Chapter 12: Solutions
12.1 Mixtures

- **Solution** - a homogeneous mixture of two or more substances in a single phase
- **Soluble** - capable of being dissolved
- **Solutions** - 2 Parts
  - **Solvent** - dissolving medium (Water)
  - **Solute** - Substance dissolved (Sugar)
Types of Solutions

- Solutions can exist as gases, liquids or solids.
- Depends upon the solvent state.

Examples:
- Solid dissolved into a liquid = liquid solution
- Liquid dissolved into a solid = solid solution
Suspensions

• Solute particles that are so large that they settle out of the solution unless they are constantly stirred.
• Particles are so large they can be seen.

• Muddy water
• Blood
Colloid

• Solute particles are intermediate in size of solutions and suspensions.
• They are dissolved but not completely and as a result if they are filtered the colloid will still remain in the liquid.
• Tyndall Effect – when light is shown through a colloid the particles will disperse the light and look foggy.
Tyndall Effect

Tyndall Effect -- The scattering of light by colloidal particles. Headlights in the fog.

Colloid  Solution  Fog
Electrolytes

• Solute that is dissolved creates a solution that conducts electricity.
• Acids are very good electrolytes and most ionic salts.
Solubility

• The amount of solute that dissolves in a given quantity of solvent at constant temperature.

• For Liquids
  • 2 liquids that dissolve in each other are said to be Miscible
  • Liquids that do not dissolve are immiscible.
Affecting the Rate of Solubility

• 3 Ways to speed up the dissolving process

• 1. Agitating the Solution
• 2. Increasing the Temperature of the Solvent
• 3. Grinding the Solute
  • Increases the Surface Area
Sample Problem

• How much sodium chloride can be dissolved in 750 g of H₂O at 20 ºC.
• Table A-13 pg 861 in Text
• Solubility of NaCl @ 20 ºC is 36 g/ 100g of H₂O
Types of Solutions

• Unsaturated Solutions
  – Have less than the maximum number of solute particles dissolved in a solution.

• Saturated Solutions
  – Have the maximum number of solute particles dissolved in a solution.

• Supersaturated Solutions
  – Have more than the maximum number of solute particles dissolved in a solution.
Effect of Pressure

• Higher Pressure = More Soluble (gas only)
• Henry’s Law – the solubility of a gas in a liquid is directly proportional to the partial pressure of that gas at the surface of the liquid.
• Effervescence – rapid escape of a gas from the liquid phase of a solution.
Effects of Temperature

• Increase Temperature = Increase in Solubility (solid solute)

• Increase Temperature = Decrease in Solubility (gaseous solute)
Concentration

• The amount of solute for given amount of solvent.
  • Dilute – small amount of solute/solvent
  • Concentrated – large amount of solute/solvent

• Three Different Expressions for Concentration
  • Molarity
  • Molality
  • Percent by Mass
Molarity

• The number of moles of solute dissolved in 1 Liter of Solution.

\[
\text{Molarity (M)} = \frac{\text{Number of Moles}}{\text{Liters of Solution}}
\]
Sample Problem

• A saline solution contains 0.90 g NaCl per 100 mL of Solution. What is the molarity?
• \[ M = \frac{\text{moles of Solute}}{\text{Liters of Sol’n}} \]
• Convert .90 g NaCl into moles
Sample Problem

• How many grams of Na$_2$SO$_4$ are needed to make a 2.0 L solution of 0.20 M Na$_2$SO$_4$?
Making Solutions (Dilutions)

• Many times a solution will be diluted to achieve a desired concentration.
  • \[ M = \frac{n}{L} \text{ or } n = ML \]
• Therefore
  • \[ M_1 V_1 = M_2 V_2 \]
• Remember when diluting acids:
  • “Do like you oughta, add acid to water”
Sample Problem

• How would you prepare 100. mL of 0.40 M MgSO₄ from a stock solution of 2.0M MgSO₄?

• \( M_1 V_1 = M_2 V_2 \)
Percent By Mass - %(m/m)

\[
\frac{\text{Mass of Solute}}{\text{Mass of Solute} + \text{Solvent}} \times 100
\]

- Percent By Volume - %(m/v)  volume = mL

\[
\frac{\text{Mass of Solute}}{\text{Volume of Solution}} \times 100
\]
Sample Problem

• A solution of sodium chloride is prepared by dissolving 5.0 grams of salt in 550. grams of water. What is the concentration of this solution given as percent by mass?
Sample Problem

• How many grams of Glucose (C$_6$H$_{12}$O$_6$) would you need to prepare 2.0 L of 2.0% glucose (m/v) solution?
Sample Problem

• Determine the mass of solute needed to prepare a 10.% solution of KI with 250.g of water.
Molality

• Number of moles of solute dissolved in 1 kg of solvent.

\[
\text{Molality (m)} = \frac{\text{Moles of Solute}}{\text{kg of Solvent}}
\]
Sample Problem

• How many grams of potassium iodide must you dissolve in 500.0 g of water to produce a 0.060 molal KI solution?
Sample Problem

• Determine the molality of a solution, that contains 50g of Na$_2$S in 2kg of water.
Mole Fraction (n = moles)

\[ X_{\text{solute}} = \frac{n_{\text{solute}}}{n_{\text{solute}} + n_{\text{solvent}}} \]
Sample Problem

-Compute the mole fraction of each component in a solution of 1.25 n NaCl and 4.00 n of Water?
Sample Problem

• Compute the mole fraction for each component in a solution that consists of 2 mol NaCl, 3.2 mol KI and 8 mol H₂O.
Chapter 13 – Aqueous Solutions

• Dissociation – Separation of ions when an ionic compound dissolves.
  • NaCl \( (s) \rightarrow \text{Na}^+ \text{(aq)} + \text{Cl}^- \text{(aq)} \)
  • CaCl\(_2\) \( (s) \rightarrow \text{Ca}^{2+} \text{(aq)} + 2\text{Cl}^- \text{(aq)} \)
Example Dissolution

•Write an equation for the dissolution of $\text{Al}_2(\text{SO}_4)_3$ in water. How many moles of aluminum and sulfate ions are produced by dissolving 1mol of aluminum sulfate? What is the total number of moles of ions produced?
Precipitation Reactions

• No ionic compound is completely (100%) insoluble.

• Some have such a low solubility that for most practical purposes it's easier for that substance to be labeled insoluble.
General Solubility Guidelines

1. Sodium, potassium and ammonium compounds are soluble in water.
2. Nitrates, acetates and chlorates are soluble.
3. Most chlorides except silver, mercury(I) and lead are soluble.
4. Most sulfates except barium, strontium, lead, calcium and mercury are soluble.
5. Most carbonates, phosphates are insoluble except with guideline #1.
6. Most sulfides are insoluble except calcium, strontium, potassium and ammonium.
Net Ionic Equations

• Includes only those compounds and ions that undergo chemical change in a reaction in an aqueous solution.

• Spectator Ions – Ions that do not take part in the chemical reaction.
  • Found as a reactant and product.
  • If equation only contains spectator ions then there is NO REACTION.
Net Ionic for Zinc Nitrate + Ammonium Sulfide

\[ \text{Zn(NO}_3\text{)}_2(aq) + (\text{NH}_4\text{)}_2\text{S(aq)} \rightarrow \text{ZnS} (s) + 2\text{NH}_4\text{NO}_3(aq) \]

• Net:
  • \( \text{Zn}^{2+} + 2\text{NO}_3^- + 2\text{NH}_4^+ + \text{S}^2- \rightarrow \text{ZnS} (s) + 2\text{NH}_4^+ + 2\text{NO}_3^- \)

• Minus all spectator ions:
  • \( \text{Zn}^{2+} (aq) + \text{S}^2- (aq) \rightarrow \text{ZnS} (s) \)
Ionization

• Ions are formed from solute molecules by the action of the solvent.

• All ions in a molecular solute are hydrated.

• Hydronium Ion, $\text{H}_3\text{O}^+$ ion, describes the acid component of a solution ionized by water.
Electrolytes

• Strong Electrolytes – any compound whose dilute aqueous solution conduct electricity well.
• A solution that has 100% or nearly 100% of the particles dissolved in the form of ion.

• Weak Electrolytes – any compound whose dilute aqueous solution conducts electricity poorly.
A solution that has a very low % of particles dissolved in the form of ion.
Weak Electrolyte Equation

• Write the net ionic equation for the following reaction.

\[ \text{HC}_6\text{H}_5\text{CO}_2\text{(aq)} + \text{NaOH}\text{(aq)} \rightarrow \text{NaC}_6\text{H}_5\text{CO}_2\text{(aq)} + \text{H}_2\text{O}\text{(l)} \]

• Note: \text{HC}_6\text{H}_5\text{CO}_2 \text{ (aq)} is a weak acid and does not dissociate 100% so you can’t break this compound into it’s ions.
Chapter 13 - Colligative Properties of Solutions

• Physical Properties of the solvent changes with the addition of a solute.

• 3 Important Colligative Properties
  • 1. Vapor Pressure Lowering
  • 2. Boiling Point Elevation
  • 3. Freezing Point Depression
Vapor Pressure Lowering

• Solvent particles form shells around solute particles
• Reduces the amount of kinetic energy of the solvent particles – therefore reducing the amount that escape into the vapor phase.
• The decrease in VP is proportional to the number of particles of solute in solution.
• Different Solutes have different affects on VP
• Vapor Pressure = mole fraction x normal vapor pressure
Vapor Pressure Example

- What is the vapor pressure, in kPa, of a solution with 5.50g MgCl\(_2\) in 500.g of water at 25\(^\circ\)C? Vapor pressure of pure water at 25\(^\circ\)C = 3.17kPa.
Boiling Point Elevation

- Recall – BP is Related to the Vapor Pressure
- Therefore if the VP is Lowered BP will be raised.
- More energy is needed for the VP to reach the External pressure.
- Attraction forces between Solvent + Solute particles
- Raise the amount of KE needed.
- BPE is directly proportional to the amount of Solute particles in the solution.
Freezing Point Depression

• When a substance freezes the particles take on an orderly pattern.
• The presence of solute particles disrupts this pattern – due to shells of water of hydration.
• Therefore, more KE needs to be withdrawn for freezing to occur.
• Result - lower freezing point.
Calculating BP & FP Changes

- $\Delta T_b = K_b m(\text{#particles})$
- $K_b = \text{Molal boiling point elevation constant}$.
- $K_b = 0.512 \degree C/m$
- The molality is based on the number of solute particles.
- Sugar Dissolves $\rightarrow$ 1 molecule = 1 solute particle
- NaCl Dissolves $\rightarrow$ 1 Formula unit = 2 solute particles
- NaCl(s) $\rightarrow$ Na$^+$ + Cl$^-$ (2 Particles)
Freezing Point Depression

• $\Delta T_f = K_f m(#\text{particles})$
• $K_f$ – Molal freezing point depression constant
• $K_f = 1.86^\circ C/m$
• How many solute particles do the following compounds contain?
  • $\text{Na}_2\text{S}$
  • $\text{C}_2\text{H}_6$
  • $\text{Ba}_3(\text{PO}_4)_2$
Sample Problem

• What is the boiling point of a solution that contains 1.20 moles of sodium chloride in 800 g of water?
Sample Problem #2

• How many grams of NaCl must be dissolved in 500g of water to raise the boiling point by 4 °C?
• $K_b$ for water = .512°C/m
Molecular Mass Determination

• If you know the amount of solvent and solute.
• If you know the change in BP or FP.
• If you know the solvent that was used.
• You can then find the molecular mass.
Sample Problem

• A solution of 7.50 g of a nonvolatile compound in 22.60 g of water boils at 100.78 °C at 760 mmHg. What is the molecular mass of the solute? (Assume the solute is a molecular cmpd.)

• $\Delta T_b = 0.78 \degree C$

• $K_b = 0.512$