Chemical Reactions

– chemical changes (chemical reactions)
– reactants and products

3.1 Chemical Equations

Reactants → Products

- Skeletal equations - show identities of reactants and products

$$H_2 + O_2 \rightarrow H_2O$$

- Law of conservation of mass
  – atoms are neither created nor destroyed (they only change bonding partners)
  – same atoms are present in reactants as in products
- Balanced chemical equations
  – same number of atoms of each element appear on each side of the equation
  – stoichiometric coefficients - needed to balance the equations

$$2H_2 + O_2 \rightarrow 2H_2O$$

(**2 mol H_2** react with **1 mol O_2** to form **2 mol H_2O**)

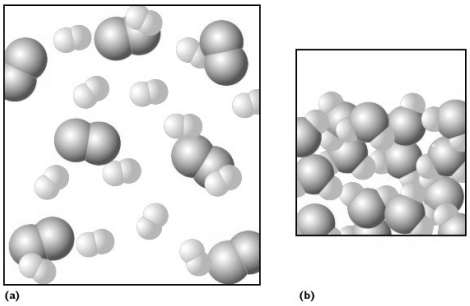

Fig. 3.3

– the stoichiometric coefficients can be treated as relative number of moles of reactants and products
– physical state symbols
  • (s) solid; (l) liquid; (g) gas; (aq) aqueous solution

$$2K(s) + 2H_2O(l) \rightarrow 2KOH(aq) + H_2(g)$$

3.2 Balancing Chemical Equations

- Balancing by inspection (only simple cases)
  – change stoichiometric coefficients
  – never change subscripts of formulas

- Systematic method
  – balance one element at a time using coefficients
  – start with the element present in the fewest number of formulas and finish with the element present in the greatest number of formulas
  – use fractional coefficients if necessary
  – if necessary multiply the whole equation by a number to clear the fractional coefficients
  – verify that the coefficients are the smallest whole numbers
  – specify physical states

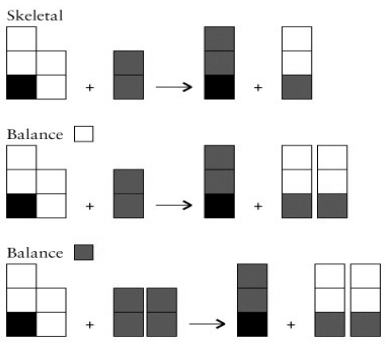

Fig. 3.4

Example: Write the balanced equation for the combustion of ethane, C_2H_6, to carbon dioxide and liquid water.

$C_2H_6 + O_2 \rightarrow CO_2 + H_2O$ **skeletal**

$C_2H_6 + O_2 \rightarrow 2CO_2 + H_2O$ **for C**

$C_2H_6 + O_2 \rightarrow 2CO_2 + 3H_2O$ **for H**

$C_2H_6 + (7/2)O_2 \rightarrow 2CO_2 + 3H_2O$ **for O**

multiply eq. by 2

$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$

$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(l)$

– Often polyatomic ions can be treated as single entities

Example: Balance the following skeletal eq. in aqueous solution: **$Co(NO_3)_3 + (NH_4)_2S \rightarrow Co_2S_3 + NH_4NO_3$**

→balance Co and S:

$2Co(NO_3)_3 + 3(NH_4)_2S \rightarrow Co_2S_3 + NH_4NO_3$

→ balance NH_4 and NO_3:

$2Co(NO_3)_3 + 3(NH_4)_2S \rightarrow Co_2S_3 + 6NH_4NO_3$

→add physical state symbols:

$2Co(NO_3)_3(aq) + 3(NH_4)_2S(aq) \rightarrow Co_2S_3(s) + 6NH_4NO_3(aq)$

Precipitation Reactions

– Precipitate formation

Fig.3.6

3.3 Aqueous Solutions

- Soluble and insoluble substances
- Concentration of solutions - amount of solute per unit volume
- Electrolytes - produce ions in solution (resulting solution conducts electricity)
  - strong electrolytes - completely ionize in solution (soluble salts, strong acids and bases such as NaCl, HCl, KOH, ...)
  - weak electrolytes - partially ionize in solution (weak acids and bases such as H_2S, NH_3, ...)

- Nonelectrolytes - do not ionize in solution (resulting solution doesn't conduct electricity)

molecular compounds (except acids and bases) such as H_2O, sugar, acetone, methanol, …

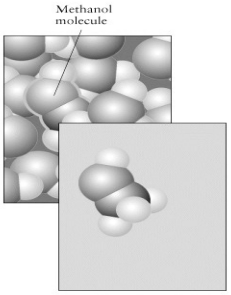

Fig. 3.10

3.4 Reactions between Strong Electrolyte Solutions

- Hydration (solvation) of ions in solution - ions are surrounded by water (solvent) molecules

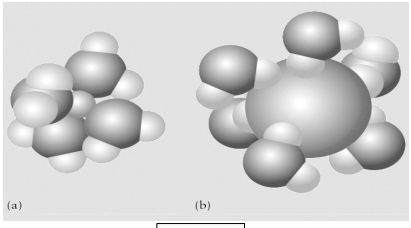

Fig. 3.13

- Precipitation reaction - formation of an insoluble product after mixing of two electrolyte solutions

$$\underset{\text{solution}}{AgNO_3(aq)} + \underset{\text{solution}}{NaCl(aq)} \rightarrow \underset{\text{precipitate}}{AgCl(s)} + \underset{\text{solution}}{NaNO_3(aq)}$$