Session 9: LECTURE OUTLINE (SECTIONS J1 – J3 pp F67 – F72)

I. Acids and Bases: The Arrhenius Theory
   a. Acid
   b. Base
   c. Examples

II. Acids and Bases: The Bronsted-Lowry Theory
   a. Acid
   b. Base
   c. Examples
   d. Inorganic acids
   e. Organic acids
   f. Monoprotic acids
   g. Polyprotic acids

III. Strong and Weak Acids and Bases
   a. Strong acids
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   c. Ionization of Strong acids and bases
   d. Ionization of Weak acids and bases

IV. Neutralization
   a- Neutralization net ionic equation
   a. Formula unit equation
   b. Complete ionic equation
   c. Spectator ions
   d. Net ionic equation
   e. Examples

V. Using Solutions in Chemical Reactions
   a- Problems

Suggested problems: pp F69-F71 J.1A, J.1B, J.2A, J.2B
p F72 J.1, J.2, I.3, J.5, J.6, J.7, J.8

ACIDS AND BASES

THE ARRHENIUS THEORY

- **Acid:** compound that produces H^+ in aqueous solution.

  HCl ---------→ H^+ + Cl^-

- **Base:** compound that produces OH^- in aqueous solution.

  $NaOH$ ----------→ Na^+ + OH^-

Sodium metal reacts with water to produce, OH^-. However, it is not considered an Arrhenius base as it is an element and not a compound.

The Arrhenius definitions are specific to one solvent only, WATER.

THE BRONSTED LOWRY THEORY

- **Acid:** An acid is a proton donor.

- **Base:** A base is a proton acceptor.

When hydrogen chloride, HCl, dissolves in water, in donates a hydrogen ion, to water. Once a water molecule accepts the H^+ from the acid, it becomes the hydronium ion, H_3O^+.
$HCl(g)$ + $H_2O(l)$ -----------→ $H_3O^+(aq)$ + $Cl^-(aq)$

Hydroxide ions accept protons from acetic acid and are therefore bases.

$OH^-(aq)$ + CH_3COOH (aq) -------→ $H_2O(l)$ + $CH_3COO^-(aq)$
NaOH is a base because it supplies OH^- ions, which in turn are the protons acceptors.
Ammonia, NH_3, is a base because it accepts a proton from water to form the ammonium ions, NH_4^+
$NH_3(aq)$ + $H_2O(l)$ -----------→ $OH^-(aq)$ + NH_4^+ (aq)
Note that compounds such as CH_4, for example, are not Bronsted acids. Although methane contains four hydrogens, it does not release hydrogen ions to other substances.

- The hydrogen atom that can be released as a proton is called the acidic hydrogen.
- In inorganic acids such as <u>H</u>Cl and <u>H</u>NO_3, the acidic hydrogen is written as the first element in the molecular formula.
- In organic acids, the acidic hydrogen is the one in the carboxyl group, COO<u>H</u>. When writing the formula of an organic acid, the COOH group is usually shown at the end of the molecular formula, example, acetic acid, CH_3COO<u>H</u>.
- An acid that donates one proton is called a monoprotic acid, example, HCl.
- An acid that can donate more than one proton is called a polyprotic acid, example, H_2SO_4.

STRONG AND WEAK ACIDS AND BASES

A strong acid ionizes completely in solution. There are seven common strong acids.

HCl	hydrochloric acid
HBr	hydrobromic acid
HI	hydroiodic acid
HNO_3	nitric acid
$HClO_3$	chloric acid
$HClO_4$	perchloric acid
H_2SO_4	sulfuric acid

A strong base dissociates completely in solution. There are eight common strong bases. They include the hydroxides of groups IA and IIA metals.

LiOH	lithium hydroxide
NaOH	sodium hydroxide
KOH	potassium hydroxide
RbOH	rubidium hydroxide
CsOH	cesium hydroxide
$Ca(OH)_2$	calcium hydroxide
$Sr(OH)_2$	strontium hydroxide
$Ba(OH)_2$	barium hydroxide

A weak acid partially ionizes in solution. Acetic acid, CH_3COOH, is a weak acid in water. Only a small fraction of its molecules undergo ionization.

$CH_3COOH\,(aq) + H_2O(l) \text{ -------}\rightarrow H_3O^+\,(aq) + CH_3COO^-(aq)$

A weak base partially ionizes or dissociates in solution. Ammonia, NH_3, is the most famous weak base. Only a small fraction of the NH_3 molecules accept a proton to form NH_4^+.

$NH_3(aq) + H_2O(l) \text{ -----------}\rightarrow OH^-(aq) + NH_4^+(aq)$

STRONG ACIDS AND STRONG BASES COMPLETELY IONIZE OR DISSOCIATE IN WATER AND THEREFORE, ARE STRONG ELECTROLYTES.
WEAK ACIDS AND WEAK BASES SLIGHTLY IONIZE OR DISSOCIATE IN WATER AND THEREFORE, ARE WEAK ELECTROLYTES.

NEUTRALIZATION

It is the reaction between an acid and a base. The neutralization reaction between a strong acid and a strong base is illustrated by the following chemical equation:

Acid + Base ---------→ Salt + water

In a neutralization reaction, the salt is made out of the anion from the acid and the cation from the base.

Example1
Write the complete ionic and the net ionic equation for the following formula unit equation:
HCl (aq) + NaOH(aq) --------------→ NaCl(aq) + H_2O(l)

The complete ionic equation is:

$H^+(aq) + Cl^-(aq) + Na^+(aq) + OH^-(aq) \text{ ---------}\rightarrow H_2O(l) + Na^+(aq) + Cl^-(aq)$

For the complete ionic equation, we break into ions everything that is a strong electrolyte. We have a strong acid and a strong base as reactants. They are both strong electrolytes and therefore, we break them into ions. On the other hand, we have water, and a soluble salt as products. Only the soluble salt is a strong electrolyte and therefore, we break it into ions and leave water alone!

The corresponding net ionic equation is:

$H^+(aq) + OH^-(aq) \text{ ---------}\rightarrow H_2O(l)$

For the net ionic equation, we cancel the spectator ions or the species that did not undergo any change in the course of the chemical reaction. These are: Na^+ and Cl^-

The net ionic equation for a neutralization reaction between a strong acid and a strong base is:
$H^+(aq) + OH^-(aq)$ ---------→ $H_2O(l)$

Example 2
Write the formula unit equation, the total ionic equation, and the net ionic equation for the neutralization reaction between nitric acid and barium hydroxide.

Formula unit equation:
$2HNO_3(aq) + Ba(OH)_2(aq)$ -------------→ $2H_2O(l) + Ba(NO_3)_2(aq)$

For the complete ionic equation, we break into ions everything that is a strong electrolyte. We have a strong acid and a strong base as reactants. They are both strong electrolytes and therefore, we break them into ions. On the other hand, we have water and a soluble salt as products. Only the soluble salt is a strong electrolyte and therefore, we break it into ions and leave water alone!
$2H^+(aq) + 2NO_3^-(aq) + Ba^{2+}(aq) + 2OH^-(aq)$ -------→
$2H_2O(l) + Ba^{2+}(aq) + 2NO_3^-(aq)$
For the net ionic equation, we cancel the spectator ions or the species that did not undergo any change in the course of the chemical reaction. These are: $Ba^{2+}(aq) + 2NO_3^-$

The equation becomes:
$2H^+(aq) + 2OH^-(aq)$ -------→ $2H_2O(l)$

NOTE: When we write a chemical equation, we have to use the smallest whole numbers possible to balance it. The equation above is balanced but not with the smallest whole numbers. By dividing the coefficients by 2, we obtain the net ionic equation in its correct form!

The net ionic equation is:
$H^+(aq) + OH^-(aq)$ -------→ $H_2O(l)$

Example 3 (answers and solution will be provided in class)

Write the formula unit equation, the total ionic equation, and the net ionic equation for the neutralization reaction between hydrofluoric acid and sodium hydroxide.

Formula unit equation

Complete ionic equation

Net ionic equation

STOICHIOMETRY PROBLEMS WHEN USING SOLUTIONS IN CHEMICAL REACTIONS

Example1

We use 625.0 mL of an NaOH solution to completely neutralize 4.50 grams of H_3PO_4. What is the molarity of the NaOH solution?

- We write the corresponding chemical equation:

  $3NaOH\ (aq) + H_3PO_4\ (aq) \longrightarrow Na_3PO_4\ (aq) + 3H_2O\ (l)$

- Calculate the available moles of H_3PO_4 and use the mole ratio to calculate the number of moles of NaOH needed for complete neutralization:

  $$\frac{4.50 \text{ g } H_3PO_4}{} \left| \frac{1 \text{ mole } H_3PO_4}{98.0 \text{ g } H_3PO_4} \right| \frac{3 \text{ moles NaOH}}{1 \text{ mol } H_3PO_4} = 0.138 \text{ mols NaOH}$$

- Calculate the molarity of the NaOH used:

  $$M = \frac{\#\text{moles}}{V\ (L)}$$

  $$M_{NaOH} = \frac{0.138 \text{ mols NaOH}}{.625 \text{ L}} = .220 \text{ M}$$

Example 2 (answers and solution will be provided in class)
What volume of 0.405 M KOH solution is just sufficient to react completely with 2.15 g of Copper(II) sulfate, $CuSO_4$?