CHAPTER 4
CHEMICAL REACTIONS

Chemists have used reactions to produce the materials Teflon, nylon, Dacron, Kevlar, polystyrene, and PVC among many others!

4.1 CHEMICAL EQUATIONS

- **chemical reaction**--transforms elements and compounds into new substances
- **balanced chemical equation**--shows the relative amounts of reactants and products
  - *s, l, g, aq*--solid, liquid, gas, aqueous solution
  - NO ENERGY or TIME is alluded to
  - Antoine Lavoisier (1743-1794)--law of conservation of matter: *matter can neither be created nor destroyed* Λ this means Abalancing equations@ is all his fault!!

4.2 BALANCING CHEMICAL EQUATIONS

- Begin with the most complicated-looking thing (often the scariest, too).
- Save the elemental thing for last.
- If you get stuck, double the most complicated-looking thing.
- MEMORIZE THE FOLLOWING:
- metals + halogens ––> M_aX_b
- CH and/or O + O_2 ––> CO_2(g) + H_2O(g)

Exercise 4.1
Balance the chemical equations for the following:
a) iron + oxygen ––> iron (III) oxide

b) the combustion of methane

c) the combustion of B_4H_{10} in oxygen to give B_2O_3(s) and water vapor

d) the reaction of carbon monoxide with hydrogen to give methyl alcohol

e) the combustion of octane

4.3 TYPES OF CHEMICAL REACTIONS

- Elements and Compounds with OXYGEN: all elements form binary oxides (some rare gasses an exception)
- C,N,P,S all form *several* binary oxides

- NO--nitrogen oxide; colorless gas
- NO_2--nitrogen dioxide; brown gas
- P_4O_{10}--tetraphosphorous decoxide; white solid
- SO_2--sulfur dioxide; when combined with even more oxygen ––> SO_3 also colorless gas; both precursors to acid rain
- COMBINATION REACTIONS:
- element + element ––>*ONE* product
- element + compound ––> *ONE* product
- DECOMPOSITION REACTIONS:
- *ONE* compound ––> 2 elements
- *ONE* compound ––> element + compound
- *metal carbonates* (upon heating) ––> *metal oxide* + CO_2(g)'

CHAPTER 5
REACTIONS IN AQUEOUS SOLUTION

Remember a **solution** is a homogeneous mixture where a **solute** is dissolved in a **solvent**. **Aqueous** solutions are solutions where the solvent is *water*.

5.1 PROPERTIES OF AQUEOUS SOLUTIONS

- **electrolytes**--solutions that conduct an electric current
- strong – completely dissociate (consult solubility rules)
- weak – do not dissociate; only about 5% dissociation (ammonia & acetic acid)
- **nonelectrolytes**--solutions where dissolving has occurred but the solute *does not* make ions and therefore cannot conduct electricity. (Pure water, sugar, alcohols, antifreeze, and starch)

SOLUBILITY RULES: *memorize!!!*

1. **Most alkali metal salts AND** NH_4^+ salts ARE ***soluble***
2. Cl^-, Br^-, I^- are ***soluble***, *except for Ag^+, Hg_2^{+2}, Pb^{+2}
3. F^- are ***soluble,*** *except for IIA metals
4. NO_3^-, ClO_3^-, ClO_4^-, and CH_3COO^- are ***soluble***
5. SO_4^{-2} are ***soluble,*** *except for Ca^{2+}, Sr^{+2}, Ba^{+2}, Ag^+, Pb^{+2}, Hg_2^{2+}
6. CO_3^{-2}, PO_4^{-3}, $C_2O_4^{-2}$, CrO_4^{-2}, S^{-2}, OH^-, and O^{-2} are ***INSOLUBLE*** (rule 1 takes priority!)

Heavy metal BAD GUYS!

It can be assumed that ionic cmpds. that dissolve in water are strong electrolytes and are therefore soluble.

Exercise 5.1
Tell whether each compound is likely to be soluble in water. If the cmpd. Dissolves in water, tell what ions exist in aqueous soln.
a) sodium bromide
b) barium sulfate
c) potassium carbonate
d) silver chloride
e) ammonium sulfate

Exercise 5.2
Write formulas for a) a soluble ionic compound containing the nitrate ion, b) an insoluble compound containing the sulfide ion, and c) a soluble cmpd. Containing the nickel (II) ion.

- **ACIDS AND BASES**
  - **acids**--any cmpd. that, on reaction with water, produces an ion called the **hydronium ion, H_3O^+ [or H^+],** and an anion (Arrhenius definition)
  - **base**--any cmpd. that provides a **hydroxide, OH^-**,and a cation in water (Arrhenius definition) **ammonia, NH_3 is an exception!!
    - STRONG ACIDS:
      - hydrohalic
      - nitric
      - perchloric
      - sulfuric
    - WEAK ACIDS:
      - acetic
      - carbonic
      - phosphoric
    - STRONG BASES:
      - sodium hydroxide
      - potassium hydroxide
      - calcium hydroxide
    - WEAK BASES:
      - ammonia

5.2 NET IONIC EQUATIONS

- **spectator ions**--not involved in the reaction process Λ started an ion finished an ion

- **net ionic eqn=**--balanced eqn= resulting from leaving out spectator ions (cleaner)
- THERE IS ALWAYS A CONSERVATION OF CHARGE IN NET IONIC EQN=S.

Exercise 5.3
Balance each of the following equations and write net ionic eqns.
a) barium chloride + sodium sulfate ––>

b) ammonium sulfide + cadmium nitrate ––>

c) lead (II) nitrate react with potassium chloride to give lead (II) chloride and potassium nitrate

5.3 TYPES OF RXNS IN AQ SOLUTIONS
EXCHANGE REACTIONS

- **exchange reactions**--a.k.a. double replacement, single replacement, metathesis, and oxidation-reduction reactions
- Precipitation rxns.--insoluble precipitate (ppt) from soluble reactants.

Exercise 5.4
Complete and balance the following. Indicate whether each substance is soluble or insoluble in water. Write the net ionic equations.
a) silver nitrate + lithium chloride ––>

b) nickel (II) chloride + sodium sulfide ––>

- acid-base reactions: form a
- salt and water when a strong base and strong acid react.
- the net ionic reaction for this process is $H_3O^+(aq) + OH^-(aq) \longrightarrow 2\ H_2O\ (l)$

Exercise 5.5
Write complete balanced equations for
a) the reaction of sulfuric acid with potassium hydroxide. Assume that both of the hydrogen ions from the acid are used in the reaction.

b) the reaction of ammonia with hydrochloric acid.

- GAS FORMING REACTIONS: carbonates with acids
- a salt and carbonic acid is formed
- carbonic acid is unstable and decomposes readily to form carbon dioxide and water (pop goes flat!)

Exercise 5.6
Write a balanced equation for the reaction of sodium carbonate with nitric acid.

Exercise 5.7
Complete and balance each of the following. Give the type of each rxn.
a) sulfuric acid + cesium hydroxide ––>

b) sulfuric acid + sodium carbonate ––>

c) nitric acid + calcium hydroxide ––>

d) cadmium chloride + sodium sulfide ––>

Exercise 5.8
Write a balanced equation to show how you would prepare each of the following salts by an acid-base, ppt, or gas-forming reaction.

a) NaCl

b) potassium nitrate

c) barium nitrate

d) iron (II) sulfide

$$\text{Molarity}\,[\text{M}] = \frac{\text{moles of solute}}{\text{Liters of solution}}$$

5.4 STOICHIOMETRY OF REACTIONS IN SOLUTION

- **<u>Molarity</u>**--concentration unit of moles per liter. [NaCl] = .75 M means .75 moles of salt is contained in 1.00 L of **solution**. The square brackets indicate whatever is inside is a) in solution and b) its concentration is expressed in molarity.

$$M = \frac{g/FW}{\text{Liters of solution}}$$

Exercise 5.9
Sodium bicarbonate is used in baking powder formulations, in fire extinguishers, and in the manufacture of plastics and ceramics, among other things. If you have 26.3 g of the compound and dissolve it in enough water to make 200. ml of solution, what is the molar concentration?

- Multiply the ions by their subscript if asked how many are present in a blah blah M soln of the whole cmpd.

Exercise 5.10
Both lithium chloride and ammonium sulfate are strong electrolytes, dissociating completely into their constituent ions when dissolved in water. For each cmpd, write a balanced equation for the dissociation. Assume enough of each has been dissolved so that [LiCl] = 1.0 M and [ammonium sulfate] = 0.5 M and then state the molar concentration of each ion and the total concentration of all ions.

- Preparing Solutions of Known concentration
- Use a **volumetric** flask, weigh out the solid as accurately as possible, use enough distilled water to dissolve the solid THEN add water, filling to the mark on the flask. If you dump solid into 1 L of water you are neglecting the space the solid will occupy and your soln will NOT be correct.

Exercise 5.11
An experiment in your lab requires 500. ml of a 0.0200 M solution of potassium permanganate. You are given a bottle of solid potassium permanganate, some distilled water, and a 500. ml volumetric flask. Describe how you would to about making up the required soln.

$$M_1V_1 = M_2V_2$$

- Preparing solutions by dilution. Often your soln involves diluting a more concentrated soln=. (most common with acids)

Exercise 5.12
An experiment calls for you to use 300. ml of 1.00 M NaOH, but you are given a large bottle of 3.00 M NaOH. Tell how you would make up the 1.00 M NaOH in the desired volume.

- Stoichiometry of Reactions in Aqueous Solns

Number of moles = M x L of solution

Exercise 5.13
If you have 25.0 ml of 0.750 M HCl, how many grams of sodium bicarbonate are required to react completely with the acid? How many grams of salt are produced?

- Titrations
- The reaction is done in such a way that you know when the base being added is *exactly* the amount required to react with **all** the acid present in soln.
- the exact volume of the base is known when you have reached the point where the exact stoichiometric reaction has occurred
- the concentration of the base is known exactly
  - **equivalence point**--# moles of OH^- equals (is equivalent to) # moles of H_3O^+
  - **indicator**--undergoes a color change near the equivalence point.
  - **buret**--*very expensive* tall skinny cylinder that is calibrated; volumes can be determined to 0.01 ml.
  - **pipet**--volumetric--even better than a buret but only good for one measurement (i.e. 10.00 ml); graduated--as good as a buret and useful for a range of measurement.
  - **standardization**--a procedure for establishing the *exact concentration* of a reagent (ex. 5.13)

Exercise 5.14
Vinegar contains acetic acid. You can determine the mass of acetic acid in a vinegar sample by titrating with sodium hydroxide of known concentration. Write the reaction that occurs:

If you find that a 25.00 ml sample of vinegar requires 28.33 ml of a 0.953 M soln of sodium hydroxide for titration to the equivalence point, how many grams of acetic acid are there in the vinegar sample? What is the molar concentration of the acetic acid in the vinegar?

Exercise 5.15
Hydrochloric acid can be purchased from chemical supply houses in solutions that are exactly 0.100 M, so these solutions can be used to standardize the solution of a base. If you titrate to the eq. pt. 25.00 ml of a sodium hydroxide solution with 32.56 ml of 0.100 M HCl, what is the concentration of the base?

- Chemical analysis of mixtures by PRECIPITATION REACTIONS
- form an insoluble salt, filter the salt out and then dry and determine its mass.
- use stoichiometry to determine the number of moles of acid/base present originally.

Exercise 5.16

Suppose you have a solid that consists of some barium chloride contaminated with sodium chloride. To analyze the mixture, you must find a way to separate the barium ions from the sodium ions and then isolate the barium ion in the form of a cmpd of known formula. Therefore, you take 1.023 g of the solid mixture, dissolve it in water, and add sulfuric acid to form insoluble barium sulfate and leave sodium chloride in soln. If the barium sulfate has a mass of 0.560 g after isolating and drying, calculate a) the weight percentage of barium in the sample and b) the number of grams of barium chloride in the original mixture.