well, as defined by the ideal gas law:

A popular prank among the gas molecules in engineering fraternities was seeing how many of them could squeeze into a telephone booth. Unfortunately the gas laws took most of the fun out of it by ruining the surprise.

Sample Problem 1

How many grams of rust (Fe_2O_3) form when iron reacts with 25.0 L of oxygen at 25°C and 200. kPa?

Step 1: Write a balanced equation

$4Fe + 3O_2 \rightarrow 2Fe_2O_3$

Step 2: Substitute values into the gas equation to get the number of moles of gas

$$n = \frac{PV}{RT} = \frac{(200.\,kPa)(1atm)(25.0\,L)}{(101.3kPa)(0.0821\,\frac{L\cdot atm}{mol\cdot K})(298\,K)} = 2.02mol$$

Step 3: Solve the remaining problem by the factor label method.

$$2.02mol_{O_2}\left(\frac{2mol_{Fe_2O_3}}{3mol_{O_2}}\right)\left(\frac{159.7g_{Fe_2O_3}}{1mol_{Fe_2O_3}}\right) = 215g_{Fe_2O_3}$$

Problems of gas stoichiometry can generally be solved by the approach above, but under some circumstances the work can be simplified. At constant temperature and pressure, volume-volume problems can be handled simply by using Avogadro's law ($V \propto n$) because all the other variables in the gas laws cancel out. Since the number of moles and the volumes are proportional, and the coefficients of the balanced equation are mole ratios, these problems can be solved by setting up a proportion.

Sample Problem 2

How many milliliters of ammonia are formed when 150.mL of hydrogen combines with nitrogen at constant temperature and pressure?

Step 1: Write a balanced equation

$N_2 + 3H_2 \rightarrow 2NH_3$

Step 2: Set up a proportion and solve

$$\frac{3mol_{H_2}}{150.ml_{H_2}} = \frac{2mol_{NH_3}}{x} \qquad x = 100ml_{NH_3}$$

Problems at STP can be simplified even when mass-volume problems are done because at STP the molar volume (GMV) of a gas is always 22.4 L. Since $22.4\,L = 1\,mol$ at STP, the GMV can be used in a factor label problem in much the same way as the molar mass (GFM).

Sample Problem 3

How many liters of oxygen are liberated when 18.4 g of potassium chlorate decompose at STP?

Step 1: Write a balanced equation.

$2KClO_3 \rightarrow 2KCl + 3O_2$

Step 2: Solve by the factor label method

$$18.4g_{KClO_3}\left(\frac{1mol_{KClO_3}}{122.6g_{KClO_3}}\right)\left(\frac{3mol_{O_2}}{2mol_{KClO_3}}\right)\left(\frac{22.4L_{O_2}}{1mol_{O_2}}\right) = 5.04\,L$$

NEXT PAGE ☞

Answer the questions below using the procedures described on the previous page. [*NOTE*: The equations provided may not be balanced.]

1. If 35.0 L of propane burns, how many liters of carbon dioxide will form at the same temperature and pressure? [$C_3H_8(g) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$]

2. If 250. mL of oxygen at STP are consumed when magnesium burns, how many grams of magnesium oxide form? [$Mg(s) + O_2(g) \rightarrow MgO(s)$]

3. Hydrogen peroxide decomposes to release oxygen. How much space does the oxygen occupy if 40.8 g of hydrogen peroxide decomposes at $-13\,°C$ and 2.40 atm? [$H_2O_2(aq) \rightarrow H_2O(\ell) + O_2(g)$]

4. Most of the carbon dioxide in the blood is carried as carbonic acid [H_2CO_3]. It decomposes in the alveoli to release carbon dioxide. How many grams of carbonic acid would have to decompose to release 15.0 mL of carbon dioxide into the lungs at 37 °C and 1 atm? [$H_2CO_3(aq) \rightarrow H_2O(\ell) + CO_2(g)$]

5. The Hindenburg, a German airship kept afloat by 1.98×10^5 kL of hydrogen at STP, exploded as it landed at the Lakehurst Naval Air Station in New Jersey on May 6, 1937. Assuming all the hydrogen was consumed in the explosion, how many kilograms of water formed? [$H_2(g) + O_2(g) \rightarrow H_2O(g)$]

Gas Stoichiometry Practice Sheet

1) For the reaction 2 $H_{2(g)}$ + $O_{2(g)}$ → 2 $H_2O_{(g)}$, how many liters of water can be made from 5 L of oxygen gas and an excess of hydrogen?

2) How many liters of water can be made from 55 grams of oxygen gas and an excess of hydrogen at STP?

3) How many liters of water can be made from 55 grams of oxygen gas and an excess of hydrogen at a pressure of 12.4 atm and a temperature of 85^0 C?

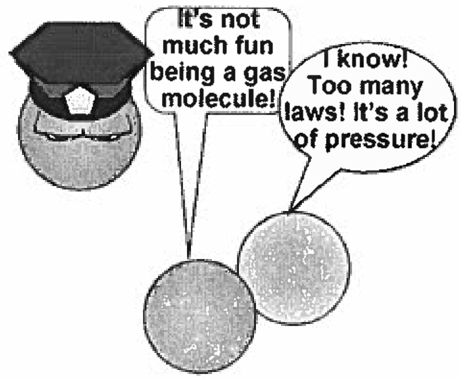
4) How many liters of water can be made from 34 grams of oxygen gas and 6.0 grams of hydrogen gas at STP? What is the limiting reactant for this reaction?

Chemistry: Form WS6.5.2A Name ____________

PHASES OF MATTER Date ____________ Period ______

The Ideal Gas Law, Molar Mass, and Density

There are several relationships between the temperature, pressure, the number of moles and the volume of gases. Boyle's law says at constant temperature, the volume and pressure of a sample of gas are inversely proportional [$V \propto 1/P$]. Charles law says at constant pressure, the volume and temperature of a sample of gas are directly proportional [$V \propto T$]. Gay-Lussac's law says at constant volume, the temperature and pressure of a sample of gas are directly proportional [$T \propto P$]. Finally Avogadro's law says at constant temperature and pressure, the volume of a gas is directly proportional to the number of moles [$V \propto n$]. That's a lot of laws. Fortunately, they can be expressed together as one relationship known as the ideal gas law:



The effect of pressure on gases.

$$PV \propto nT \quad or \quad PV = nRT$$

R is the universal gas constant. It can be derived as follows:

If $PV = nRT$

- $R = \dfrac{PV}{nT}$
- $at\ STP,\ when\ n = 1,\ V = 22.4L,\ T = 273K,\ P = 1atm$
- $R = \dfrac{(1atm)(22.4L)}{(1mol)(273K)} = 0.0821\,\frac{L\cdot atm}{mol\cdot K}$

Using the gas constant and the ideal gas law, it is possible to determine the value of any of the four variables knowing the other three. Mass can even be used as one of the variables since it has a relationship with moles.

Sample Problem

What is the volume of 6.06 g of hydrogen at 27°C and 1.50 atm?

$$PV = nRT \quad \therefore \quad V = \frac{nRT}{P}$$

$$6.06g\left(\frac{1mol}{2.02g}\right) = 3.00mol$$

$$V = \frac{(3.00mol)(0.0821\,\frac{L\cdot atm}{mol\cdot K})(300.K)}{1.50atm} = 49.3L$$

The molar mass and density of a gas can be determined from the ideal gas law.

$PV = nRT;\ If\ m = mass\ and\ M = molar\ mass,\ n = \dfrac{m}{M}$

- $PV = \dfrac{mRT}{M}$
- $M = \dfrac{mRT}{PV}\ but\ D = \dfrac{m}{V}\ so\ M = \dfrac{DRT}{P}$
- $D = \dfrac{MP}{RT}$

Sample Problem 1

What is the molar mass of a gas that has a density of 2.16 g/L at 15°C and 3.00 atm?

$$M = \frac{(2.16\,g/L)(0.0821\,\frac{L\cdot atm}{mol\cdot K})(288K)}{3.00atm} = 17.0\,g/mol$$

Sample Problem 2

What is the density of methane (CH_4) at 100.°C and 2.00 atm?

$$D = \frac{(16.0\,g/mol)(2.00atm)}{(0.0821\,\frac{L\cdot atm}{mol\cdot K})(373K)} = 1.04\,g/L$$

CONTINUE ON NEXT PAGE ☞

Answer the questions below using the procedures illustrated on the previous page.

1. What is the volume of 20.0 mol of gas at 20.0°C and 200. kPa? [*NOTE:* 1 atm = 101.3 kPa]

2. How many grams of oxygen occupy150. mL at 25.0°C and 0.250 atm?

3. What is the density of nitrogen at –25.0°C and 4.25 atm?

4. What is the molar mass of a gas with a density of 4.03 g/L at –73°C and 1,140 torr? [*NOTE:* 1 atm = 760. torr]

5. At what pressure will 99.0 g of steam (H_2O) occupy 61.6 L at 125°C?

IDEAL GAS LAW

Name ____________________

Use the Ideal Gas Law below to solve the following problems.

PV = nRT where	P = pressure in atmospheres
	V = volume in liters
	n = number of moles of gas
	R = Universal Gas Constant 0.0821 L•atm/mol•K
	T = Kelvin temperature

1. How many moles of oxygen will occupy a volume of 2.5 liters at 1.2 atm and 25° C?

   ____

2. What volume will 2.0 moles of nitrogen occupy at 720 torr and $2\bar{0}$° C?

   ____

3. What pressure will be exerted by 25 g of CO_2 at a temperature of 25° C and a volume of $50\bar{0}$ mL? ____________

4. At what temperature will 5.00 g of Cl_2 exert a pressure of 900. torr at a volume of $75\bar{0}$ mL? ____________

5. What is the density of NH_3 at $80\bar{0}$ torr and 25° C? ____________

6. If the density of a gas is 1.2 g/L at 745. torr and $2\bar{0}$° C, what is its molecular mass?

   ____

7. How many moles of nitrogen gas will occupy a volume of 347 mL at 6680 torr and 27° C? ____________

8. What volume will 454 grams (1 lb) of hydrogen occupy at 1.05 atm and 25° C?

   ____

9. Find the number of grams of CO_2 that exert a pressure of 785 torrs at a volume of 32.5 L and a temperature of 32° C. ____________

10. An elemental gas has a mass of 10.3 g. If the volume is 58.4 L and the pressure is 758 torrs at a temperature of 2.5° C, what is the gas? ____________

Ideal Gas Law Problems

Use the ideal gas law to solve the following problems:

1) If I have 4 moles of a gas at a pressure of 5.6 atm and a volume of 12 liters, what is the temperature?

2) If I have an unknown quantity of gas at a pressure of 1.2 atm, a volume of 31 liters, and a temperature of 87 ^{0}C, how many moles of gas do I have?

3) If I contain 3 moles of gas in a container with a volume of 60 liters and at a temperature of 400 K, what is the pressure inside the container?

4) If I have 7.7 moles of gas at a pressure of 0.09 atm and at a temperature of 56 ^{0}C, what is the volume of the container that the gas is in?

5) If I have 17 moles of gas at a temperature of 67 ^{0}C, and a volume of 88.89 liters, what is the pressure of the gas?

6) If I have an unknown quantity of gas at a pressure of 0.5 atm, a volume of 25 liters, and a temperature of 300 K, how many moles of gas do I have?

7) If I have 21 moles of gas held at a pressure of 78 atm and a temperature of 900 K, what is the volume of the gas?

8) If I have 1.9 moles of gas held at a pressure of 5 atm and in a container with a volume of 50 liters, what is the temperature of the gas?

9) If I have 2.4 moles of gas held at a temperature of 97 ^{0}C and in a container with a volume of 45 liters, what is the pressure of the gas?

10) If I have an unknown quantity of gas held at a temperature of 1195 K in a container with a volume of 25 liters and a pressure of 560 atm, how many moles of gas do I have?

11) If I have 0.275 moles of gas at a temperature of 75 K and a pressure of 1.75 atmospheres, what is the volume of the gas?

12) If I have 72 liters of gas held at a pressure of 3.4 atm and a temperature of 225 K, how many moles of gas do I have?

DALTON'S LAW OF PARTIAL PRESSURES

Name ____________________

Dalton's Law says that the sum of the individual pressures of all the gases that make up a mixture is equal to the total pressure or : $P_T = P_1 + P_2 + P_3 + \ldots$ The partial pressure of each gas is equal to the mole fraction of each gas x total pressure.

$$P_T = P_1 + P_2 + P_3 + \ldots \quad \text{or} \quad \frac{\text{moles gas}_x}{\text{total moles}} \times P_T = P_x$$

Solve the following problems.

1. A 250. mL sample of oxygen is collected over water at 25° C and 760.0 torr pressure. What is the pressure of the dry gas alone? (Vapor pressure of water at 25° C = 23.8 torr)

   ____

2. A 32.0 mL sample of hydrogen is collected over water at $2\bar{0}$° C and 750.0 torr pressure. What is the volume of the dry gas at STP? (Vapor pressure of water at $2\bar{0}$° C = 17.5 torr)

   ____

3. A 54.0 mL sample of oxygen is collected over water at 23° C and 770.0 torr pressure. What is the volume of the dry gas at STP? (Vapor pressure of water at 23° C = 21.1 torr)

   ____

4. A mixture of 2.00 moles of H_2, 3.00 moles of NH_3, 4.00 moles of CO_2 and 5.00 moles of N_2 exerts a total pressure of $80\bar{0}$ torr. What is the partial pressure of each gas?

   ____

5. The partial pressure of F_2 in a mixture of gases where the total pressure is 1.00 atm is 300. torr. What is the mole fraction of F_2?

   ____

Dalton's Law Worksheet

1) A metal tank contains three gases: oxygen, helium, and nitrogen. If the partial pressures of the three gases in the tank are 35 atm of O_2, 5 atm of N_2, and 25 atm of He, what is the total pressure inside of the tank?

2) Blast furnaces give off many unpleasant and unhealthy gases. If the total air pressure is 0.99 atm, the partial pressure of carbon dioxide is 0.05 atm, and the partial pressure of hydrogen sulfide is 0.02 atm, what is the partial pressure of the remaining air?

3) If the air from problem 2 contains 22% oxygen, what is the partial pressure of oxygen near a blast furnace?

GRAHAM'S LAW OF EFFUSION

Name ____________________

Graham's Law says that a gas will effuse at a rate that is inversely proportional to the square root of its molecular mass, MM. Expressed mathematically:

$$\frac{rate_1}{rate_2} = \sqrt{\frac{MM_2}{MM_1}}$$

Solve the following problems.

1. Under the same conditions of temperature and pressure, how many times faster will hydrogen effuse compared to carbon dioxide?

   ____

2. If the carbon dioxide in Problem 1 takes 32 sec to effuse, how long will the hydrogen take?

   ____

3. What is the relative rate of diffusion of NH_3 compared to He? Does NH_3 effuse faster or slower than He?

   ____

4. If the He in Problem 3 takes 20 sec to effuse, how long will NH_3 take?

   ____

5. An unknown gas diffuses 0.25 times as fast as He. What is the molecular mass of the unknown gas?

   ____