GAS LAWS CONTINUED

Ideal Gas Law: allows for the calculation of the amount of a gas in regards to pressure, volume, temperature.

n= number of moles of gas = mass/molar mass

R= ideal gas constant, value depends upon units

$0.0821 \frac{\text{L atm}}{\text{mol K}}$ or $8.31 \frac{\text{L kPa}}{\text{mol K}}$ or $62.4 \frac{\text{L mmHg}}{\text{mol K}}$

PV=*n*RT

****Hint be sure to change any mass into moles!**

- For example: What volume would be occupied by 100. g of oxygen gas at a pressure of 1.5 atm and a temperature of 25°C?

  $100.\text{g} \times \frac{1 \text{ mol } O_2}{32.00 \text{ g } O_2} = 3.13 \text{ mol } O_2$

  $(1.5 \text{ atm})(V) = (3.13 \text{ mol } O_2)(0.0821 \frac{\text{L atm}}{\text{mol K}})(298 \text{ K})$

  $(1.5 \text{ atm})(V) = 76.6 \text{ L atm}$

  $V = 51 \text{ L of } O_2$

Practice: Complete the following.

1. A gas sample occupies 2.62 L at 285°C and 3.42 atm. How many moles are present in this sample?

2. How many grams of argon would it take to fill a 0.475 L light bulb at STP (calculate in mmHg)?

3. A balloon is filled with 0.2494 g of helium to a pressure of 1.26 atm. If the desired volume of the balloon is 1.250 L, what must the temperature be in °C?

Gas Density – Changing Conditions: when conditions change density changes. Mass remains constant, therefore, it is the volume that changes.

D=M/V

Hints:

1. one mole of any gas has a volume of 22.4L at STP.
2. Density = molar mass/molar volume If the actual volume is unknown then think of density as $\frac{\text{density in grams}}{1.0 \text{ Liters}}$ at STP.

- For example: What is the density of HCl gas at STP?
  1 mol of HCl at STP is 22.4L, its is also 36.46 g.
  density is expressed as mass/volume so:
  the density of HCl at STP is 36.46g/22.4 L = 1.62 g/L

- The density of hydrogen sulfide is 1.52g/L at STP. Determine its density at 99.8 kPa and 303 K.
  Think of this as having 1.52g/ 1.00 L, V_1 becomes 1.00 L. To determine the new volume at the new conditions use the combined gas law.
  $\frac{(101.3 \text{ kPa})(1.00 \text{ L})}{(273 \text{ K})} = \frac{(99.8 \text{ kPa})(V_2)}{(303 \text{ K})}$

  $V_2 = 1.13$ L ← place this in density set up.
  D = 1.52 g/1.13 L = 1.35 g/L at 99.8 kPa and 303 K

Practice: Complete the following.

1. Determine the density of CO_2 at STP.

2. Determine the density of C_2H_6 at STP.

3. Based on question 2, determine the density of C_2H_6 at 3 atm and 41°C.

4. The density of chlorine gas is 3.17 g/L at STP. What is the mass of 3 L of Cl_2 at 800 mmHg and 250 K?

Dalton's Law of Partial Pressures: at a constant volume and temperature, the total pressure exerted by a mixture of gases is equal to the sum of partial pressures of the component gases.

$$P_{total}=P_1+P_2+P_3.....$$

Water Displacement: water vapor pressure can be determined based on its temperature. (use supplied charts) This information can be used with Dalton's Law of Partial Pressures to determine the pressure of a gas collected over water.

$$P_{total}-P_{water\ vapor}=P_{gas}$$

Steps:

1. Determine the partial pressure of the water vapor.
2. Determine the partial pressure of the gas.
3. Determine the volume of the gas alone at STP. (Hint: use the pressure of the gas)

- For example: 85.0 ml of CO_2 is collected over water at 278 K. The total pressure is 821 mmHg. A) What is the partial pressure of the water? B) What is the partial pressure of the gas? C) What would the volume of dry gas be at STP?

  A) Refer to the attached Vapor Pressure charts for water. Determine water's vapor pressure at 278 K.
  The partial pressure for water is 6.54 mmHg.

  B) To determine the pressure for the gas use: $P_{total} - P_{watervapor} = P_{gas}$
  $821 - 6.54 = 814$mmHg (gas)

  C) $$\frac{(0.085\ L)(814\ mmHg)}{(278\ K)} = \frac{(760\ mmHg)(V_2)}{(273\ K)}$$

  $V_2 = 0.0894$ L of dry CO_2

Practice: Complete the following.

1. A 2.69 L sample of O_2 is collected over water at 38°C. The total pressure was 3.9 atm. What is the volume of the dry gas at STP?

2. A 308 cm^3 sample of gas was collected over water at 325 K. The total pressure was 149 kPa. What is the volume of the dry gas at STP?

3. The volume of a gas collected over water was 6.42 L at 307 K. The total pressure was 788 mmHg. What was the volume of the dry gas?

Mass-Volume at Non-Standard Conditions: using your knowledge of molar conversions and the above gas laws you can determine the mass or volume of a substance. (Remember all stoichiometry problems are at STP)
Steps:

1. write a balanced equation
2. A. <u>if given mass</u>: determine the volume, then apply gas law
   B. <u>if given volume</u>: apply gas law, then determine the mass based on volume.

- For example: What volume of Cl_2 at 740mmHg and 22°C reacts with 1.00g Fe to produce FeCl?
  $Cl_2 + 2\ Fe \rightarrow 2\ FeCl$
  $1.0\ g\ Fe \times \frac{1\ mol\ Fe}{55.85\ g\ Fe} \times \frac{1\ mol\ Cl_2}{2\ mol\ Fe} \times \frac{22.4\ L\ Cl_2}{1\ mol\ Cl_2} = 0.20\ L\ Cl_2$ at STP

  $$\frac{(760\ mmHg)(0.20\ L)}{273\ K} = \frac{(V_2)(740\ mmHg)}{295\ K}$$

  $$0.5568\ \frac{mmHg\ L}{K} = (V_2)\ 2.508\ \frac{mmHg}{K}$$

  $V_2 = 0.22\ L\ Cl_2$ at 740 mmHg and 22°C

Practice: Complete the following.

1. Hydrogen is produced when zinc and hydrochloric acid are reacted. How many grams of zinc would be required to produce 5.0 L of hydrogen at 30°C and 740mm?

2. How many liters of oxygen gas are formed when 2.4 L of water undergoes electrolysis at 298 K and 107.3 kPa?

3. White phosphorus reacts with chlorine gas at 740 mmHg and 25°C to make phosphorus trichloride according to the reaction:
   $P_4(s) + 6\ Cl_2(g) \rightarrow 4\ PCl_3(s)$
   What volume chlorine is required to produce 5.49 g PCl ?

WATER VAPOR PRESSURES

Temperature °C	Pressure kPa	Temperature °C	Pressure kPa
0	0.61	26	3.36
5	0.87	27	3.56
10	1.23	28	3.77
15	1.71	29	4.00
16	1.81	30	4.24
17	1.93	40	7.37
18	2.07	50	12.33
19	2.20	60	19.91
20	2.33	70	31.15
21	2.49	80	47.33
22	2.64	90	70.03
23	2.81	100	101.3
24	2.99	105	120.8
25	3.17	110	143.2

WATER-VAPOR PRESSURE

Temperature (°C)	Pressure (mm Hg)	Temperature (°C)	Pressure (mm Hg)	Temperature (°C)	Pressure (mm Hg)
0.0	4.6	19.5	17.0	27.0	26.7
5.0	6.5	20.0	17.5	28.0	28.3
10.0	9.2	20.5	18.1	29.0	30.0
12.5	10.9	21.0	18.6	30.0	31.8
15.0	12.8	21.5	19.2	35.0	42.2
15.5	13.2	22.0	19.8	40.0	55.3
16.0	13.6	22.5	20.4	50.0	92.5
16.5	14.1	23.0	21.1	60.0	149.4
17.0	14.5	23.5	21.7	70.0	233.7
17.5	15.0	24.0	22.4	80.0	355.1
18.0	15.5	24.5	23.1	90.0	525.8
18.5	16.0	25.0	23.8	95.0	633.9
19.0	16.5	26.0	25.2	100.0	760.0

Name: _____ Period: ___ Date: _____

Homework: Ideal Gas Law, Gas Density, Gases under changing conditions, Water Displacement

Complete the following problems. (complete on a separate sheet of paper)

1. What volume will be occupied by 34 grams of ammonia at 24°C and 710 mmHg?

2. What is the pressure in a 16.0 gram sample of methane (CH_4) that has a volume of 6.00 liters at 26°C?

3. Calculate the pressure of 34.0 grams of ammonia in a 50.0 liter container at 27°C.

4. A 5.6 liter flask contains 0.120 moles of a certain gas. What temperature must be maintained to ensure a pressure of 735 mmHg?

5. What volume is occupied by 3.40 moles of CO_2 under a pressure of 124 atm and 323 K?

6. What is the density of N_2H_4?

7. What is the density of SO_2?

8. The density of CO_2 is 1.98 g/L at STP. What is the mass of exactly one liter of the gas if the pressure increases by 40 mmHg?

9. The density of oxygen at STP is 1.43 g/L. Find the mass of exactly two liters of oxygen at a temperature of 39°C, the pressure remains unchanged.

10. The density of nitrogen is 1.25 g/L at STP. Find the mass of 1.5 liters of the gas at a temperature of 300. K and 900. mmHg.

11. When propane (C_3H_8) burns it combines with oxygen to form water and carbon dioxide. What volume of oxygen is needed to completely burn 2.50 L of propane at 312 K and 780 mmHg?

12. Hydrogen is produced when zinc and hydrochloric acid are reacted. How many grams of zinc would be required to produce 5.0 L of hydrogen at 30°C and 740 mmHg?

13. Hydrogen gas reacts with nitrogen gas to form ammonia. How many grams of ammonia will be formed by 14 L of nitrogen gas at 50°C and 2.00 atm?

14. A sample of 132 g of iron (II) sulfide reacts with hydrochloric acid to produce iron (II) chloride and hydrogen sulfide. What is the volume, in liters, of hydrogen sulfide gas produced at 303 K and 95.1 kPa?

15. When 35.2 grams of sodium chloride breaks down sodium and chlorine gas are formed. How much chlorine gas is formed if the reaction occurs at 351 K and 8.02 kPa?

16. A 50.0 ml volume of oxygen was collected over water at 25°C. The total pressure is 727.0 mmHg. What is the volume of oxygen at STP?

17. Nitrogen gas is collected over water at 38°C, the volume is 450 L. The total pressure is 732 mmHg. What is the volume of nitrogen at STP?

18. 25.0 cm^3 of hydrogen is collected over water at 17°C. The total pressure is 178 kPa. What is the volume of hydrogen at STP?

19. 35.00 ml of hydrogen sulfide gas was collected over water at 298 K. The total pressure was 121.0 kPa. What is the volume of hydrogen sulfide at STP?

20. 1.20 liters of carbon dioxide gas was collected over water at 51°C. The total pressure was 700 mmHg. What was the volume of carbon dioxide at STP?