CHAPTER 10: STOICHIOMETRY

DO Problems: 1-2, 7-11, 19-36, 49-66, 75-79
(Be sure to balance equations for #'s 22-28 and 31-36)

1.1 Interpreting a Chemical Equation

$H_2(g)$ + $Cl_2(g)$ → 2 $HCl(g)$

1 molecule 1 molecule 2 molecules

$N_2(g)$ + 3 $H_2(g)$ → 2 $NH_3(g)$

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

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

2 $H_2(g)$ + $O_2(g)$ → 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 $H_2(g)$ + $O_2(g)$ → 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. $H_2(g)$ + $Cl_2(g)$ → 2 $HCl(g)$

   ____ mole(s) ____ mole(s) ____ mole(s)

2. $C_3H_8(g)$ + 5 $O_2(g)$ → 3 $CO_2(g)$ + 4 $H_2O(g)$

   ____ mole(s) ____ mole(s) ____ mole(s) ____ mole(s)

10.2 Mole-Mole Relationships

Consider the following reaction:

$$C_3H_8\,(g) + 5\,O_2\,(g) \rightarrow 3\,CO_2\,(g) + 4\,H_2O\,(g)$$

1. Use unit factors to determine how many moles of O_2 are needed to completely react with 2.25 moles of C_3H_8.

2. How many moles of CO_2 form when 3.50 moles of O_2 react?

3. How many moles of H_2O form when 4.75 moles of CO_2 form?

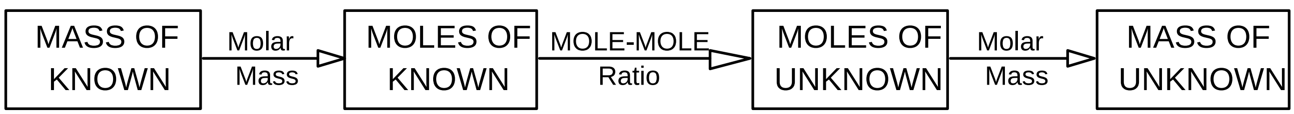
4. How many moles of C_3H_8 are required to produce 1.50 moles of H_2O?

10.3 Types of Stoichiometry Problems

stoichiometry (STOY-key-OM-etry):

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

10.4 Mass-Mass (Stoichiometry) Problems



Example: Consider the following reaction to produce iron, Fe (s):

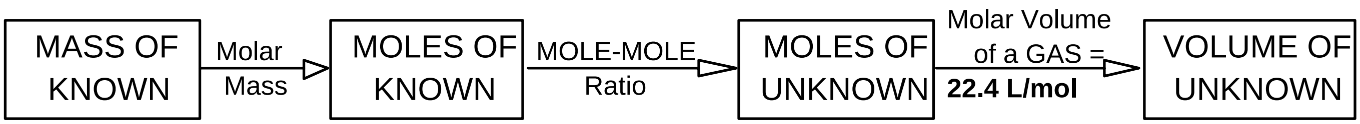
$$Fe_2O_3\,(s) + 3\,CO\,(g) \rightarrow 2\,Fe\,(s) + 3\,CO_2\,(g)$$

1. Calculate the mass of CO needed to react completely with 50.0 g of Fe_2O_3 .

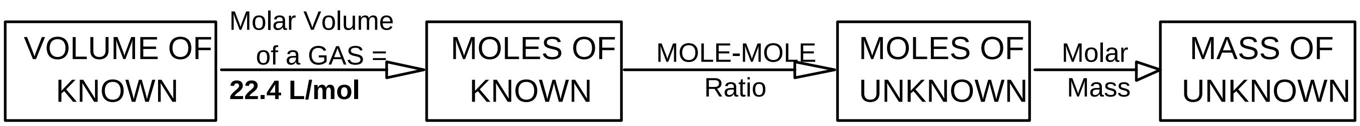
2. Calculate the mass of iron produced when 125 g of CO reacts completely.

3. Calculate the mass of CO_2 produced when 75.0 g of iron is produced.

10.5 Mass-Volume (Stoichiometry) Problems



OR



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

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

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

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

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?

10.7 The Limiting Reactant Concept (LIMITING REAGENT)

In practice, reactants will not always be present in the exact amounts necessary for all reactants to be converted completely into products.

Some reactants (usually the least expensive) are present in larger amounts and are never complete used up

→ **“reactant(s) in excess”**

Only in a limited supply of the other reactants (usually the more expensive) are present, so these are completely used up

→ **“limiting reactant”** since it limits the amount of product that can be made

MAKING BICYCLES

- Parts needed:
  - 1 bicycle frame
  - 1 seat
  - 2 pedals
  - 2 wheels (rims + tires)

Example: How many bicycles can be made with 5 frames, 6 seats, 15 pedals and 8 wheels? (Indicate the limiting reactant and reactants in excess.)

MAKING BISQUICK™PANCAKES

2 cups Bisquick, 1 cup milk, 2 eggs ⟩ 14 pancakes

2 cups of Bisquick™ + 1 cup milk + 2 eggs $\rightarrow$ 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.)

10.8 Limiting Reactant Problems

GUIDELINES FOR SOLVING LIMITING REAGENT PROBLEMS:

1. Calculate the **amount** (**moles, mass, or volume) of product** formed using the amount of **each reactant given**
   — Use mass-mass, mass-volume, volume-volume conversions
   → ***Smallest amount = amount of product formed!***
2. Whichever reactant produces the smaller amount of product
   → **limiting reagent**
3. All other reactant(s) → **in excess**

Ex. 1: Consider the reaction between aluminum metal and hydrochloric acid to produce hydrogen gas:

$$2\ Al\ (s) + 6\ HCl\ (aq) \rightarrow 2\ AlCl_3\ (aq) + 3\ H_2\ (g)$$

Calculate the number of moles of hydrogen gas produced when 5.00 moles of aluminum metal react with 5.00 moles of HCl.

Limiting reactant = ___________ Reactant in excess = ______________

Ex. 2: Consider the reaction for propane (C_3H_8) burning:

$$C_3H_8\ (g) + 5\ O_2\ (g) \rightarrow 3\ CO_2\ (g) + 4\ H_2O\ (g)$$

Calculate the number of moles of carbon dioxide gas produced when 1.50 moles of propane react with 5.00 moles of oxygen.

Limiting reactant = ___________ Reactant in excess = ______________

Ex. 2: Given the same reaction between aluminum metal and hydrochloric acid to produce hydrogen gas,

$$2\ Al\,(s) + 6\ HCl\,(aq) \rightarrow 2\ AlCl_3\,(aq) + 3\ H_2\,(g)$$

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 = __________

10.9 Percent yield = $\frac{\textbf{actual yield}}{\textbf{theoretical yield}}$ **x100%**

theoretical yield: Amount of product one *should* get based on the chemical equation and the amount of reactants present
— One generally calculates this in grams from info given

actual yield: Amount of produce one actually obtains
— Generally smaller than the theoretical yield because of impurities and other adverse conditions in the lab
— This value has to be provided in a problem

Ex. 1: For the reaction of 50.0 g aluminum with 50.0 g of HCl at STP, what was the theoretical yield of hydrogen gas? (See your work on p. 8)

theoretical yield = ________________________

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.

Ex. 2: Calculate the percent yield for a reaction with a theoretical yield of 75.0 g of carbon dioxide if the actual amount of carbon dioxide produced was 59.1 g.

Example: Consider the reaction for propane (C_3H_8) burning:

$$C_3H_8\,(g) + 5\,O_2\,(g) \rightarrow 3\,CO_2\,(g) + 4\,H_2O\,(g)$$

a. Calculate the mass of CO_2 gas produced when 125 g of C_3H_8 reacts at STP.

b. Calculate the mass of CO_2 gas produced when 125 L of oxygen reacts at STP.

c. When 125 g of C_3H_8 react with 125 L of oxygen at STP, the mass of CO_2 gas produced is ___________________, the limiting reactant is ____________, and the reactant in excess is ____________.

d. Calculate the percent yield if 86.7 g of carbon dioxide are actually produced when 125 g of C_3H_8 react with 125 L of oxygen at STP.