Chapter 10

Stoichiometry

Interpreting a Chemical Equation

$$H_2\,(g) + Cl_2\,(g) \rightarrow 2\,HCl\,(g)$$

1 molecule *1 molecule* *2 molecules*

$$N_2\,(g) + 3\,H_2\,(g) \rightarrow 2\,NH_3\,(g)$$

____ molecule(s) **____ molecule(s)** **____ molecule(s)**

It follows that any multiples of these coefficients will be in same ratio!

$$2\,H_2\,(g) + O_2\,(g) \rightarrow 2\,H_2O\,(g)$$

x 1000 **_____ molecule(s)** **_____ molecule(s)** **_____ molecule(s)**

x N **_____ molecule(s)** **_____ molecule(s)** **_____ molecule(s)**

Since **N=Avogadro's # = 6.02×10^{23} molecules = 1 mole**

$2\ H_2\ (g) + O_2\ (g) \rightarrow 2\ H_2O\ (g)$
_____ mole(s) _____ mole(s) _____ mole(s)

Thus, the coefficients in a chemical equation give the **mole ratios of reactants** and products in a reaction.

Give the mole ratios for each of the following:

1. ___H_2 (g) + ___Cl_2 (g) → ___HCl (g)
   ____ mole(s) ____ mole(s) ____ mole(s)

2. ___C_3H_8 (g) + ___O_2 (g) → ___CO_2 (g) + ___H_2O(g)
   ____ mole(s) ____ mole(s) ____ mole(s) ____ mole(s)

Mole-Mole Relationships

____ Fe_2O_3 (l) + ____ CO (g) ⟶ ____ Fe (l) + ____CO_2 (g)

1 mol 3 mol 2 mol 3 mol

1 mol Fe_2O_3 reacts with 3 mol CO: $\frac{1\text{ mol } Fe_2O_3}{3\text{ mol CO}}$ and $\frac{3\text{ mol CO}}{1\text{ mol } Fe_2O_3}$

3 mol CO reacts to produce 2 mol Fe

2 mol Fe and 3 mol CO_2 are produced

1 mol Fe_2O_3 produces 3 mol CO_2

Fe_2O_3 (l) + 3 CO (g) ⟶ 2 Fe (l) + 3 CO_2 (g)

1. Suppose 2.25 mol iron (III) oxide reacts, how much carbon dioxide gas is made?

2. If 4.56 mol of molten iron was produced, how much carbon monoxide gas was used?

3. How much carbon monoxide is required to react with 1.75 mol iron (III) oxide?

STOY-key-OM-etry

- refers to the amounts of reactants and products in a chemical reaction
- generally involves relating amounts of reactants and/or products to each other in terms of moles.

Mass – Mass

Section 10.5

Mass – Volume

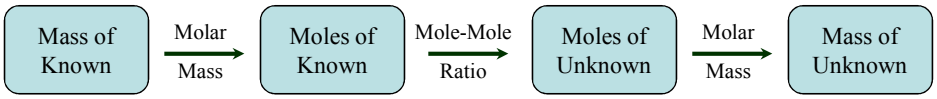
Section 10.6

Volume – Volume

Section 10.7 (skip)

Mass – Mass

Section 10.5



$$3\ FeO\ (l) + 2\ Al\ (l) \longrightarrow 3\ Fe\ (l) + Al_2O_3\ (l)$$

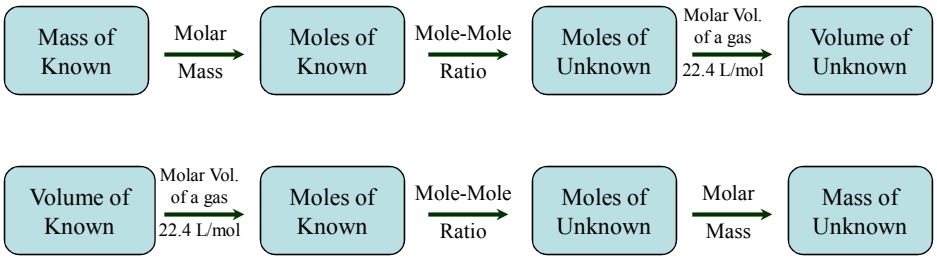
1. Calculate the mass of iron (II) oxide needed to react completely with 5.55 g of molten aluminum.

2. Calculate the mass of aluminum oxide produced when 10.25 g of molten aluminum reacts completely.

3. Calculate the mass of molten iron produced when 25.25 g of molten aluminum oxide is produced.

Mass – Volume

Section 10.6



$$4\ Al\ (s) + 3\ O_2\ (g) \longrightarrow 2\ Al_2O_3\ (s)$$

Calculate the volume (in L) of oxygen gas that reacts to produce 100.0 g of aluminum oxide.

Example 1: Calculate the volume (in liters) of oxygen gas required to react with 50.0 g of aluminum at STP.

$$4\ Al\ (s) + 3\ O_2\ (g) \xrightarrow{spark} 2\ Al_2O_3\ (s)$$

Example 2: An automobile airbag inflates when N_2 gas results from the explosive decomposition of sodium azide (NaN_3),

$$2\ NaN_3\ (s) \xrightarrow{spark} 2\ Na\ (s) + 3\ N_2\ (g)$$

a. Calculate the mass of NaN_3 required to produce 50.0 L of N_2 gas at STP.

b. What volume (in L) of N_2 gas is produced forms when 175 g of sodium form at STP?

Limiting Reagent (Reactant)

If we were making up some baskets of flowers and each basket was to have 5 red roses, 2 yellow roses, and 3 white roses and we started with

20 red roses
30 yellow roses
30 white roses

How many baskets can we make?

Red roses: 20/5 = 4 baskets
Yellow roses: 30/2 = 15 baskets
White roses: 30/3 = 10 baskets

When there are two or more reactants in distinct quantities, the *formation* of product is limited by the limiting reagent.

One reactant will always be used up first!!!

Recall: We always compare things on the mole scale

Elements get their mass by the number of protons, electrons, and neutrons.
1 mol of Au compared to 1 mol of N – the masses might be different but no matter what
1 mol = 6.022×10^{23} atoms of each

MAKING BISQUICK™ PANCAKES

2 cups Bisquick
1 cup milk
2 eggs
} 14 pancakes

2 cups of Bisquick™ + 1 cup milk + 2 eggs → 14 pancakes

Example: If you have 10 cups of Bisquick™, 10 cups of milk, and 12 eggs, how many pancakes can you make? (Indicate the limiting reagent(s) and the reagent(s) in excess.)

Desired Method

1. **Write a balanced equation.**
2. **Find mol of each reactant present.**
3. **Determine mol of product produced from each reagent required to completely react.**
5. **Determine the limiting reagent (the one that forms the LEAST amount of product is the limiting reagent).**
6. **Determine the amount of product formed.**

Iron reacts with oxygen to form iron (III) oxide.

If a student starts with 5.00 g iron and 2.56 g of oxygen,
How much product will form?

In a reaction, 50.0 g of manganese (IV) oxide reacts with 25.0 g of aluminum. Calculate the mass of manganese metal produced.

$$3\ MnO_2\ (l) + 4\ Al\ (l) \rightarrow 3\ Mn\ (l) + 2\ Al_2O_3\ (s)$$

If 1.00 g of aluminum hydroxide reacts with 0.605 g of sulfuric acid, what is the mass of aluminum sulfate?

$$2\ Al(OH)_3\ (s) + 3\ H_2SO_4\ (aq) \rightarrow Al_2(SO_4)_3\ (s) + 6\ H_2O\ (l)$$

When 2.35 g of powdered antimony (Sb) is sprinkled into a flask containing 4.69 g chlorine gas, how much antimony trichloride is produced?

$$2\ Sb\ (s) + 3\ Cl_2\ (g) \rightarrow 2\ SbCl_3\ (s)$$

Percent Yield

Theoretical Yield

The amount of product formed from the *complete* conversion of the given amount of reactant to product.

Actual Yield (experimental yield)

The amount of product formed experimentally. Often side reactions or incomplete reactions occur causing the actual yield to be less than theoretically planned.

Percent Yield : (Actual Yield/Theoretical Yield) x 100%

Example:

A solution containing excess sodium sulfate is added to a second solution containing 3.18 g of barium nitrate.
Barium sulfate precipitates, is collected and dried, and found to weigh 1.20 g.

What is the percent yield?

1. **Write a balanced equation**
2. **Calculate theoretical yield.**
3. **Calculate percent yield.**

Harder Example:

1. A procedure for preparing sodium sulfate typically produces a 79.8% yield in a manufacturing plant.

$$2\ S\ (s) + 3\ O_2\ (g) + 4\ NaOH\ (aq) \rightarrow 2\ Na_2SO_4\ (aq) + 2\ H_2O\ (l)$$

Find the number of grams of sodium sulfate recovered from the reaction of 36.9 g sodium hydroxide (all other reagents are present in excess).

1. **Determine theoretical yield.**
2. **Plug into algebraic percent yield expression.**
3. **Solve for Actual yield.**

Example with all concepts of Chapter 10 (Hint: good test question!!)

Given the single replacement reaction between aluminum metal and hydrochloric acid:

___ Al (s) + ___ HCl (aq) → _____ + _____

a. Calculate the volume (in liters) of hydrogen gas produced from 50.0 g of aluminum metal at STP.

b. Calculate the volume (in liters) of hydrogen gas produced from 50.0 g of HCl at STP.

c. When 50.0 g of aluminum reacts with 50.0 g of HCl at STP,
the volume (in L)of hydrogen gas produced is _____,
the Limiting Reactant = _____ and Reactant in excess = _____

d. If 12.5 L of hydrogen gas was actually produced when 50.0 g of aluminum reacts with 50.0 g of HCl at STP, calculate the percent yield for the reaction.