STOICHIOMETRY

Reaction Stoichiometry

- the numerical relationships between chemical amounts in a reaction is called **stoichiometry**
- the coefficients in a balanced chemical equation specify the relative amounts in moles of each of the substances involved in the reaction

$$2\ C_8H_{18}(l) + 25\ O_2(g) \rightarrow 16\ CO_2(g) + 18\ H_2O(g)$$

2 molecules of C_8H_{18} react with 25 molecules of O_2 to form 16 molecules of CO_2 and 18 molecules of H_2O

2 moles of C_8H_{18} react with 25 moles of O_2 to form 16 moles of CO_2 and 18 moles of H_2O

2 mol C_8H_{18} : 25 mol O_2 : 16 mol CO_2 : 18 mol H_2O

Predicting Amounts from Stoichiometry

- the amounts of any other substance in a chemical reaction can be determined from the amount of just one substance
- How much CO_2 can be made from 22.0 moles of C_8H_{18} in the combustion of C_8H_{18}?

$$2\ C_8H_{18}(l) + 25\ O_2(g) \rightarrow 16\ CO_2(g) + 18\ H_2O(g)$$

2 moles C_8H_{18} : 16 moles CO_2

$$22.0\ \text{moles } C_8H_{18} \times \frac{16\ \text{mol } CO_2}{2\ \text{mol } C_8H_{18}} = 176\ \text{moles } CO_2$$


Stoichiometry

1. Finely divided sulfur ignites spontaneously in fluorine to produce sulfur hexafluoride according to the following unbalanced equation:

$$S(s) + F_2(g) \rightarrow SF_6(g)$$

A. How many grams of $SF_6(g)$ can be produced from 5.00 g of sulfur?

B. How many grams of fluorine are required to react with the 5.00 g of sulfur?

2. Deuterated ammonia, $ND_3(g)$, can be prepared by reacting lithium nitride with heavy water, $D_2O(l)$, according to the following equation:

$$Li_3N(s) + D_2O(l) \rightarrow LiOD(s) + ND_3(g)$$
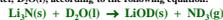
A. How many milligrams of heavy water are required to produce 7.15 mg of $ND_3(g)$? Take the atomic mass of deuterium to be 2.014 amu.

B. Given that the density of heavy water is 1.106 g/mL at room temperature, how many milliliters of heavy water are required?

Workshop 4A on Balancing Chemical Equations & Stoichiometry

1. Balance the following chemical equations shown below:

A. $KClO_3(s) \rightarrow KCl(s) + O_2(g)$
B. $NH_3(g) + O_2(g) \rightarrow N_2(g) + H_2O(g)$
C. $Fe(s) + H_2O(g) \rightarrow Fe_3O_4(s) + H_2(g)$
D. $H_2S(g) + SO_2(g) \rightarrow H_2O(l) + S(s)$

2. A frequently used method for preparing oxygen in the laboratory is by the thermal decomposition of potassium chlorate according to the following unbalanced chemical equation:

$$KClO_3(s) \rightarrow KCl(s) + O_2(g)$$

How many grams of $O_2(g)$ can be prepared from 30.6 g of $KClO_3(s)$?

3. Consider the combustion of propane, C_3H_8.

A. How many grams of O_2 are required to burn 75.0 g of propane?

B. How many grams of CO_2 are produced?

Limiting Reagent

When chemicals are mixed together to undergo a reaction, they are often mixed in stoichiometric quantities, that is, in exactly the correct amounts so that all reactants "run out" at the same time. However, if one or more reactant(s) is used in excess, then the scarce reagent is called the limiting reagent (or reactant). In any stoichiometric problem, it is ESSENTIAL to determine which reactant is limiting in order to calculate correctly the amounts of products that will be formed.

A mixture is prepared from 25.0 g of aluminum and 85.0 g of Fe_2O_3. The reaction that occurs is described by the following equation:

$$Fe_2O_3(s) + Al(s) \rightarrow Al_2O_3(s) + Fe(l)$$

How much iron is produced in the reaction?

Workshop 4B on Limiting Reagent

1. Calcium sulfide can be made by heating calcium sulfate with charcoal at high temperature according to the following unbalanced chemical equation:

$$CaSO_4(s) + C(s) \rightarrow CaS(s) + CO(g)$$

How many grams of $CaS(s)$ can be prepared from 100.0 g each of $CaSO_4(s)$ and $C(s)$? How many grams of unreacted reactant remain at the end of this reaction?

2. If 21.4 g of solid zinc are treated with 3.13 L 0.200 M HCl, how many grams of hydrogen gas will theoretically be formed? How much of which reactant will be left unreacted? The products of this reaction are hydrogen gas and zinc chloride.

Percentage Yield

$$\text{Percent yield} = \frac{\text{Actual Yield}}{\text{Theoretical Yield}} \times 100$$
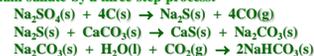
1. Liquid tin(IV) chloride can be made by heating tin in an atmosphere of dry chlorine. If the percentage yield of this process is 64.3%, then how many grams of tin are required to produce 0.106 g of the product?

2. Aluminum burns in bromine, producing aluminum bromide. When 6.0 g of aluminum was reacted with an excess of bromine, 50.3 g of aluminum bromide was isolated. Calculate the theoretical and percent yield of this reaction.

Workshop 4C on Percentage Yield

1. A 0.473-g sample of phosphorus is reacted with an excess of chlorine, and 2.12 g of phosphorus pentachloride is collected. What is the percentage yield of the product?

2. A century ago, sodium bicarbonate was prepared from sodium sulfate by a three-step process:

$$Na_2SO_4(s) + 4C(s) \rightarrow Na_2S(s) + 4CO(g)$$
$$Na_2S(s) + CaCO_3(s) \rightarrow CaS(s) + Na_2CO_3(s)$$
$$Na_2CO_3(s) + H_2O(l) + CO_2(g) \rightarrow 2NaHCO_3(s)$$

How many kilograms of sodium bicarbonate could be formed from one kilogram of sodium sulfate, assuming an 82% yield in each step?

Workshop 4E on STOICHIOMETRY & PERCENT

1. Impure nickel can be purified by first forming the compound $Ni(CO)_4$, which is then decomposed by heating to yield very pure nickel. Metallic nickel reacts with gaseous carbon monoxide as follows:

$$Ni\ (s) + 4\ CO\ (g) \rightarrow Ni(CO)_4\ (g)$$
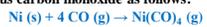
Other metals present do not react. If 94.2 g of a metal mixture produces 98.4 g of $Ni(CO)_4$, what is the mass percent of nickel in the original sample?

2. A 1.0000g sample of XI_2 is dissolved in water, and excess silver nitrate is added to precipitate all if the iodide as silver iodide. The mass of the dry AgI, is found to be 1.375g. Calculate the molar mass of X.