ACIDS AND BASES

1. THEORIES OF ACIDS AND BASES

1.1. Arrhenius Theory

An **Arrhenius acid** is a substance that when added to water increases the concentration of H^+ ions present. The chemical formulas of Arrhenius acids are written with the acidic hydrogens first. An **Arrhenius base** is a substance that when added to water increases the concentration of OH^- ions present. HCl is an example of an Arrhenius acid and NaOH is an example of an Arrhenius base.

$$HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$$
$$NaOH(aq) \rightarrow Na^+(aq) + OH^-(aq)$$

The H^{1+} ion produced by an Arrhenius acid is always associated with a water molecule to form the hydronium ion, $H_3O^+(aq)$. Arrhenius acids are frequently referred to as proton donors, hydrogen ion donors, or hydronium ion donors, depending on whether we are trying to emphasize the species liberated by the acid (proton or hydrogen ion) or the species present in solution (hydronium ion). To represent the transfer of the H^+ ion to water to form the hydronium ion, we must include H_2O in the chemical equation for acid ionization.

$$HCl(aq) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$$

Arrenhius theory most limited of the three theories since it requires reactions be aqueous and applies only to substances producing H_3O^+ or OH^-.

1.2. Bronsted/Lowry Theory

Unlike the Arrenhius theory, their approach was not limited to aqueous solutions but for all proton (H+) containing systems.

- **ACID: Substance that can donate proton (H^+).**
- **BASE: Substance that can accept proton (must contain lone pair of electrons).**

Acids may be cations, neutral molecules, or anions, while bases may be anions or neutral molecules. Just as a reduction must always accompany an oxidation, a proton donor (acid) must accompany a proton acceptor (base). Once an acid transfers its proton it becomes the conjugate base (CB) and once a base accepts the proton it becomes the conjugate acid (CA). Since protons are always transferred in the Arrenhius concept, **all Arrhenius acid/base reactions are also Bronsted-Lowry acid/base reactions**.

But if water is not involved (HCl & NH3), the reaction can be explained by Bronsted/Lowry concept and not Arrenhius.

$$\mathrm{HCl(aq) + NH_3(aq) \rightarrow NH_4^+(aq) + Cl^-}$$

Bronsted/Lowry expands Arrenhius to include any proton transfer (water not requirement).

1.3. Lewis Theory

Just as the Arrenhius theory did not support observations of acid-base behavior in nonaqueous systems, the Bronsted-Lowry model excluded nonprotonated systems. Lewis suggested his theory in a 1923 book "Thermodynamics and the Free Energy of Chemical Substances" and fully developed the theory in 1938.

- **ACID: Substance that can accept a pair of electrons from another atom to form a new bond.**
- **BASE: Substance that can donate a pair of electrons to another atom to form a new bond.**

The product of Lewis acid-base reaction referred to as adduct. The proton itself can act as Lewis acid. Lewis expands acid/base reactions to include many substances without H in formula.

$$F_3B + : NH_3 \rightarrow F_3B: NH_3$$

The above reaction can be explained by Lewis but not Arrenhius nor Bronsted Lowry. **All Bronsted/Lowry acid/base reactions are also Lewis acid/base reactions.**