Acid-Base Reactions

- There are four acid-base reaction combinations that are possible:
  - Strong acids – strong bases
  - Strong acids – weak bases
  - Weak acids – strong bases
  - Weak acids – weak bases
- General name – neutralization reactions
- Most of these reactions result in the formation of salt and water

Strong Acid + Strong Base

- Type 1 – formation of a soluble salt:
  - $HNO_3(aq) + NaOH(aq) \rightarrow NaNO_3(aq) + H_2O(\ell)$
  - $2HBr(aq) + Ca(OH)_2(s) \rightarrow CaBr_2(aq) + 2H_2O(\ell)$
- Type 2 – formation of an insoluble salt:
  - $H_2SO_4(aq) + Ba(OH)_2(aq) \rightarrow BaSO_4(s) + 2H_2O(\ell)$

Strong Acid + Weak Base

- Always form a soluble salt:
  - $HNO_3(aq) + NH_3(g) \rightarrow NH_4NO_3(aq)$
  - $H_2SO_4(aq) + NH_3(g) \rightarrow (NH_4)_2SO_4(aq)$
- Reactions of acids with ammonia lead only to the formation of soluble salts
- Water is not formed in these reactions

Weak Acid + Strong Base

- Always form a soluble salt:
  - $HNO_2(aq) + NaOH(aq) \rightarrow NaNO_2(aq) + H_2O\ (\ell)$
  - $H_2SO_3(aq) + 2RbOH(aq) \rightarrow Rb_2SO_3(aq) + 2H_2O\ (\ell)$

Weak Acid + Weak Base

- Always form a soluble salt:
  - $CH_3COOH(l) + NH_3(g) \rightarrow NH_4(CH_3COO)(aq)$
  - $HF(g) + NH_3(g) \rightarrow NH_4F(aq)$
- But…

  these reactions proceed in the opposite direction because the products are unstable in water
- The salts formed by weak acid and weak base are not stable in aqueous solution !!!

Acidic Salts

- Polyprotic acids have more than one proton in their molecules
- When reacted with insufficient amount of a base, such acids do not lose all of their protons
- The salts formed in such reactions are called acidic salts since they can further react with bases

Acidic Salts

- Example
- Sulfuric acid and sodium hydroxide are reacted

  - in a **1:1** ratio

  $H_2SO_4(aq) + NaOH(aq) \rightarrow NaHSO_4(aq) + H_2O(\ell)$

  The acidic salt sodium hydrogen sulfate is formed

  - in a **1:2** ratio

  $H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(\ell)$

  The normal salt sodium sulfate is formed

- Sodium sulfate can also be formed from the acidic salt sodium hydrogen sulfate:

  $NaHSO_4(aq) + NaOH(aq) \rightarrow Na_2SO_4(aq) + H_2O(\ell)$

Example 1

- Write total and net ionic equations for the reaction of 2 moles of cesium hydroxide with 1 mole of phosphoric acid. Name the salt that is formed.

Basic Salts

- Basic salts are formed by the reaction of polyhydroxy bases with less than the stoichiometric amount of acid
- Example

$$Ba(OH)_2(aq) + HCl(aq) \rightarrow Ba(OH)Cl(aq) + H_2O(\ell)$$

The basic salt barium hydroxochloride is formed

$$Ba(OH)_2(aq) + 2HCl(aq) \rightarrow BaCl_2(aq) + 2H_2O(\ell)$$

The normal salt barium chloride is formed

- Barium chloride can also be formed from the basic salt barium hydroxochloride:

$$Ba(OH)Cl(aq) + HCl(aq) \rightarrow BaCl_2(aq) + H_2O(\ell)$$

Example 2

- Write total and net ionic equations for the reaction of 1 mole of strontium hydroxide with 1 mole of hydrobromic acid. Name the salt that is formed.

The Lewis Theory

- This is the most general of the present day acid-base theories
  - It emphasizes what happens to the electrons as opposed to what happens to the protons
- Acids are **electron pair acceptors**
- Bases are **electron pair donors**
- An acid-base reaction is a transfer of the electron pair from base to acid

The Lewis Theory: Examples

- $NH_3 + H_2O \rightarrow NH_4^+ + OH^-$

- $HBr + H_2O \rightarrow H_3O^+ + Br^-$

The Lewis Theory

- The Lewis theory is more general than the Brønsted-Lowry theory since it is not limited to the compounds with protons

$$NaF + BF_3 \rightarrow Na^+ + BF_4^-$$

- Neutralization in the sense of the Lewis theory is the formation of a covalent bond through the donor-acceptor mechanism

Example 3

- Describe the reaction between BF_3 and NH_3 in terms of the Lewis theory

The Lewis Theory

- Lewis bases – electron pair donors
  - Species with a lone pair of electrons
  - Anions
- Lewis acids – electron pair acceptors
  - Species with an incomplete octet
  - Cations
  - Molecules with polar double bonds
  - Atoms with expandable valence shells

The Lewis Theory: Examples

- $H^+ + OH^- \rightarrow$
- $Na^+ + Cl^- \rightarrow$
- $CO_2 + H_2O \rightarrow$
- $SnCl_4 + 2Cl^- \rightarrow$

CHAPTER 11

- Reactions in Aqueous Solutions II: Calculations

Concentration of Solutions

- Percent by mass

$$\%\ \text{by mass of solute} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100\%$$

- Molarity

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

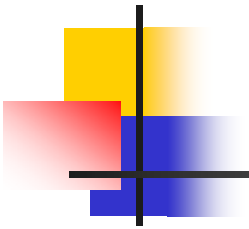
Example 4

- 12.4 g of Na_2SO_4 is dissolved in 120 ml of water. What is the molarity of the soltution with respect to

  - sodium sulfate ?
  - sulfate anions ?
  - sodium cations ?

Example 5

- 300 ml of a 0.2 M solution of cesium hydroxide was neutralized with 200 ml of a 0.3 M solution of acetic acid. What is the resulting molarity of the obtained cesium acetate solution?



Reading Assignments

- Read Chapter 10 completely
- Read Sections 4-5 & 4-6 of Chapter 4
- Read Section 6-8 of Chapter 6