

Chapter Summary and Review

Key Learning Outcomes

CHAPTER OBJECTIVES	Assessment
Determine Whether a Solute Is Soluble in a Solvent (13.2)	<ul style="list-style-type: none"> Example 13.1 For Practice 13.1 Exercises 25, 26, 27, 28, 29, 30
Use Henry's Law to Predict the Solubility of Gases with Increasing Pressure (13.4)	<ul style="list-style-type: none"> Example 13.2 For Practice 13.2 Exercises 41, 42, 43, 44, 45, 46
Calculate Concentrations of Solutions (13.5)	<ul style="list-style-type: none"> Examples 13.3, 13.4 For Practice 13.3, 13.4 For More Practice 13.3 Exercises 47, 48, 59, 60
Convert between Concentration Units (13.5)	<ul style="list-style-type: none"> Example 13.5 For Practice 13.5 Exercises 61, 62, 63, 64
Determine the Vapor Pressure of a Solution Containing a Nonelectrolyte and Nonvolatile Solute (13.6)	<ul style="list-style-type: none"> Example 13.6 For Practice 13.6 For More Practice 13.6 Exercises 67, 68
Determine the Vapor Pressure of a Two-Component Solution (13.6)	<ul style="list-style-type: none"> Example 13.7 For Practice 13.7 Exercises 69, 70, 71, 72
Calculate Freezing Point Depression (13.6)	<ul style="list-style-type: none"> Example 13.8 For Practice 13.8 Exercises 73, 74, 75, 76, 83, 84, 85
Calculate Boiling Point Elevation (13.6)	<ul style="list-style-type: none"> Example 13.9 For Practice 13.9 Exercises 73, 74, 83, 84, 86, 87
Determine the Osmotic Pressure (13.6)	<ul style="list-style-type: none"> Example 13.10 For Practice 13.10 Exercises 79, 80, 81, 82
Determine and Use the van't Hoff Factor (13.7)	<ul style="list-style-type: none"> Example 13.11 For Practice 13.11 Exercises 83, 84, 85, 87, 88, 89, 90, 91, 92
Determine the Vapor Pressure of a Solution Containing an Ionic Solute (13.7)	<ul style="list-style-type: none"> Example 13.12 For Practice 13.12 Exercises 93, 94

Key Terms

Section 13.1

solution 

solvent 

solute

Section 13.2

aqueous solution 

solubility 

entropy 

miscible 

Section 13.3

enthalpy of solution (ΔH_{soln}) 

heat of hydration ($\Delta H_{\text{hydration}}$) 

Section 13.4

dynamic equilibrium 

saturated solution 

unsaturated solution 

supersaturated solution 

recrystallization 

Henry's law 

Section 13.5

dilute solution 

concentrated solution 

molarity (M) 

molality (m) 

parts by mass 

percent by mass 

parts per million (ppm) 

parts per billion (ppb) 

parts by volume 

mole fraction (χ_{solute}) 

mole percent (mol %) 

Section 13.6

colligative property 

Raoult's law 

ideal solution 

freezing point depression 

boiling point elevation 

osmosis 

semipermeable membrane 

osmotic pressure 

Section 13.7

van't Hoff factor (i) 

Key Concepts

Solutions (13.1, 13.2)

- A solution is a homogeneous mixture of two or more substances. In a solution; the majority component is the solvent and the minority component is the solute.
- The tendency toward greater entropy (or greater energy dispersal) is the driving force for solution formation.
- In aqueous solutions, water is a solvent, and a solid, liquid, or gas is the solute.


Solubility and Energetics of Solution Formation (13.2, 13.3)

- The solubility of a substance is the amount of the substance that will dissolve in a given amount of solvent. The solubility of one substance in another depends on the types of intermolecular forces that exist *between* the substances as well as *within* each substance.
- We determine the overall enthalpy change upon solution formation by adding the enthalpy changes for the three steps of solution formation: (1) separation of the solute particles, (2) separation of the solvent particles, and (3) mixing of the solute and solvent particles. The first two steps are both endothermic, while the last is exothermic.
- In aqueous solutions of an ionic compound, we combine the change in enthalpy for Steps 2 and 3 as the heat of hydration ($\Delta H_{\text{hydration}}$), which is always negative.

Solution Equilibrium (13.4)

- Dynamic equilibrium in a solution occurs when the rates of dissolution and recrystallization in a solution are equal. A solution in this state is saturated. Solutions containing less than or more than the equilibrium amount of solute are unsaturated or supersaturated, respectively.
- The solubility of most solids in water increases with increasing temperature.
- The solubility of gases in liquids generally decreases with increasing temperature, but it increases with increasing pressure.

Concentration Units (13.5)

- Common units used to express solution concentration are molarity (M), molality (m), mole fraction (χ), mole percent (mol %), percent (%) by mass or volume, parts per million (ppm) by mass or volume, and parts per billion (ppb) by mass or volume. These units are summarized in Table 13.5 .

Vapor Pressure Lowering, Freezing Point Depression, Boiling Point Elevation, and Osmosis (13.6, 13.7)

- The presence of a nonvolatile solute in a liquid results in a lower vapor pressure of the solution relative to the vapor pressure of the pure liquid. This lower vapor pressure is predicted by Raoult's law for an ideal solution.
- If the solute-solvent interactions are particularly strong, the actual vapor pressure of the solution is lower than that predicted by Raoult's law.
- If the solute-solvent interactions are particularly weak, the actual vapor pressure of the solution is higher than that predicted by Raoult's law.
- The addition of a nonvolatile solute to a liquid results in a solution that has a lower freezing point and a higher boiling point than the pure solvent.
- The flow of solvent from a solution of lower concentration to a solution of higher concentration is osmosis.
- Vapor pressure lowering, freezing point depression, boiling point elevation, and osmosis are colligative properties and depend only on the number of solute particles added, not the type of solute particles.

- Electrolyte solutes have a greater effect on these colligative properties than the corresponding amount of a nonelectrolyte solute as specified by the van't Hoff factor.

Key Equations and Relationships

Henry's Law: Solubility of Gases with Increasing Pressure (13.4)

$$S_{\text{gas}} = k_{\text{H}} P_{\text{gas}} \text{ is Henry's law constant}$$

Molarity (M) of a Solution (13.5)

$$(M) = \frac{\text{amount solute (in mol)}}{\text{volume solution (in L)}}$$

Molality (m) of a Solution (13.5)

$$(m) = \frac{\text{amount solute (in mol)}}{\text{mass solvent (in kg)}}$$

Concentration of a Solution in Parts by Mass and Parts by Volume (13.5)

$$\begin{aligned} \text{percent by mass} &= \frac{\text{mass solute} \times 100\%}{\text{mass solution}} \\ \text{parts per million (ppm)} &= \frac{\text{mass solute} \times 10^6}{\text{mass solution}} \\ \text{parts per billion (ppb)} &= \frac{\text{mass solute} \times 10^9}{\text{mass solution}} \\ \text{parts by volume} &= \frac{\text{volume solute} \times \text{multiplication factor}}{\text{volume solution}} \end{aligned}$$

Concentration of a Solution in Mole Fraction (χ) and Mole Percent (13.5)

$$\begin{aligned} \chi_{\text{solute}} &= \frac{n_{\text{solute}}}{n_{\text{solute}} + n_{\text{solvent}}} \\ \text{Mol}\% &= \chi \times 100\% \end{aligned}$$

Raoult's Law: Relationship between the Vapor Pressure of a Solution (P_{solution}), the Mole Fraction of the Solvent (χ_{solvent}), and the Vapor Pressure of the Pure Solvent ($P_{\text{solvent}}^{\circ}$) (13.6)

$$P_{\text{solution}} = \chi_{\text{solvent}} P_{\text{solvent}}^{\circ}$$

The Vapor Pressure of a Solution Containing Two Volatile Components (13.6)

$$\begin{aligned} P_{\text{A}} &= \chi_{\text{A}} P_{\text{A}}^{\circ} \\ P_{\text{B}} &= \chi_{\text{B}} P_{\text{B}}^{\circ} \\ P_{\text{tot}} &= P_{\text{A}} + P_{\text{B}} \end{aligned}$$

Relationship between Freezing Point Depression (ΔT_{f}), Molality (m), and Freezing Point Depression Constant K_{f} (13.6)


$$\Delta T_{\text{f}} = m \times K_{\text{f}}$$

Relationship between Boiling Point Elevation (ΔT_{b}), Molality (m), and Boiling Point Elevation Constant (K_{b}) (13.6)

$$\Delta T_{\text{b}} = m \times K_{\text{b}}$$

Relationship between Osmotic Pressure (Π), Molarity (m), the Ideal Gas Constant (R), and Temperature (T , in K) (13.6)

$$\Pi = MRT (R = 0.08206 \text{ L} \cdot \text{atm} / \text{mol} \cdot \text{K})$$

van't Hoff Factor (i): Ratio of Moles of Particles in Solution to Moles of Formula Units Dissolved (13.7 )

$$i = \frac{\text{moles of particles in solution}}{\text{moles of formula units dissolved}}$$

Not for Distribution

Not for Distribution