STOICHIOMETRY

&

Limiting Reactant

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

MOLE RATIO

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}?

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

$$2 \text{ moles } C_8H_{18} : 16 \text{ moles } CO_2$$

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

Stoichiometry – Lecture Questions

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?

Step 1: balanced equation $S(s) + 3F_2(g) \rightarrow SF_6(g)$

Step 2: make a list under respective species

$$\begin{array}{cccc} S(s) & + 3F_2(g) & \rightarrow & SF_6(g) \\ 5.00\text{ g} & & & m = ? \\ 32\text{ g/mol} & & & 146\text{ g/mol} \end{array}$$

Step 3: unit analysis

$$5.00\text{g S}\left(\frac{1\text{mol S}}{32\text{ g S}}\right)\left(\frac{1\text{ mol } SF_6}{1\text{ mol S}}\right)\left(\frac{146\text{ g}}{1\text{ mol } SF_6}\right) = 22.8\text{g } SF_6(g)$$

Theoretical yield

B) $$5.00\text{ g S}\left(\frac{1\text{mol S}}{32\text{ g S}}\right)\left(\frac{3\text{ mol } F_2}{1\text{ mol S}}\right)\left(\frac{38\text{g}}{1\text{ mol } F_2}\right) = 17.8\text{ g } F_2(g)$$

Minimum required reactant

Theoretical Yield

- The **theoretical yield** is the maximum amount of product that can be made.
  - In other words, it is the amount of product possible as calculated through the stoichiometry problem.
- This is different from the **actual yield**, which is the amount one actually produces and measures.

Stoichiometry – Lecture Questions

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. Calculate the theoretical yield (mg) of heavy water are required to produce 7.15 mg of $ND_3(g)$? The atomic mass of deuterium is 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?

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.

Limiting Reagent

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?

Percentage Yield - lecture questions

$$\text{Percent yield} = \frac{\text{Actual Yield}}{\text{Theoretical Yield}} x100$$

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?

Step 1: ? **Write a balanced equation**

Step 2: **Make a list of given and implied information**

Step 3: **In this problem we need to find the theoretical yield**

Step 4: **Use stoichiometry to relate tin(IV) chloride to tin**

Percentage Yield - lecture questions

$$\text{Percent yield} = \frac{\text{Actual Yield}}{\text{Theoretical Yield}} x100$$

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.

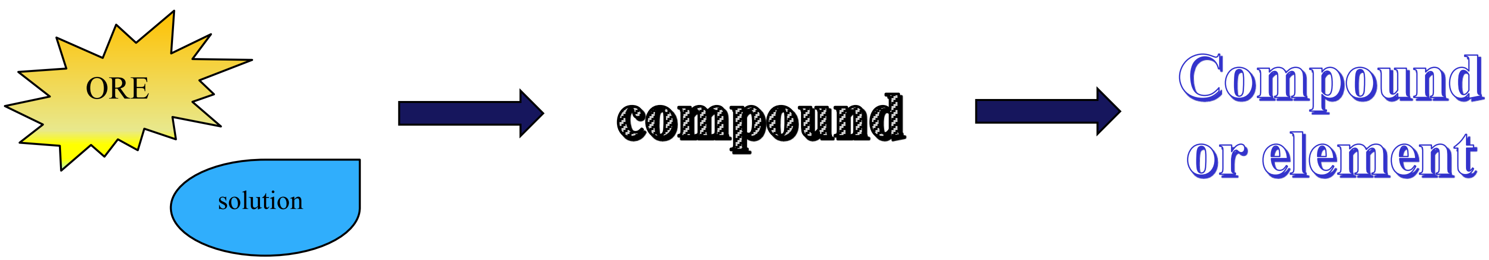
INTRODUCTION TO GRAVIMETRIC ANALYSIS

(advance stoichiometry)

INTRODUCTION to GRAVIMETRIC ANALYSIS

MANY TIMES IN LAB, WE DO NOT HAVE ALL THE INFORMATION AND/OR DATA NECESSARY TO COMPLETE STOICHIOMETRIC PROBLEMS WITH BALANCED CHEMICAL EQUATIONS. IN THIS CASE, WE USE A METHOD REFERED TO AS GRAVIMETRIC ANALYSIS.

Step 1: Since a balanced equation is sometimes not possible; in gravimetric analysis the first step is to draw out a plan or draw a picture to represent the physical process in the lab.



Step 2: Find correlations and relationships (maybe common element)

Step 3: Stoichiometry

GRAVIMETRIC ANALYSIS – Lecture problems

1) Under a certain set of laboratory conditions, 2.1 g of sodium reacts with water to form 1.14 L of hydrogen gas. When 3.4 g of another alkali metal is reacted with water under the same conditions, 497 mL of hydrogen gas is evolved. Identify the alkali metal.

In this problem, we will try to set up some relationships:

$$\underset{\substack{2.1\text{ g}\\23.0\text{ g}}}{2\,Na} + 2\,H_2O \rightarrow \underset{1.14}{H_2} + 2\,NaOH$$

$$2.1\text{g Na}\left(\frac{1\text{ mol Na}}{23.0\text{ g Na}}\right)\left(\frac{1\text{mol }H_2}{2\text{mol Na}}\right)\left(Z\right) = 1.14\text{ L }H_2$$

$$0.04565\,Z = 1.14$$

$$Z = 24.97$$

GRAVIMETRIC ANALYSIS – Lecture problems

1) **Under a certain set of laboratory conditions, 2.1 g of sodium reacts with water to form 1.14 L of hydrogen gas. When 3.4 g of another alkali metal is reacted with water under the same conditions, 497 mL of hydrogen gas is evolved. Identify the alkali metal.**

NOW let's use that relationship on our unknown:

$$2\,X + 2\,H_2O \rightarrow H_2 + 2\,XOH$$

3.4 g ⠀⠀⠀⠀⠀⠀⠀⠀ 0.497 L

????

$$3.4\text{g X}\left(\frac{1\text{ mol X}}{?\text{ g X}}\right)\left(\frac{1\text{mol }H_2}{2\text{mol X}}\right)\left(Z\right) = 0.497\text{ L }H_2$$

PV=nRT

But Z = 24.97

V=nRT/P

42.4514 (1/ ?) = 0.497

? = 85.42 g/mol

Rb

V=n Z

2. You are given a solid that is a mixture of Na_2SO_4 and K_2SO_4. A 0.205 g sample of the mixture is dissolved in water. An excess of an aqueous solution of $BaCl_2$ is added. The $BaSO_4$ that is formed is filtered, dried, and weighted. Its mass is 0.298g.

(a) What is the mass percent of sulfate ion in the sample?
(b) What is the percent composition by mass of Na_2SO_4 & K_2SO_4 in the sample?

0.205 g 

$\rightarrow$ SO_4^{2-} $\rightarrow$ $BaSO_4$

0.298 g

?? Na_2SO_4 and ? K_2SO_4

$$0.298\text{g } BaSO_4 \left(\frac{1\text{mol } BaSO_4}{233\text{g } BaSO_4}\right)\left(\frac{1\text{mol } SO_4^{2-}}{1\text{mol } BaSO_4}\right)\left(\frac{96\text{ g } SO_4^{2-}}{1\text{mol } SO_4^{2-}}\right)$$

$$= 0.12277\text{ g } SO_4^{2-}$$

$$\%\ SO_4^{2-} = \left(\frac{0.1227744\text{ g } SO_4^{2-}}{0.205\text{ g mixture}}\right)100 \quad = \quad 59.9\%\ SO_4^{2-}$$

2. You are given a solid that is a mixture of Na_2SO_4 and K_2SO_4. A 0.205 g sample of the mixture is dissolved in water. An excess of an aqueous solution of $BaCl_2$ is added. The $BaSO_4$ that is formed is filtered, dried, and weighted. Its mass is 0.298g.

(a) What is the mass percent of sulfate ion in the sample?

(b) What is the percent composition by mass of Na_2SO_4 & K_2SO_4 in the sample?

0.205 g 

$\rightarrow$ SO_4^{2-} $\rightarrow$ $BaSO_4$

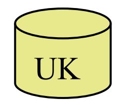
0.298 g

?? Na_2SO_4 and ? K_2SO_4

2. You are given a solid that is a mixture of Na_2SO_4 and K_2SO_4. A 0.205 g sample of the mixture is dissolved in water. An excess of an aqueous solution of $BaCl_2$ is added. The $BaSO_4$ that is formed is filtered, dried, and weighted. Its mass is 0.298g.

(a) What is the mass percent of sulfate ion in the sample?
(b) What is the percent composition by mass of Na_2SO_4 & K_2SO_4 in the sample?

$$0.298\text{g } BaSO_4 \; \frac{1\text{mol } BaSO_4}{233\text{g } BaSO_4} \; \frac{1\text{mol } SO_4^{2-}}{1\text{mol } BaSO_4} = \mathbf{1.2789 \times 10^{-3}\ mol\ SO_4^{2-}}$$



?? Na_2SO_4 and ? K_2SO_4

0.205 g

Relationships:

(1) 1 mol Na_2SO_4 = 1 mol SO_4^{2-}

(2) ?mol Na_2SO_4 + ?mol K_2SO_4 = 1.2789×10^{-3} mol SO_4^{2-}

(3) n = m/MM so replace n with m/MM

(4) $$\frac{mN}{142_{g/mol}} + \frac{mK}{174_{g/mol}} = 1.2789 \times 10^{-3} \text{ mol } SO_4^{2-}$$

(5) mN + mK = 0.205 g mixture so mN = 0.205g - mK

$$\frac{0.205 - mK}{142} + \frac{mK}{174} = 1.2789 \times 10^{-3} \text{ mol } SO_4^{2-}$$

Solving for mK = 4.0709/32 = 0.127 g therefore mN = 0.0778g

% K_2SO_4 = (0.127g/0.205g)100 = 61.95%

% Na_2SO_4 = (0.0778g/0.205g)100 = 37.9%

GROUP LECTURE QUIZ #9

An ionic compound MX_3 is prepared according to the following unbalanced chemical equation:

$$M + X_2 \rightarrow MX_3$$

A 0.105 g sample of X_2 contains 8.92×10^{20} molecules. The compound MX_3 consists of 54.47% X by mass. What are the identities of M and X, and what is the correct name for MX_3? Starting with 1.00 g each of M and X_2, what mass of MX_3 can be prepared?