AVOGADRO'S LAW

Avogadro postulated that equal volumes of gases at the same temperature and pressure would contain the same number of particles.

At a constant pressure and temperature the volume is directly proportional to the number of moles. This means when you double the number of moles of gas you will double the volume etc…

Avogadro's Law can be expressed as;

$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$

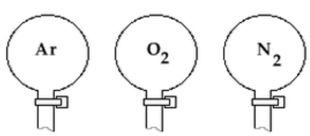
Problem:

Suppose we have 12.2 L of a sample containing 0.50 moles of oxygen at a pressure of 1 atm and a temperature of 25°C. If all this oxygen were converted to ozone at the same temperature and pressure, what would be the volume of the ozone?

Chemical equation:
The first step is always to write the complete, balanced chemical equation.

$3O_{2(g)}$	→	$2\ O_{3(g)}$
3 moles		2 moles
0.5 moles		______

V_1/n_1 = V_2/n_2
V_2 =



Volume:	22.4 L	22.4 L	22.4 L
Mass:	40 g	32 g	28 g
Quantity:	1 mol	1 mol	1 mol
Pressure:	1 atm	1 atm	1 atm
Temperature:	273 K	273 K	273 K

1 mole of ANY gas takes up a volume of ______________ at STP. This is called ____________ ___________________.

How many molecules of any gas are there in 22.4 L at STP? ______________

How many molecules of gas would be in 1.0 L at STP? ________________

At STP, 1.0 L of Helium gas contains the same number of atoms as:
A. 2.0 L of Kr B. 1.0 L of Ne C. 0.5 L of Rn D.1.5 L of Ar

Avogadro's Law and Stoichiometry!

Decomposition of Water

$2H_2O(l)$	**→ $2H_2(g)$**	**+**	**$O_2(g)$**
2 moles	**2 moles**		**1 mole**
	2 volumes		**1 volume**

The molar ratio of the GASES in the chemical equation gives you the ratio of the volumes of each gas. So when you decompose water and you are able to separate the gases, at the same temperature and pressure, you can determine the ratio of the volumes of each gas. For example in the above example, if you produce 2 liters of hydrogen you would only produce 1 liter of oxygen! If you produced 10 mL of oxygen you would only produce 20 mL of hydrogen.

Fill in the following blanks using the molar ratio from the equation:

$2H_2O(l)$ →	**$2H_2(g)$**	**+**	**$O_2(g)$**
	2mL		_______
	_______		**5.0 L**
	120 mL		_______

LAW OF COMBINING VOLUMES

When measured at the same temperature and pressure, volumes of gaseous reactants and products of chemical reactions are always in simple ratios of whole numbers.

Example:

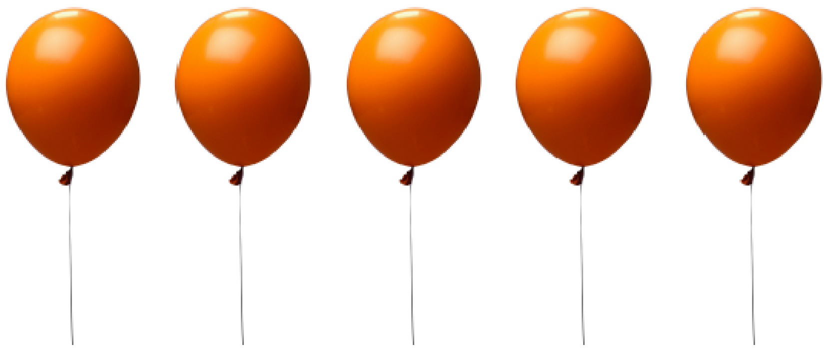
$N_2(g)$	**+**	**$3H_2(g)$**	**------→**	**$2NH_3(g)$**
1mole		**3 mole**		**2 moles**
1L		**3 L**		**2 L**
2L		**6 L**		**4 L**

Providing that the reactants and products are at the same temperature and pressure. How many liters of carbon dioxide are produced by the combustion of 4 liters of butane? How many liters of oxygen are required for the complete combustion of 4L?

$2\ C_4H_{10}(g)$	**+**	**$13\ O_2(g)$ →**	**$8CO_2(g)$**	**+**	**$10\ H_2O(g)$**
4 L		_______	_______		

AVOGADRO'S THEORY

Equal volumes of gases at the same temperature and pressure contain equal numbers of molecules.



Ar(g) **H_2(g)** **Cl_2(g)** **CH_4 (g)** **He(g)**

These balloons each hold 1.0 L of gas at 25°C and 1 atm. They each contain the same number of molecules. This means that one mole of any gas at the same temperature and pressure will occupy the same volume. It has been determined that the **Molar Volume at STP the volume of one mole is 22.4 L**

What is the molar volume at SATP?

Use the combined gas law to do this calculation. Check your answer with the one provided on the back of your periodic table. V_{STP} and V_{SATP} under measured quantities.

Initial	**T_1=273 K** **P_1=101.3 kPa** **V_1=22.4 L**	**Final**	**T_2=298 K** **P_2=100. kPa** **V_2=?**

Complete

1. **What volume of oxygen is required to completely burn 15.0 L of methane gas? Assume the same temperature and pressure.**

2. **What volume of carbon dioxide gas is produced by the combustion of 3.2 kL of octane (C_8H_{18}(g)) at the same temperature and pressure?**

3. **What volume does 12.4 g of CO_2 occupy at STP? *recall that 1.00 moles occupies 22.4 L at STP, this quantity V_{STP} is on the back of the periodic table**

GAS LAWS AND AVOGADRO'S THEORY

Expanding gases provide the power of explosives, as chemical energy is converted to mechanical energy.

1. Gunpowder is a mixture of saltpeter ($KNO_{3(s)}$), charcoal, and sulfur. When heated or struck a sharp blow, the saltpeter decomposes to produce oxygen which reacts rapidly with the charcoal and sulfur. The decomposition of saltpeter is shown by the following equation:
   $4KNO_{3(s)} \rightarrow 2K_2O_{(s)} + 2N_{2(g)} + 5O_{2(g)}$
   Assuming both gases are measured at the same temperature and pressure, what volume of oxygen is produced along with 15.0 L of nitrogen?

2. Alfred Nobel made a fortune from his discovery that adsorbing nitroglycerine on diatomaceous earth made it stable enough to transport and store. The explosive is called *dynamite* and its reaction can be represented by the following reaction:
   $4C_3H_5(NO_3)_{3(l)} \rightarrow 12CO_{2(g)} + 6N_{2(g)} + 10H_2O_{(g)} + O_{2(g)}$
   (a) Calculate the volume at SATP of each gaseous product formed by the decomposition of 1.00 mol of $C_3H_5(NO_3)_{3(l)}$.

   (b) While blasting rock with dynamite, 2.90 mol of gaseous product at 800°C was produced in a 1.00 L cavity. Calculate the gas pressure in the cavity.

3. The reaction of 2,4,6-trinitrotoluene (TNT) and oxygen is given by the equation:
   $4C_7H_5(NO_2)_{3(l)} + 21O_{2(g)} \rightarrow 28CO_{2(g)} + 6N_{2(g)} + 10H_2O_{(g)}$
   Assuming all gases are measured at SATP, what volume of each gaseous product is formed when 10.0 L of oxygen gas is consumed?

4. Ammonium nitrate is widely used as a fertilizer, but it can also be used as an explosive.
   $2NH_4NO_{3(s)} \rightarrow 2N_{2(g)} + 4H_2O_{(g)} + O_{2(g)}$
   Predict the numbers of molecules of water vapor and oxygen that are produced along with 6.02×10^{23} molecules of nitrogen.

5. The combustion of hydrazine rocket fuel, $N_2H_{4(l)}$, is represented by the following equation:
   $N_2H_{4(l)} + 3O_{2(g)} \rightarrow 2NO_{2(g)} + 2H_2O_{(g)}$
   Predict the volume of nitrogen dioxide produced at 850°C and 180.kPa, when 50.L of oxygen gas (measured at STP) is consumed.