Introduction

Chemical reactions provide two important pieces of information.

1. They tell us the type and number of atoms and molecules that interact and how they arrange.
2. They tell us the relative number of moles of atoms and molecules that interact and form.

Let us examine a chemical reaction to show how this is true.

$$H_2 + Cl_2 \rightarrow 2HCl$$

Reaction ----->	1 H_2	+	1 Cl_2	→	2 HCl
The reaction indicates that if we had 1 molecule of H_2, then	1 molecule of H_2	+	1 molecule of Cl_2	→	2 molecules of HCl
These are relative ratios therefore, if we had 10 molecules	10 molecules	+	10 molecules	→	20 molecules
If we had 1,000 molecules,	1,000 molecules	+	1,000 molecules	→	2,000 molecules
If we had a mole of Hydrogen then	1 mole	+	1 mole	→	2 mole

- *2 moles of HCl are produced for every 1 mole of H_2 consumed*
- *2 moles of HCl are produced for every 1 mole of Cl_2 consumed*
- *1 mole of H_2 is consumed for every 1 mole Cl_2 consumed*

** Think about it this way: If you had 2 suckers and 2 gummi bears and combined them to make a treat bag with one sucker and one gummi bear in each, then you could make 2 treat bags.*

As you learned previously, moles can be converted to masses, volumes or particles; therefore we can use a chemical reaction to calculate how much of a substance will form or react.

Stoichiometry is the name we give to the process of using a chemical reaction to predict the amount of products that might form or reactant that might be used up. Stoichiometry literally means to measure elements.

Mole to Mole Stoichiometry

Mole to mole problems are sort of like "introductory" or "skill-building" problems that will help you practice using the molar ratios given by balanced chemical reactions. These problems introduce a stoichiometric factor-**a mole ratio**-that is a central conversion factor in stoichiometric problems. The harder stoichiometry problems, which we will do next, all make use of the mole ratio.

Example 1: How many moles of oxygen (O_2) are required to react completely with 3 moles of glucose ($C_6H_{12}O_6$) according to the *balanced* chemical equation shown below?

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2$$

glucose + oxygen → water + carbon dioxide

The trick to solving this problem is to look at the coefficients in front of each of the substances in the reaction. For example, the fact that both water and carbon dioxide have a six in front of them means that the same number of moles of each will be generated as the products of this reaction. The ratio 6:6 can be reduced to 1:1 so if you produce 1 mole of water you will produce 1 mole of carbon dioxide. Set up as ratios:

Example 2: How many moles of oxygen (O_2) are required to react completely with 0.25 moles of glucose ($C_6H_{12}O_6$) according to the same balanced equation?
The ratios will look like:
glucose:oxygen
1:6
0.25:x

***If you are not given the balanced chemical equation, you must be able to come up with one**

Example 3: How many moles of O_2 are produced from the decomposition of 1.76 moles of potassium chlorate? Note: potassium chlorate breaks down into potassium chloride and oxygen gas.

Mass – Mass Problems

We can use a simple 3 step method to solve stoichiometric questions with balanced equations.

1. Identify the given and convert it to moles.
2. Identify the desired, and **multiply** the given number of moles by the mole ratio to produce moles of desired substance.
3. Convert moles of desired substance to the units asked for in the question.

Example:

Question; What mass of **methane gas in grams** must burn to produce *365 grams of water*, by the following chemical reactions ?

$$\_\_CH_4(g) \quad + \quad \_\_O_2(g) \quad \rightarrow \quad \_\_H_2O\ (g) \quad + \quad \_\_CO_2(g)$$

1. Balance equation
2. Set up ratio
3. Calculate moles from molar mass of given
4. Calculate moles desired
5. Convert moles to mass for desired

Gas Stoichiometry

The same mole method is used to solve questions involving gas volumes. Converting to and from moles requires us to multiply or divide by the molar volume (24.8 L/mol at SATP)

Example:

Ammonia gas is reacted with sulfuric acid to form the important fertilizer ammonium sulfate. What mass of ammonium sulfate can be produced from 85 L of ammonia reacting according to the below at SATP.

$$\_\_NH_3 \quad + \quad \_\_H_2SO_4 \quad \rightarrow \quad \_\_(NH_4)_2SO_4$$

1.6 Assignment

Answer the following questions:

1) In the cylinder of a car nitrogen reacts with oxygen according to the following unbalanced equation.

   ___N_2 (g) + ___O_2 (g) → ___NO (g)

   Calculate the **number of moles of NO (g)** that would form if *7.8 moles of N_2 (g) reacted*.

2) An orange precipitate of iron(III) hydroxide is formed when iron(III) chloride reacts with sodium hydroxide. The unbalanced equation below describes the reaction.

   __ NaOH(aq) + __ $FeCl_3$(aq) → __$Fe(OH)_3$ (s) + __ NaCl (aq)

   Calculate the number of moles of $Fe(OH)_3$ (s) that forms if 26.9 moles of NaOH (aq) reacts.

3) A black solid of Lithium nitride forms when Lithium is (exposed to the air) and combines with nitrogen. The unbalanced equation below describes this reaction.

   ___Li (s) + ___N_2(g) → ___Li_3N (s)

   Calculate how many moles of Lithium nitride will form if 1.69 mol of Lithium reacts.

4) Carbon in the form of charcoal in briquettes is unsafe to burn indoor due to the production of carbon monoxide. Write a balanced chemical reaction for the burning of carbon in oxygen to form carbon monoxide. Predict how many moles of carbon monoxide would be produced by the burning of a 420 moles of carbon (charcoal briquettes ,approximately 5 Kg).

5) Sulfur dioxide may be catalytically oxidized to sulfur trioxide. How many grams of sulfur dioxide could be converted by this process if 100.0 grams of oxygen are available for the oxidation by the following **unbalanced chemical reaction**?

$$\_\_\_\_SO_{2(g)} + \_\_\_\_O_{2\,(g)} \rightarrow \_\_\_\_\ SO_{3\,(g)}$$

6) Ferric oxide (Iron (III) oxide) may be reduced to pure iron with coke (pure carbon) . If we have 150 Kg of Iron (III) oxide how much coke would be needed to completely convert it to iron by the **following unbalanced equation.**

$$\_\_\_\_Fe_2O_3\ (s) + \_\_\_\_C\ (s) \rightarrow \_\_\_\_CO_2\ (g) + \_\_\_\_Fe\ (s)$$

7) Sodium tetraborate is produced by combining boric acid with sodium hydroxide, according to the following unbalanced chemical reaction. How many grams of NaOH would we need to produce 5.00 grams of sodium tetraborate?

$$\_\_\_ H_3BO_3 + \_\_\_ NaOH \rightarrow \_\_\_ H_2O + \_\_\_ Na_2B_4O_7$$

8) Gold will dissolve in the acid mixture known as aqua regia according to the following reaction.

$$\_\_\_ Au + \_\_\_ HNO_3 + \_\_\_ HCl \rightarrow \_\_\_ AuCl_3 + \_\_\_ NO + \_\_\_ H_2O$$

How much gold (III) chloride would be produced if 250 grams of HCl is consumed in the reaction?

9) How many grams of ammonia will be evolved when 34 grams of ammonium chloride is added to an excess of potassium hydroxide, by the following equation.

$$\_\_\_ NH_4Cl + \_\_\_ KOH \rightarrow \_\_\_ NH_3 + \_\_\_ H_2O + \_\_\_ KCl$$

10) Lightning discharges in the atmosphere catalyze the conversion of nitrogen gas to nitric oxide gas. How many grams of nitrogen gas would be required to make 55 kL of nitric oxide at SATP?

$$\_\_\_ N_2 (g) + \_\_\_ O_2 (g) \rightarrow \_\_\_ N_2O (g)$$

11) What mass of sulfur will be required to produce 150 L of sulfur dioxide when it is burned in oxygen gas, according to the following unbalanced reaction at STP.

$$\_\_\_\_S_8\,(s) + \_\_\_\_O_2\,(g) \rightarrow \_\_\_\_SO_3\,(g)$$

12) How much carbon monoxide in kL (at SATP) will be produced when 150 grams of calcium phosphate reacts with enough silicon dioxide and carbon, according to the following unbalanced reaction.

$$\_\_\_\_Ca_3(PO_4)_2 + \_\_\_\_SiO_2 + \_\_\_\_C \rightarrow \_\_\_\_CaSiO_3 + \_\_\_\_CO + \_\_\_\_P_4$$

13) Calcium phosphide when added to water produces phosphine gas (PH_3). How many kL at SATP of the gas will be produced when 350 grams of calcium phosphide is added to an excess amount of water.

$$\_\_\_Ca_3P_2 + \_\_\_H_2O \rightarrow \_\_\_PH_3 + \_\_\_CaO$$

14) What mass of O_2 is consumed in the complete synthesis of water if 6.86 g of H_2 participate in the reaction?