CHAPTER 4

CHEMICAL REACTIONS

KEY CONCEPTS:

1. BALANCING CHEMICAL EQUATIONS

2. STOICHIOMETRY AND THE MOLE METHOD

3. CONCENTRATIONS OF SOLUTIONS

4. LIMITING REACTANT PROBLEMS

5. PERCENT YIELDS

Chemical Equations

- the physical state of the reactants and products may be indicated: gas (g), liquid (l), solid (s), or in aqueous solution (aq)
- for the dissolution of compound in water, the following notation may be used:

Because of the principle of the conservation of matter, an equation must be balanced.

CONSERVATION OF MATTER: MATTER CANNOT BE CREATED OR DESTROYED, ONLY REARRANGED IN SPACE AND CHANGED INTO DIFFERENT TYPES OF PARTICLES

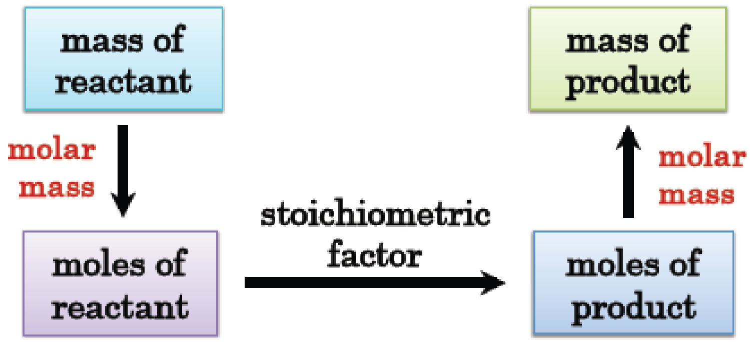
Balancing Equation Strategy

- Balance elements that occur in only one compound on each side first.
- Balance free elements last.
- Balance unchanged polyatomics as groups.
- Fractional coefficients are acceptable and can be cleared at the end by multiplication.

Using Stoichiometry

- if the quantity of a reactant is known, it is possible to calculate the quantity of product that will be formed (or vice-versa)
- to simplify the process, we use the *mole method*: we use units of moles instead of grams or millilitres

Step 1: Identify all reactants and products
Step 2: Balance the chemical equation
Step 3: Follow the mole method



Chemical Reactions in Solution

Close contact between reagents is necessary for chemical reaction to occur – can be achieved by using solutions

- **Solution:** solute dissolved in solvent to form a homogeneous mixture
- **Solute:** present in smallest amount
- **Solvent:** present in largest amount
  - when the solvent is water = *aqueous solutions*

- **Concentration:** the measure of the amount of solute in a solution
- **Molarity:** Moles of solute per liter of solution.

$$\text{Molarity} = \frac{\text{moles of solute}}{\text{volume of solution in liters}}$$

Other forms of concentration

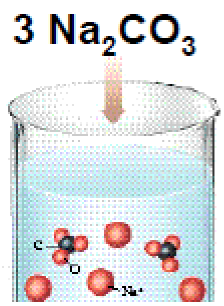
Molarity	M (or C)	$\frac{n_{solute}}{V_{solution}}$
Mass Percent	m/m%	$\frac{m_{solute}}{m_{solution}} = \frac{x \text{ g solute}}{100 \text{ g solution}}$
Volume percent	v/v%	$\frac{V_{solute}}{V_{solution}} = \frac{x \text{ mL solute}}{100 \text{ mL solution}}$
Mass/volume percent	m/v%	$\frac{m_{solute}}{V_{solution}} = \frac{x \text{ g solute}}{100 \text{ mL solution}}$

Parts per million	ppm	$\frac{1 \text{ part solute}}{10^6 \text{ parts solution}} = \frac{x \text{ g solute}}{10^6 \text{ g solution}} \approx \frac{x \text{ mg solute}}{\text{L solution}}$
Molality	m	$\frac{n_{solute}}{m_{solvent}} = \frac{x \text{ mol solute}}{1 \text{ kg solvent}}$
Mole Fraction	χ	$\frac{n_A}{n_{total}} = \frac{x \text{ mol of "A"}}{1 \text{ mol solution}}$

The Nature of a Na_2CO_3 Solution

This water-soluble compound is ionic

$Na_2CO_3(aq) \longrightarrow 2\ Na^+(aq) + CO_3^{2-}(aq)$



If $[Na_2CO_3] = 0.100$ M, then

$[Na^+] =$ 0.200 M

$[CO_3^{2-}] =$ 0.100 M

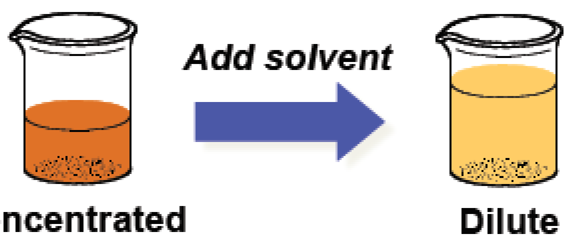
Concentrations of Solutions

Dilution

- We recognize that the number of moles are the same in dilute and concentrated solutions.
- So we can dilute a concentrated solution to get one that is less concentrated:

$M_{dilute} V_{dilute} = \text{moles} = M_{conc.} \cdot V_{conc.}$

mol



V = (0.15 mol NaOH)(1 L/0.50 mol) = 0.30 L

or 300 mL = volume of final solution

Therefore, add enough water to make the intitial 50.0 mL of 3.0 M NaOH to a final volume of 300 mL and the final molarity will be 0.50 M NaOH.

A shortcut:

$$M_{initial} \cdot V_{initial} = M_{final} \cdot V_{final}$$

Solution Stoichiometry and Chemical Analysis

There are two different types of units:
- *laboratory units* (macroscopic units: measure in lab);
- *chemical units* (microscopic units: relate to moles).

Always convert the laboratory units into chemical units first.
- *Grams* are converted to *moles* using molar mass.
- *Volume* or *molarity* are converted into *moles* using *M*

Use the stoichiometric coefficients to move between reactants and product.

Reactions Involving a LIMITING REACTANT

- Definition: In a given reaction, there is *not enough of one reagent* to use up the other reagent completely
- The reagent in short supply LIMITS the quantity of product that can be formed
- The stoichiometric coefficients are used to determine the limiting reagent

Reaction Yields

- the *theoretical yield* is the amount of product expected if the reactants react to completion
- the *actual yield* is always smaller than this value!
  - the inverse reaction occurs
  - other side-products are products
  - difficult to collect all of the product

$$\%\ \text{yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$$