Chapter 9

Chemical Formula & Molar Mass

Chemical Stoichiometry:

When we speak of *chemical stoichiometry,* we are speaking of the determination of how much product can be produced from reactants for a given chemical equation.

When we are examining chemical stoichiometry, we will look at the molar ratios of the reactants and products in a given balanced equation.

Example:

$$CH_3CH_2OH + 3\ O_2 \longrightarrow 2\ CO_2 + 3\ H_2O$$

In-Class Problem:

Based on the chemical equation given below, calculate how many moles of CO_2 will be formed from the oxidation of 2.5 moles of ethanol (CH_3CH_2OH).

$$CH_3CH_2OH + 3\ O_2 \longrightarrow 2\ CO_2 + 3\ H_2O$$

In-Class Problem:

Calcium metal reacts with aqueous HCl according to the chemical equation shown below. How many oles of HCl are required to react completely with 3.25 moles of Ca?

$$Ca + 2\ HCl \longrightarrow CaCl_2 + H_2$$

In-Class Problem:

Ethane gas reacts with oxygen to produce carbon dioxide and water according to the equation shown below. Balance the equation and determine the number of moles of molecular oxygen required to produce 1.70 moles of carbon dioxide.

$$CH_3CH_3 + O_2 \longrightarrow CO_2 + H_2O$$

In-Class Problem:

A standard method for the production of small quantities of O_2 gas is the thermal decomposition of potassium chlorate. How many grams of $KClO_3$ are required to produce 2.25 moles of oxygen *atoms*?

$$2\ KClO_3 \longrightarrow 2\ KCl + 3\ O_2$$

In-Class Problem:

When zinc sulfide is heated in the presence of oxygen, zinc oxide and sulfur dioxide are formed, according to the chemical equation shown below. How many *grams* of zinc oxide will be formed when 25.0 *grams* of zinc sulfide is heated in the presence of "excess" oxygen.

$$2\ ZnS + 3\ O_2 \longrightarrow 2\ ZnO + 2\ SO_2$$

In-Class Problem:

Aluminum sulfide can be produced by heating a mixture of aluminum and sulfur, according to the chemical equation shown below. If 5.0 moles of sulfur are heated in the presence of 11.278 moles of aluminum, how many moles of Al_2S_3 will be formed?

$$2\ Al + 3\ S \longrightarrow Al_2S_3$$

Limiting Reagents:

In the previous two problems, one of the reactants was provided in molar excess to that required by the stoichiometry of the chemical reaction. The reactant that would react to produce the smaller molar amount of product is referred to as the *limiting reagent.* The reactant or reactants that are "left over" after all the limiting reagent has been consumed are referred to as *excess reagents.*

Limiting Reagents:

Example:

Aluminum sulfide can be produced by heating a mixture of aluminum and sulfur, according to the chemical equation shown below. If 5.0 moles of sulfur are heated in the presence of 11.278 moles of aluminum, how many moles of Al_2S_3 will be formed?

$$2\ Al + 3\ S \longrightarrow Al_2S_3$$

$$x = 5\text{ mole S}\left(\frac{1\text{ mole }Al_2S_3}{3\text{ moles S}}\right)$$

$$x = 1.7\text{ mole }Al_2S_3$$

Limiting Reagents:

Example:

Aluminum sulfide can be produced by heating a mixture of aluminum and sulfur, according to the chemical equation shown below. If 5.0 moles of sulfur are heated in the presence of 11.278 moles of aluminum, how many moles of Al_2S_3 will be formed?

$$2\ Al + 3\ S \longrightarrow Al_2S_3$$

$$x = 11.278\text{ mole Al}\left(\frac{1\text{ mole }Al_2S_3}{2\text{ moles Al}}\right)$$

$$x = 5.639\text{ mole }Al_2S_3$$

In-Class Problem:

A reaction mixture is prepared containing 10.0 grams of Al_2O_3 and 2.00 grams of C. This mixture is heated and allowed to react to *completely* form products, according to the chemical equation shown below. What mass of Al will be formed?

$$2\ Al_2O_3 + 3\ C \longrightarrow 4\ Al + 3\ CO_2$$

In-Class Problem:

A reaction mixture is prepared containing 22.0 grams of CH_3CH_3 and 16.0 grams of O_2. This mixture is allowed to react to *completely* form products, according to the chemical equation shown below. What mass of CO_2 will be formed?

$$2\ CH_3CH_3 + 7\ O_2 \longrightarrow 4\ CO_2 + 6\ H_2O$$

In-Class Problem:

A reaction mixture is prepared containing 51.5 grams of NaBr and 17 grams of Cl_2. This mixture is allowed to react to *completely* form products, according to the chemical equation shown below. What mass of Br_2 will be formed?

$$2\ NaBr + Cl_2 \longrightarrow Br_2 + 2\ NaCl$$

Percentage Yield:

The amount of product or products formed in a reaction is called the *reaction yield*.

The *theoretical yield* is the yield which is calculated based on the reaction stoichiometry.

The *actual yield* is the amount of product actually isolated or obtained from the reaction process.

The *percentage yield* is the relationship between these two, expressed as a percentage.

Percentage Yield:

Example:

In the reaction shown below, 5.0 moles of sulfur are expected 1.7 moles of Al_2S_3. On completion of the reaction, only 1.5 moles of Al_2S_3 are isolated from the reaction mixture. What is the percentage yield in this reaction?

$$2\ Al + 3\ S \longrightarrow Al_2S_3$$

$$\text{percentage yield} = \left(\frac{1.5\text{ mole }Al_2S_3}{1.7\text{ mole }Al_2S_3}\right) \times 100$$

percentage yield = 88%

In-Class Problem:

Aqueous potassium chloride reacts with aqueous silver nitrate to produce solid silver chloride, according the reaction shown below. In a reaction, 1.0 mole of each reactant are utilized and 125 grams of AgCl*(s)* are isolated. What is the *yield* in this reaction?

$$KCl(aq) + AgNO_3(aq) \longrightarrow AgCl(s) + KNO_3(aq)$$

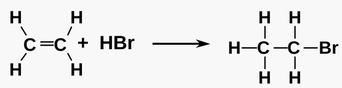
In-Class Problem:

Nitric monoxide (NO) reacts with O_2 to form nitrogen dioxide according to the chemical equation shown below. When 10.0 grams of NO are reacted with excess oxygen, 9.7 grams of NO_2 are formed. What is the percentage yield in this reaction?

$$2\ NO + O_2 \longrightarrow 2\ NO_2$$

In-Class Problem:

Ethene reacts with HBr to form bromoethane according to the chemical equation shown below. When 12.0 grams of ethene are reacted with 10.7 grams of HBr, 14.0 grams of bromoethane are formed. Which is the limiting reagent? What is the percentage yield in this reaction?



In-Class Problem:

When 1.85 grams of lead (II) nitrate reacts with 11.0 grams of sodium chromate, 1.62 grams of $PbCrO_4$ is obtained, according to the chemical equation shown below. Which is the limiting reagent? What is the percentage yield in this reaction?

$$Pb(NO_3)_2 + Na_2CrO_4 \longrightarrow PbCrO_4 + 2\ NaNO_3$$