Stoichiometry

Chapter 3

Stoichiometry

- the study of the weight relationships in chemical formulas & equations

Atomic Mass (or atomic weight)

- the weighted average of all of the naturally occurring isotopes of an element
- the weight found on the Periodic Table

ex. ^{12}C = 12.0000 amu 98.89% ^{13}C = 13.0034 amu 1.11%
(.9889)(12.0000) + (.0111)(13.0034) = 11.8668 + .1443377 = 12.011138 amu

Mole

- the number of atoms found in 12 grams of ^{12}C
- 6.02×10^{23} (Avogadro's Number)
- a sample of an element with a mass equal to the elements atomic mass expressed in grams

How big is 6.02×10^{23}?

ex. The Earth is 4.5 billion (4.5×10^{9}) years old. What is the age of the Earth in moles of seconds?

Mole Conversions

grams ←→ moles ←→ # of particles

- multiply by the correct conversion factor (the relationship between the 2 units with the given unit in the denominator and the desired unit in the numerator)

A. 1) g→mol 1) (g)(1 mol/g) = mol
   2) g←mol 2) (mol)(g/mol) = g
B. 3) mol→# particles 3) (mol)(6.02×10^{23} parts/mol) = # parts
   4) mol←# particles 4) (parts)(1 mol/6.02×10^{23} parts) = mol

Ex. 3.2 Compute the mass, in grams, of 6.00 atoms of Americium.

Ex. 3.3 How many atoms are present in a 10.0g sample of aluminum?

Ex. 3.4 A Silicon chip used in an integrated circuit of a computer has a mass of 5.68mg. How many Si atoms are present in this chip?

Ex: How many protons are present in 65.0g of gold?

Molar Mass

- The mass of one mole of a compound
- The sum of the masses of all of the atoms present in the formula of a compound

Ex. CH_4 1 C = 12
4 H = 4
16g = molar mass

- This would be the molecular mass if expressed in amu's
- (ionic compounds are sometimes referred to by formula mass rather than molecular mass)

Ex. 3.6 (p88) (read the question from the text)
Juglone, $C_{10}H_6O_3$
a) molar mass?
b) 1.56×10^{-2}g = ? mol

Ex. 3.7 (p89) (read the problem)
a) $CaCO_3$ molecular weight = ?
b) 4.86 mol $CaCO_3$ mass = ? mass of CO_3^{-2} = ?

Ex: How many atoms of oxygen are present in 38.0g of calcium phosphate?

Ex. 3.8 (p90) (read from text)
1.0×10^{-6}g $C_7H_{14}O_2$
How many atoms of C are present?

Percent Composition of Compounds

- The calculation of the percent, by mass, of a given element in a compound

$$\%\text{element} = \frac{\text{mass of element in compound}}{\text{mass of 1 mol of compound}} x100\%$$

Ex. 3.9 (p91) $C_{10}H_{14}O$ carvone (caraway seeds, spearmint oil)

Ex. 3.10 (p92) $C_{14}H_{20}N_2SO_4$ penicillin

Determining Formulas from Percent Composition

Chemical Formula = a ratio of MOLES!!

- Calculate the number of moles of each element from the percent composition
- Reducing these numbers to lowest whole numbers gives the Empirical Formula

Empirical Formula → the lowest whole number ratios in which atoms combine

- If the molecular weight is also known, the molecular formula can also be calculated

Molecular Formula = (empirical formula)x

x = some whole number

Molecular weight = (empirical formula)x

$$x = \frac{\text{molecular weight}}{\text{empirical weight}}$$

Ex. 3.11 (p96) 71.65% Cl, 24.27% C, 4.07% H mol weight = 98.96g

Find: empirical formula & molecular formula

Ex: .1156g of a compound containing only C, H, & N is reacted with O_2. 0.1638g CO_2 & 0.1676g of H_2O are formed. What is the compounds empirical formula?

Ex. 3.12 (p97) 43.64% P, 56.36% O mol weight = 283.88g
Find empirical formula & molecular formula

Chemical Equations

- Using symbols & formulas to describe a chemical change
- Reactants appear on the left side of the yield side and products appear on the right side

Reactants → Products

- All atoms in the reactants must appear in the products (conservation of mass)
- Coefficients are used to balance the equation
- Coefficients indicate the number of atoms or molecules or moles of atoms or molecules participating in the reaction
- Information about physical states may also be given:
  (s) solid (g) gas (l) liquid (aq) aqueous

Ex: $2Na_{(s)} + 2H_2O_{(l)} \rightarrow 2NaOH_{(aq)} + H_{2\,(g)}$

- Most equations can be balanced by inspection (trail & error)

Ex. 3.14 (p104) $(NH_4)_2Cr_2O_{7\,(s)} \rightarrow Cr_2O_{3\,(s)} + N_{2\,(g)} + 4H_2O_{(g)}$

Ex. 3.15 (p106) $NH_{3\,(g)} + O_{2\,(g)} \rightarrow NO_{(g)} + H_2O_{(g)}$

Problems Involving Equations

- These deal with masses of reactants used up or of products formed
- Usually solved in 4 steps
  1. Balance the equation
     -this relates the reactants & products in terms of MOLES
  2. Convert the given data to MOLES
  3. Using the ratio established by the proper coefficients in the equation, Calculate the number of moles of the substance asked about
  4. Convert the number of moles of the substance asked about to grams (or desired units)

Ex. 3.16 (p111) $LiOH_{(s)} + CO_{2\,(g)} \rightarrow Li2CO3_{\,(s)} + H_2O_{\,(l)}$

Chang 3.6 (p106) Calculate the number of grams of sodium phospahet needed to prepare 45.9g of sodium chloride. The unbalanced equation is $CaCl_2 + Na_3PO_4 \rightarrow Ca_3(PO_4)_2 + NaCl$

Limiting Reagent (Limiter)

- When amounts of more than one reactant are given, one reactant will be used up first
- When any reactant is used up the reaction will stop
- The reactant that gets used up is called the limiting reagent or limiter
- Any other reactant that is not used up is said to be "excess"
- When information about more than one reactant is given, you must determine which reactant is the limiter and solve the problem using that substance

Identifying the Limiter

- Convert the given amount of each reactant to moles
- Divide the number of moles of each reactant by its coefficient from the equation
- This indicates how many times the reaction can be run with each number of moles of reactants

$$\frac{\text{moles}}{\text{moles}} = \#\text{ of reactions}$$
$$\text{reacation}$$

- The reactant that will run the reaction the least number of times if the limiter

Ex. 3.18 (p119) 18.1g NH_3 & 90.4g CuO
?g of N_2 formed ?g of which reactant is left over

Ex: Aqueous sodium sulfate reacts with aqueous barium chloride to yield solid barium sulfate and aqueous sodium chloride.

A. How many grams of barium sulfate can be produced using 255g of sodium sulfate and 155g of barium chloride?
B. How many grams of which reactant is left unused?

Theoretical Yield

- The amount of product formed if the limiter is completely consumed
- This is the amount you have been calculating
- In reality side reactions may occur and less than the theoretical yield can be produced
- The actual amount produced by a reaction is often reported as the "percent yield"

$$\frac{\text{Actual Yield}}{\text{Theoretical Yield}} \times 100\% = \text{Percent Yield}$$

Ex. 3.19 (p120) 68.5kg CO & 8.60kg H_2 Theoretical yield of CH_3OH?
% yield if 3.57×10^4g CH_3OH is produced?
$CO + H_2 \rightarrow CH_3OH$

Ex. 3.20 (p91) 169kg $FeCr_2O_4$, 298kg K_2CO_3, & 75.0kg O_2
194kg K_2CrO_4 obtained. % yield = ?
$FeCr_2O_4 + K_2CO_3 + O_2 \rightarrow K_2CrO_4 + Fe_2O_3 + CO_2$