A general chemistry Libretexts Textmap organized around the textbook

Chemistry: The Central Science
by Brown, LeMay, Busten, Murphy, and Woodward

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These is a summary of key concepts of the chapter in the Textmap created for "Chemistry: The Central Science" by Brown et al.
13.1: The Solution Process

- interaction between solute and solvent molecules
- hydration – solvation when solvent is water

13.1.1 Energy Changes and Solution Formation

- overall enthalpy change in formation of a solution
  \[ \Delta H_{\text{soln}} = \Delta H_1 + \Delta H_2 + \Delta H_3 \]
  - \( \Delta H_1 \) = separation of solute molecules
  - \( \Delta H_2 \) = separation of solvent molecules
  - \( \Delta H_3 \) = formation of solute-solvent interactions

- separation of solute particles is endothermic
- separation of solvent is endothermic
- third is exothermic
- formation of solution can be either exothermic or endothermic
- exothermic processes are spontaneous
- solution will not form if enthalpy is too endothermic
- \( H_3 \) has to be comparable to \( H_1 + H_2 \)
  - Ionic substances cannot dissolve in nonpolar liquids
  - Polar liquids do not form solutions with nonpolar liquids

13.1.2 Solution Formation, Spontaneity, and Disorder

- two nonpolar substances dissolve in one another
- attractive forces = London dispersion forces
- two factors in processes that are spontaneous: energy and disorder
- processes in which the energy content of the system decreases tend to occur spontaneously
  - exothermic
- processes in which the disorder of the system increases tend to occur spontaneously
- solutions will form unless solute-solute or solvent-solvent interactions too strong relative to solute-solvent interactions

13.1.3 Solution Formation and Chemical Reactions

- distinguish between physical process of solution formation from chemical process that leads to a solution

13.2: Saturated Solutions and Solubility

- crystallization – reverse process of solution
- dynamic equilibrium – when equilibrium exists between process of solution and crystallization
• solute said to be saturated
• **solvability** – amount of solute needed to saturate a solution
• **unsaturated** – when there isn’t enough solute to saturate a solution
• **supersaturated** – when there is more solute than needed to saturate a solution
• for most salts crystallization of excess solute is exothermic

13.3: Factors Affecting Solubility

Solute-Solvent Interactions

• solubility increases with increasing molar mass
• London dispersion forces increase with increasing size and mass of gas molecules
• **Miscible** – pairs of liquids that mix in all proportions
• **Immiscible** – opposite of miscible
• Hydrogen-bonding interactions between solute and solvent leads to high solubility
• Substances with similar intermolecular attractive forces tend to be soluble in one another
• "like dissolves like"

Pressure Effects

• solubility of a gas in any solvent increases as pressure of gas over solvent increases
• relationship between pressure and solubility: Henry’s Law:
  ◦ \( C_g = kP_g \)
  ◦ \( C_g \) solubility of gas in solution phase (usually expressed as molarity), \( P_g \) partial pressure of gas over solution, \( k \) is proportionality constant (Henry’s Law constant)
  ◦ Henry’s law constant different for each solute-solvent pair, and temperature

Temperature Effects

• solubility of most solid solutes in water increases as temperature of solution increase
• solubility of gases in water decreases with increasing temperature
• decreases solubility of \( O_2 \) in water as temperature increases in one the effects of thermal pollution

13.4: Ways of Expressing Concentration

• dilute and concentrated used to describe solution qualitatively
• mass percentage of component in solution:

\[
\text{mass\% of component} = \frac{\text{mass\ of\ component\ in\ soln}}{\text{total\ mass\ of\ soln}} \times 100\%
\]
very dilute solutions expressed in parts per million (ppm)

\[
\text{ppm of component} = \frac{\text{mass of component in soln}}{\text{total mass of soln}} \times 10^6
\]

- 1 ppm = 1g solute for each \((10^6)\) grams of solution or 1mg solute per kg solution
- 1ppm = 1mg solute/L solution
- 1 ppb = 1g of solute/10^9 grams of solution or 1 mg solute/ L of solution

### 13.4.1 Mole Fraction, Molarity, and Molality

\[
\text{mole fraction of component} = \frac{\text{moles of component}}{\text{total moles of all components}}
\]

- sum of mole fractions of all components of solution must equal one
- \(\text{molarity} = \frac{\text{moles solute}}{\text{liters soln}}\)
- \(\text{molality} = \frac{\text{moles solute}}{\text{kilograms of solvent}}\)
- molality goes not vary with temperature
- molarity changes with temperature because of expansion and contraction of solution

### 13.5: Colligative Properties

Colligative properties are physical properties that depend on quantity

#### Lowering the Vapor Pressure

- vapor pressure over pure solvent higher than that over solution
- vapor pressure needed to obtain equilibrium of pure solvent higher than that of solution

**Raoult’s Law**

- Raoult’s law: \((P_A = X_A P^\circ)\)
  - \(P_A\) = vapor pressure of solution, \(X_A\) = mole fraction of solvent, \(P^\circ\) = vapor pressure of the pure solvent
  - **Ideal solution** – solution that obeys Raoult’s law
  - Solute concentration is low, solute and solvent have similar molecular sizes and similar types of intermolecular attractions

#### Boiling-Point Elevation

- normal boiling point of pure liquid is the temperature at which pressure is 1 atm
- addition of a nonvolatile solute lowers vapor pressure of solution
- \((\Delta T_b=K_b m)\)
- \(K_b\) = molal boiling-point-elevation constant
  - Depends only on solvent
boiling point elevation proportional to number of solute particles present in given quantity of solution

**Freezing-Point Depression**

- Freezing point of solution is temperature at which the first crystals of pure solvent form in equilibrium.
- Freezing point of solution lower than pure liquid.
- Freezing point directly proportional to the molality of the solute:
  - $\Delta T_f = K_f m$
  - $K_f =$ molal freezing-point-depression constant

**Osmosis**

- **semipermeable** – membranes that allow passage of some molecules and not others
- **osmosis** – the net movement of solvent molecules from the less concentrated solution to the more concentrated solution
- Net movement of solvent always toward the solution with the higher solute concentration
- Osmotic pressure – pressure needed to prevent osmosis, $p$
  - $\pi = \left(\frac{n}{V}\right)RT = MRT$
  - $M =$ molarity of solution
- If solutions identical osmosis will not occur and said to be **isotonic**
- If one solution lower osmotic pressure = **hypotonic**, the solution that has higher osmotic pressure = **hypertonic**
- **crenation** = when cells shrivel up from the loss of water
- **hemolysis** = when cells rupture due to too much water

**Determination of Molar Mass**

- Colligative properties can be used to find molar mass

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**13.6: Colloids**

Colloidal dispersions (colloids) are intermediate types of dispersions or suspensions

- Intermediate solutions between solutions and heterogeneous mixtures
- Colloids can be gases, liquids, or solids
- Colloid particles have size between 10 - 2000Å
- Tyndall effect – scattering of light by colloids

**Hydrophilic and Hydrophobic Colloids**

- **hydrophilic** – colloids in which the dispersion medium is water
- **hydrophobic** – colloids not dispersed in water
- Hydrophobic colloids have to be stabilized before being put in water
  - Natural lack of affinity for water causes separation
• can be stabilized by the adsorption of ions on the surface
• adsorbed ions interact with water
• can also be stabilized by presence of other hydrophilic groups on surface

Removal of Colloidal Particles

• coagulation – enlarging colloidal particles
  ◦ heating or adding an electrolyte to mixture
  ◦ heating increases number of collisions and particles stick together increasing their size
  ◦ electrolytes causes neutralization of the surface charges of the particles which remove the electrostatic repulsion
  ◦ dialysis – use of semipermeable membranes to filter out colloidal particles