Session 8: LECTURE OUTLINE (SECTIONS I1 – I4 pp F61 – F67)

I. Elecrolytes
   a. Soluble substances
   b. Insoluble substances
   c. Electrolytes
   d. Non-Electrolytes
   e. Ions and electrical conductivity
   f. Strong and weak electrolytes

II. Strong Electrolytes
   a. Strong acids
   b. Strong soluble bases
   c. Soluble salts
   d. Solubility rules (table I.1 p. F65)

III. Weak Electrolytes
   a. Weak acids
   b. Weak bases
   c. Sparingly soluble salts

IV. Ions and Net Ionic Equations
   a. Formula unit equation
   b. Complete ionic equation
   c. Spectator ions
   d. Net ionic equation
   e. Example

V. Precipitation Reactions
   a- Definition
   b- Examples

Suggested problems: pp F63-F64 I.1A, I.1B, I.2A, I.2B
pp F66-F67 I.3A, I.3B, I.1, I.3, I.7, I.9, I.11, I.13, I.15, I.17, I.19

ELECTROLYTES

- Soluble substances dissolve to a good extent in a specific solvent.
- Insoluble substances do not dissolve to a good extent in a specific solvent (not more than 0.1 mol/L)
- In water, a soluble substance is classified as either an electrolyte or a non-electrolyte.
- A substance whose aqueous solution conducts electricity is called an electrolyte.
- A substance whose aqueous solution does not conduct electricity is called a non-electrolyte.
- In order for a solution to conduct electricity, it must contain ions.
- Non-electrolytes dissolve without producing ions in water. Table sugar is a non-electrolyte. If we were able to look at the molecular level of an aqueous solution of table sugar, we would see the individual molecules intact and dispersed in the solution surrounded by water molecules.
- Electrolytes break into ions as they dissolve in water. A compound that breaks entirely into ions as it dissolves in water is called a strong electrolyte. A compound that breaks partially into ions as it dissolves in water is a weak electrolyte. *At the same molar concentration a strong electrolyte is a much better conductor than a non-electrolyte.*

STRONG ELECTROLYTES

As mentioned above, a compound that breaks entirely into ions as it dissolves in water is called a strong electrolyte. Substances that are strong electrolytes include: strong acids, strong bases, and the soluble salts.

Strong acid $HCl \text{ ---------} \rightarrow H^+ + Cl^-$
Strong base $NaOH \text{ ------} \rightarrow Na^+ + OH^-$
Soluble salt $NaCl \text{ --------} \rightarrow Na^+ + Cl^-$

How do we recognize the strong acids and the strong bases?
We memorize them! The seven common strong acids are:

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

The eight common strong bases are:

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

In order to determine whether a salt is soluble or not, one can check the solubility rules for ionic compounds:

Generally Soluble	**Exceptions**
Grp 1 element compounds	No common exceptions
Ammonium NH_4^+ compounds	No common exceptions
chlorides (Cl^-), bromides (Br^-);	those of Ag^+, Pb^{+2}, and Hg_2^{+2}
sulfates (SO_4^{2-})	$BaSO_4$, $PbSO_4$, $HgSO_4$ $CaSO_4$, $SrSO_4$, Ag_2SO_4
nitrates (NO_3^-), chlorates (ClO_3^-), perchlorates (ClO_4^-), acetate (CH_3COO^-)	No common exceptions

Generally Insoluble	**Exceptions**
Sulfides (S^{2-})	Soluble: those of NH_4^+, and those of Grp I and II elements.
oxides (O^{2-}) and	Soluble: Li_2O, LiOH, Na_2O,
hydroxides (OH^-)	NaOH, K_2O, KOH, BaO, $Ba(OH)_2$
	Moderately soluble: CaO, $Ca(OH)_2$, SrO, $Sr(OH)_2$
carbonates (CO_3^{2-}), phosphates (PO_4^{3-}), chromates (CrO_4^{2-})	Soluble; those of NH_4^+ and those of Grp I

oxalates ($C_2O_4^{2-}$)

WEAK ELECTROLYTES

A compound that breaks partially into ions as it dissolves in water is called a weak electrolyte. The weak electrolyte category includes the slightly soluble salts, the weak acids, and the weak bases.

IONS AND NET IONIC EQUATIONS

Formula unit equations: Show all reactants and products each followed by their physical state: (s), (l), (g), or (aq).

Complete ionic equations: Show each substance in its predominant form in aqueous solution. Only strong electrolytes exist predominantly as ions in aqueous solutions and therefore, in total ionic equations, they have to be separated into their corresponding ions. Everything else is left in its formula unit form.

Net ionic equations: Show all the species that take an active part in the actual chemical reaction. Net ionic equations are obtained by canceling spectator ions.

Example: Write the complete ionic and net ionic equations that correspond to the following formula unit equation:

Na_2SO_4 (aq) + $Ba(NO_3)_2$ (aq) ----------→ $BaSO_4$ (s) + 2$NaNO_3$ (aq)

The complete ionic equation:
$2Na^+(aq) + SO_4^{-2}(aq) + Ba^{+2}(aq) + 2NO_3^-(aq)$---→ $BaSO_4(s) + 2Na^+(aq) + 2NO_3^-(aq)$

We break into ions the strong electrolytes. In the above chemical equation, we have only salts. We know that soluble salts are strong electrolytes. These are: sodium sulfate, barium nitrate, and sodium nitrate. Note that we do not need to check the solubility rules as the status of each salt is specified in the above chemical equation. A soluble salt status is identified as aqueous (aq) and an insoluble salt is identified as solid (s).

We eliminate spectator ions to get the net ionic equation:
$SO_4^{-2}(aq) + Ba^{+2}(aq)$ ---→ $BaSO_4(s)$

The Na^+ ion and the nitrate ion exist on both the reactants side and the products side. They did not undergo any change and therefore are spectator ions.

PRECIPITATION REACTIONS

The chemical equation in the above example represents a precipitation reaction. In general, a precipitation reaction occurs when solutions of two strong electrolytes react to give a precipitate.

Na_2SO_4 (aq) + $Ba(NO_3)_2$ (aq) ----------→ $BaSO_4$ (s) + 2$NaNO_3$ (aq)

Example1

Predict if a precipitate would form when aqueous solutions of silver nitrate and potassium chloride are mixed together. Write the corresponding net ionic equation for the reaction.

We can predict if a precipitate would form by deciding which ions are present in the mixed solutions, and considering all possible new combinations. We will then consult the solubility rules to check if any of the possible combination corresponds to an insoluble compound. Once this combination identified, we write the corresponding net ionic equation.

Ions present: Ag^+, NO_3^-, K^+, Cl^-
The possible new combinations are: AgCl, and KNO_3.
The insoluble combination is: AgCl
So, we write the net ionic equation:
Ag^+ (aq) + Cl^- (aq) ---------→ AgCl (s)

Example2

Suggest two solutions that can be mixed to prepare calcium phosphate.

We need to start with two solutions that contain the needed ions: Ca^{2+} and PO_4^{3-} By checking the solubility rules, we notice that nitrate salts are always soluble and so are the sodium salts. So it makes sense to use calcium nitrate, $Ca(NO_3)_2$, as a source of Ca^{2+} and sodium phosphate, Na_3PO_4, as a source of PO_4^{3-}.