Chapter 14 - Ions in Aqueous Solutions and Colligative Properties

14-1 Compounds in Aqueous Solutions

I. Dissociation

A. Dissociation

1. The separation of ions that occurs when an ionic compound dissolves
    a. One formula unit of NaCl produces two ions
    b. One mole of NaCl produces two moles of ions

$$NaCl(s) \xrightarrow{H_2O} Na^+(aq) + Cl^-(aq)$$

    c. One formula unit of $CaCl_2$ produces three ions
    d. One mole of $CaCl_2$ produces three moles of ions

$$CaCl_2(s) \xrightarrow{H_2O} Ca^{2+}(aq) + 2Cl^-(aq)$$

II. Precipitation Reactions

A. Solubility Rules

1. No compound is completely insoluble
2. Compounds of very low solubility can be considered insoluble
3. Dissociation equations cannot be written for insoluble compounds

Table 14-1 **General Solubility Guidelines**
1. Most sodium, potassium, and ammonium compounds are soluble in water.
2. Most nitrates, acetates, and chlorates are soluble
3. Most chlorides are soluble, except those of silver, mercury(I), and lead. Lead(II) chloride is soluble in hot water
4. Most sulfates are soluble, except those of barium, strontium, and lead
5. Most carbonates, phosphates, and silicates, are insoluble, except those of sodium, potassium, and ammonium
6. Most sulfides are insoluble, except those of calcium, strontium, sodium, potassium, and ammonium

B. Precipitation Reactions

1. A reaction between two soluble compounds in solution, resulting in at least one insoluble product
    a. Write the dissociation equations for the reacting compounds

$$Na_2SO_4(s) \xrightarrow{H_2O} 2Na^+(aq) + SO_4^{2-}(aq)$$
$$BaCl_2(s) \xrightarrow{H_2O} Ba^{2+}(aq) + 2Cl^-(aq)$$

    b. Identify the insoluble product if there is one

$$Na_2SO_4(aq) + BaCl_2(aq) \rightarrow 2NaCl(aq) + BaSO_4(s)$$

C. Net Ionic Equations

1. Includes only those compounds and ions that undergo a chemical change in a reaction in an aqueous solution
    a. Write a complete ionic equation

$$2Na^{+}(aq) + SO_4^{2-}(aq) + Ba^{2+}(aq) + 2Cl^{-}(aq) \rightarrow 2Na^{+}(aq) + 2Cl^{-}(aq) + BaSO_4(s)$$

    b. Generate a net ionic equation by eliminating spectator ions

$$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$$

Spectator ions are those ions that do not take part in a chemical rxn and are found in solution both before and after the rxn: $Na^{+}(aq)$ and $Cl^{-}(aq)$ in this rxn

III. <u>Ionization</u>

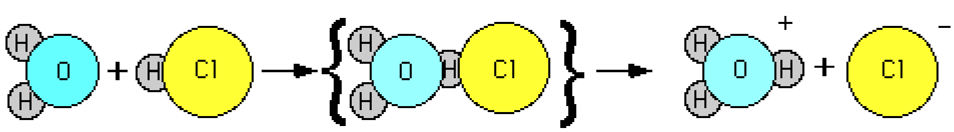
A. Ionization

1. Ions are formed from solute molecules by the action of the solvent
2. Polar water molecules are attracted to polar solute molecules
    a. Electronegative oxygen of water is attracted to electropositive portion of a solute molecule
    b. Electropositive hydrogen of water is attracted to the electronegative portion of a solute molecule

$$HCl \xrightarrow{H_2O} H^{+}(aq) + Cl^{-}(aq)$$

B. The Hydronium Ion

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



1. H_3O^{+} is called the "hydronium" ion

IV. <u>Strong and Weak Electrolytes</u>

A. Strong Electrolytes

1. Any compound of which all or almost all of the dissolved compound exists as ions in an aqueous solution
    a. All ionic compounds are strong electrolytes
    b. Hydrogen halides
        (1) HCl, HBr, HI
2. Compounds do not have to be highly soluble to be strong electrolytes.

B. Weak Electrolytes

1. A compound of which a relatively small amount of the dissolved compound exists as ions in an aqueous solution
    a. HF, organic acids

14-2 Colligative Properties

Colligative Properties: Properties that depend on the concentration of solute particles but not on their identity

I. Vapor Pressure Lowering
   A. Volatility
      1. Nonvolatile substances
         a. Substances that have little or no tendency to become a gas under existing conditions
      2. Volatile substances
         a. Substances with a definite tendency to become gases under existing conditions
   B. Effect of Solutes on Vapor-Pressure
      1. Any nonvolatile solute will lower the vapor pressure of a solution, having two noticeable effects
         a. Raising the boiling point of the solution
         b. Lowering the freezing point of the solution

II. Freezing-Point Depression
   A. Molal Freezing-Point Constant for Water
      1. The freezing-point depression of the solvent in a 1-molal solution of a nonvolatile, nonelectrolyte solute
      2. K_f = -1.86 °C/m
   B. Freezing-Point Depression
      1. The difference between the freezing points of the pure solvent and a solution of a nonelectrolyte in that solvent

$$\Delta t_f = K_f m$$

   C. Molal Boiling-Point Constant for Water
      1. The boiling point elevation of the solvent in a 1-molal solution of a nonvolatile, nonelectrolyte solute
      2. K_b = 0.51 °C/m
   D. Boiling-Point Elevation
      1. The difference between the boiling points of the pure solvent and a solution of a nonelectrolyte in that solvent

$$\Delta t_b = K_b m$$

III. Osmotic Pressure
   A. Semipermeable membranes
      1. Membranes that allow the movement of some particles while blocking the movement of others
   B. Osmosis
      1. The movement of solvent through a semipermeable membrane from the side of lower solute concentration to the side of higher solute concentration
      2. Osmosis occurs when two solutions of different concentration are separated by a semipermeable membrane

C. Osmotic Pressure
   1. The external pressure that must be applied to stop osmosis
   2. Osmotic pressure increases with the concentration of solute particles
   3. Osmotic pressure is not dependent on the TYPE of solute particles

IV. <u>Electrolytes and Colligative Properties</u>
A. Electrolytes and Solution Concentration
   1. Electrolytes dissociate or ionize to form two or more moles of particles for each mole of solute added to solution
      a. One mole of $BaCl_2$ produces 3 moles of ions in solution

$$BaCl_2(s) \xrightarrow{H_2O} Ba^{2+}(aq) + 2Cl^-(aq)$$

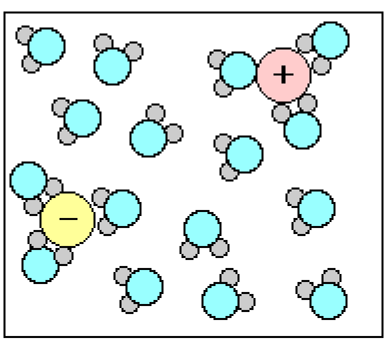
   2. Electrolytes in water solutions lower the freezing point nearly two, three, or more times as much as nonelectrolytes of the same molality
   3. Nonvolatile electrolytes in water solutions raise the boiling point nearly two, or three, or more times as much as nonelectrolytes of same molality

B. Calculated Values for Electrolyte Solutions
   1. For a 1.0 molal solution of $BaCl_2$:

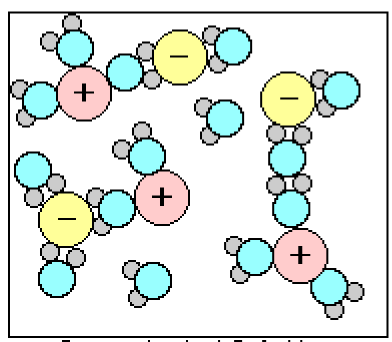
$$\Delta t_f = (-1.86\ °C/m)(3.0m) = -5.58\ °C$$

$$\Delta t_b = (0.51\ °C/m)(3.0m) = 1.53\ °C$$

C. Actual Values for Electrolyte Solutions
   1. Real values for Δt_f and Δt_b are slightly less than calculated values for electrolyte solutions
      a. Attractive forces between ions cause clustering
      b. Clustering is greatest in concentrated solutions
      c. Ideal and real results are closest in very dilute solutions
   2. The Debye-Huckel Theory
      a. Clustering hinders the movements of ions, so fewer ions appear to be present



Dilute solution



Concentrated Solution