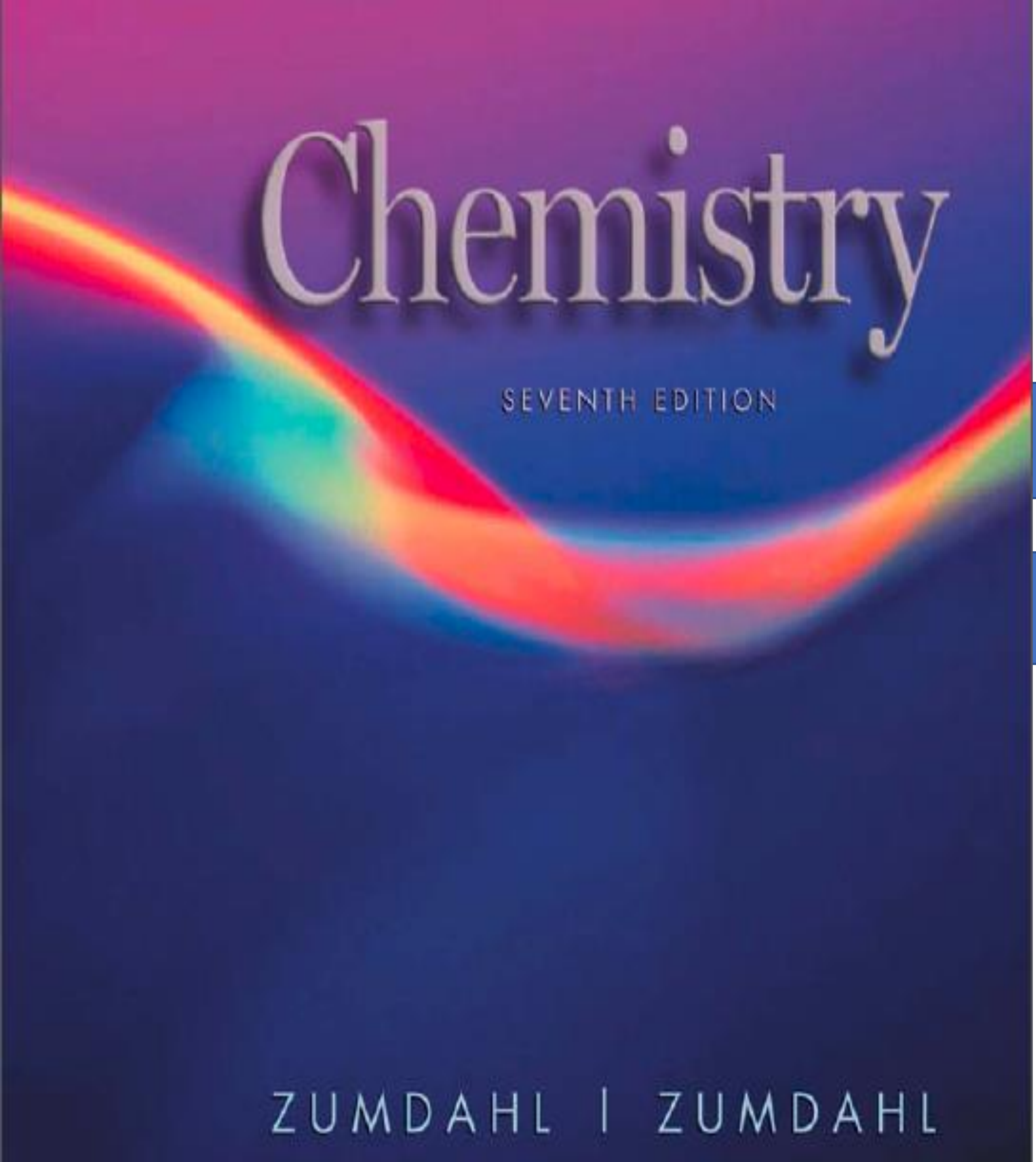


Chapter 9

Properties of Solution

- When the components of a mixture are uniformly intermingled (homogeneous) is called a *solution.*
- Solution Composition

$$\text{Molarity } (M) = \frac{\text{moles of solute}}{\text{liters of solution}}$$

$$\text{Mass (weight) percent} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100\%$$

$$\text{Mole fraction } (\chi_A) = \frac{\text{moles}_A}{\text{total moles of solution}}$$

$$\text{Molality } (m) = \frac{\text{moles of solute}}{\text{kilogram of solvent}}$$

- Solute: is the substance being dissolved
-
- Solvent: is the dissolving medium

- When liquids are mixed, the liquid present in the largest amount is called the *solvent*.

Sample Exercise 9.1

- A solution is prepared by mixing 1.00 g ethanol (C_2H_5OH) with 100.0 g water to give a final volume of 101 mL. Calculate the molarity, mass percent, mole fraction, and molality of ethanol in this solution.

- ***Solution***
- ***a.*** $moles of C_2H_5OH = \frac{mass\ of\ C_2H_5OH\ (g)}{molar\ mass} = \frac{1.00g}{46.07}$ = 2.17x10^{-2} mol, *volume* = $\frac{101}{1000}$ = 0.101 L

$$\text{Molarity of } C_2H_5OH = \frac{\text{moles of } C_2H_5OH}{\text{liters of solution}} = \frac{2.17 \times 10^{-2}\ \text{mol}}{0.101\ \text{L}} = 0.215\ M$$

- ***b.*** **Mass percent:**

$$\text{Mass percent } C_2H_5OH = \left(\frac{\text{mass of } C_2H_5OH}{\text{mass of solution}}\right) \times 100\% = \left(\frac{1.00\ \text{g } C_2H_5OH}{100.0\ \text{g } H_2O + 1.00\ \text{g } C_2H_5OH}\right) \times 100\% = 0.990\%$$

- ***c.*** **Mole fraction:**

$$\text{Mole fraction of } C_2H_5OH = \frac{n_{C_2H_5OH}}{n_{C_2H_5OH} + n_{H_2O}}$$

$moles of H_2O = \frac{mass\ of\ H_2O(g)}{molar\ mass} = \frac{100g}{18}$ = 5.56 mol

$$\chi_{C_2H_5OH} = \frac{2.17 \times 10^{-2}\ \text{mol}}{2.17 \times 10^{-2}\ \text{mol} + 5.56\ \text{r}} = \frac{2.17 \times 10^{-2}}{5.58} = 0.00389$$

- d. molality

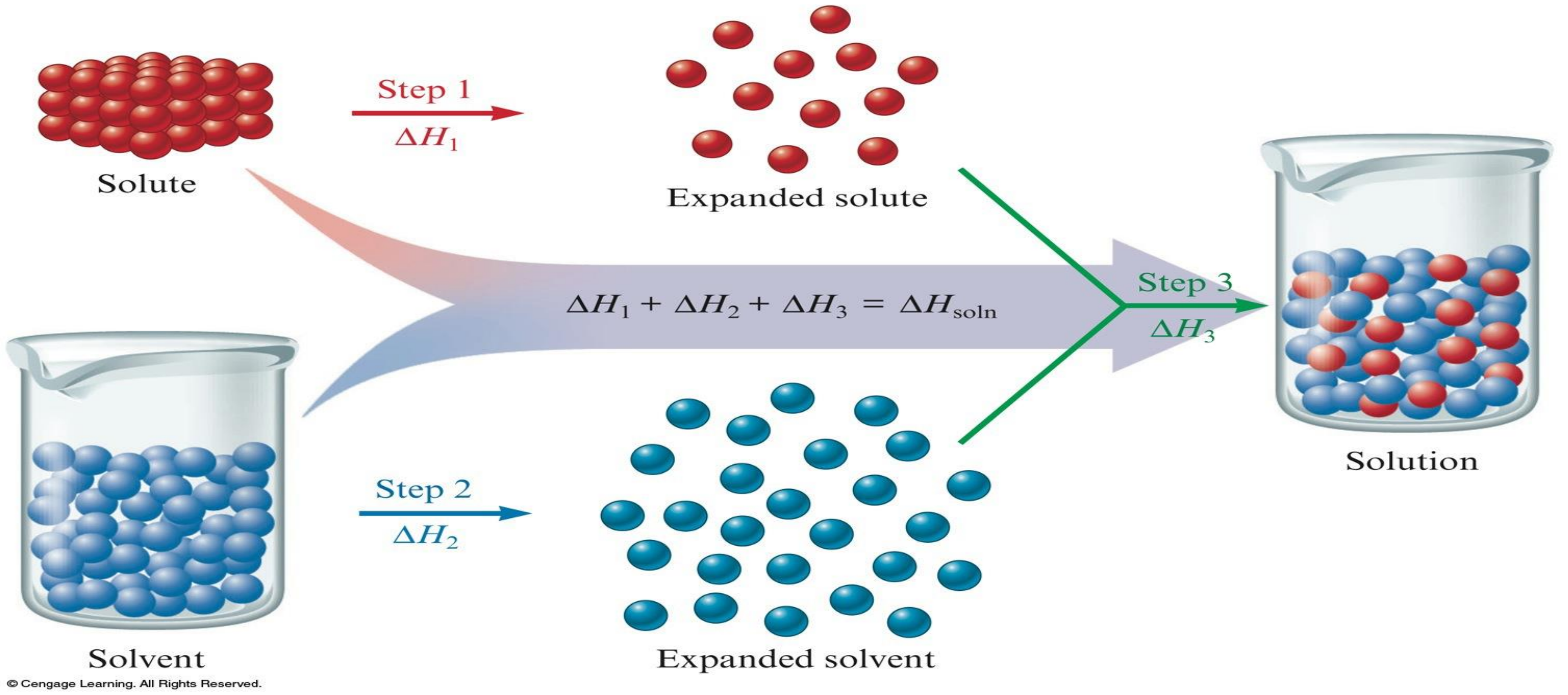
$$\text{Molality of } C_2H_5OH = \frac{\text{moles of } C_2H_5OH}{\text{kilogram of } H_2O}$$

kilogram of solvent(H_2O) $= \frac{100}{1000} = 0.1000 \text{ kg}$

$$\text{Molality of } C_2H_5OH = \frac{\text{moles of } C_2H_5OH}{\text{kilogram of } H_2O} = \frac{2.17 \times 10^{-2} \text{ mol}}{0.1000 \text{ kg}} = 0.217\ m$$

- Formation of a Liquid Solution

1. Separating the solute into its individual components (expanding the solute).
2. Overcoming intermolecular forces in the solvent to make room for the solute (expanding the solvent).
3. Allowing the solute and solvent to interact to form the solution



• Enthalpy (Heat) of Solution

- Enthalpy change associated with the formation of the solution is the sum of the ΔH values for the steps:

$$\Delta H_{soln} = \Delta H_1 + \Delta H_2 + \Delta H_3$$

- ΔH_{soln} may have a positive sign (energy absorbed) or a negative sign (energy released).

• For example dissolving NaCl in H_2O

$$NaCl(s) \longrightarrow Na^+(g) + Cl^-(g) \qquad \Delta H_1 = 786 \text{ kJ/mol}$$

$$H_2O(l) + Na^+(g) + Cl^-(g) \longrightarrow Na^+(aq) + Cl^-(aq) \qquad \Delta H_{hyd} = \Delta H_2 + \Delta H_3 = -783 \text{ kJ/mol}$$

$$\Delta H_{soln} = 786 \text{ kJ/mol} - 783 \text{ kJ/mol} = 3 \text{ kJ/mol}$$

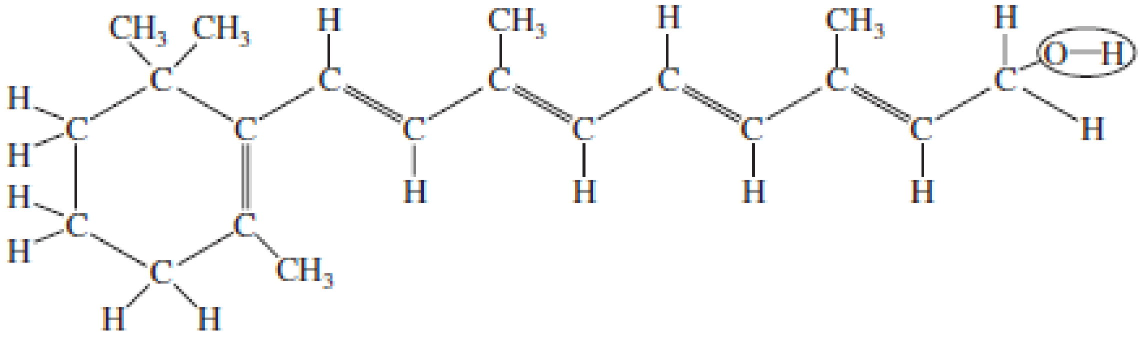
- Factors Affecting Solubility

- Structure Effects:
  - Polarity
- Pressure Effects:
  - Henry’ s law
- Temperature Effects:
  - Affecting aqueous solutions

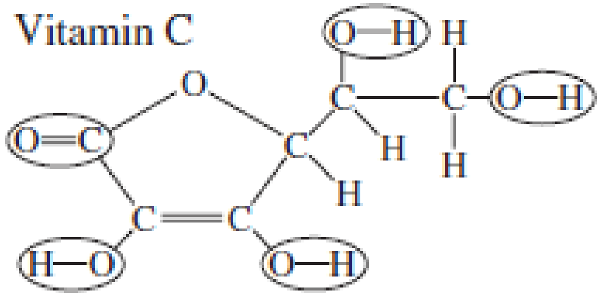
Section 9.2
Factors Affecting Solubility

- Structure Effects
  - Hydrophobic (water fearing)
    - Non-polar substances as vitamins A,D,E,and K. they composed of many C-H bonds (nonpolar bonds) this cause it be soluble in nonpolar solvent as body fat (fat soluble)
  - Hydrophilic (water loving)
    - Polar substances as vitamins B and C, they have many polar O-H, and C-O bonds, making it polar compounds and thus water soluble

Vitamin A



Vitamin C



- Pressure Effects
  - Little effect on solubility of solids or liquids
- Henry’s law:
  - Amount of gas dissolved in a solution is directly proportional to the pressure of the gas above the solution.

$$C = kP$$

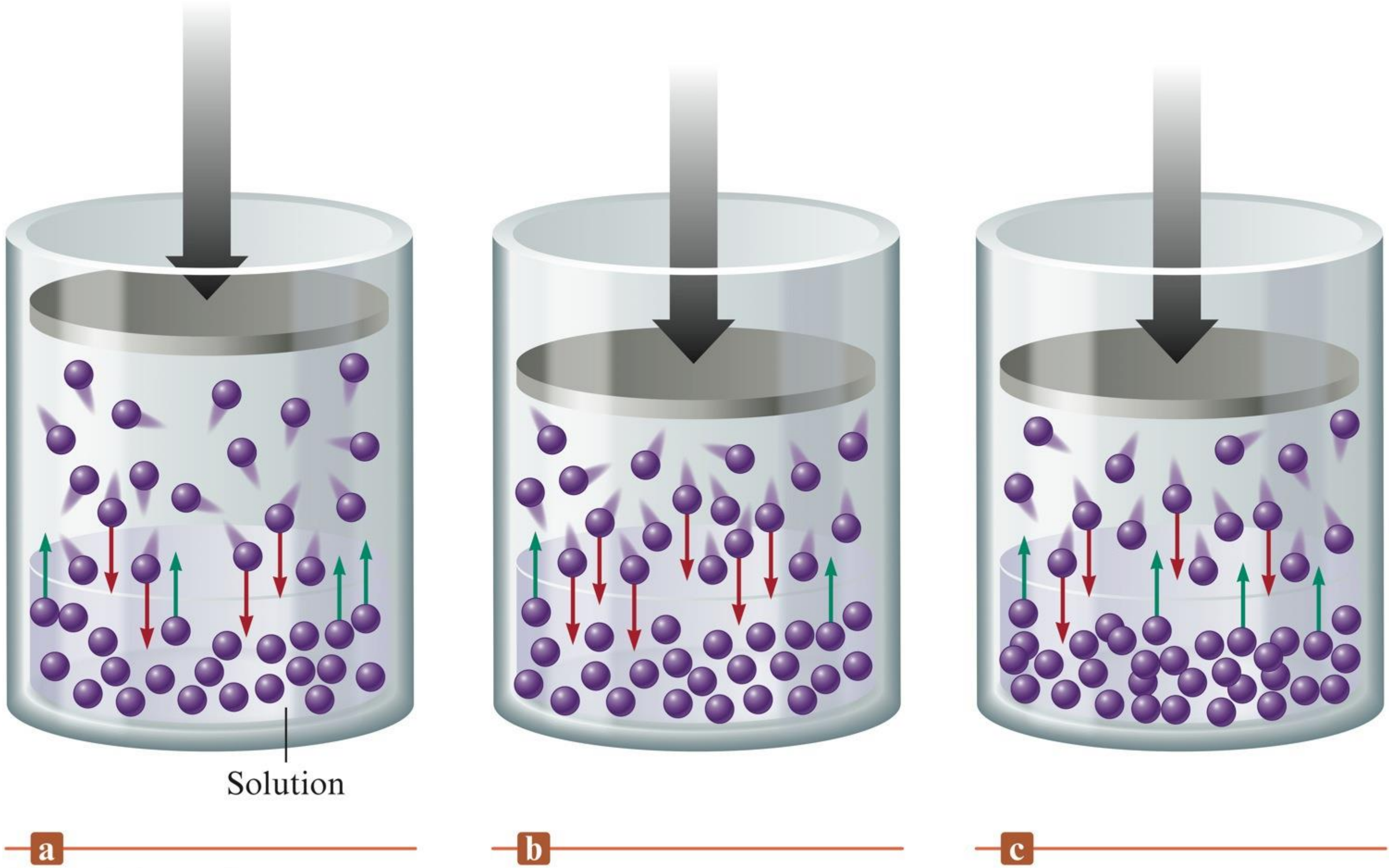
C = concentration of dissolved gas

k = constant

P = partial pressure of gas solute above the solution

- A Gaseous Solute

FIGURE 11.5
(a) A gaseous solute in equilibrium with a solution. (b) The piston is pushed in, which increases the pressure of the gas and the number of gas molecules per unit volume. This causes an increase in the rate at which the gas enters the solution, so the concentration of dissolved gas increases. (c) The greater gas concentration in the solution causes an increase in the rate of escape. A new equilibrium is reached.



Sample Exercise 9.2

A certain soft drink is bottled so that a bottle at 25°C contains CO_2 gas at a pressure of 5.0 atm over the liquid. Assuming that the partial pressure of CO_2 in the atmosphere is 4.0×10^{-4} atm, calculate the equilibrium concentrations of CO_2 in the soda both before and after the bottle is opened. The Henry's law constant for CO_2 in aqueous solution is 3.1×10^{-2} mol/L · atm at 25°C.

- ***Solution***
- ***Before opening the bottle***
- We can write Henry's law for CO_2 as

$$C_{CO_2} = k_{CO_2} P_{CO_2}$$

where $k_{CO_2} = 3.1 \times 10^{-2}$ mol/L · atm., $P_{CO_2} = 5.0$ atm

$$C_{CO_2} = k_{CO_2} P_{CO_2} = (3.1 \times 10^{-2} \text{ mol/L} \cdot \text{atm})(5.0 \text{ atm}) = 0.16 \text{ mol/L}$$

- ***After opening the bottle***

In the *opened* bottle, the CO_2 in the soda eventually reaches equilibrium with the atmos-pheric CO_2, so $P_{CO_2} = 4.0 \times 10^{-4}$ atm

$$C_{CO_2} = k_{CO_2} P_{CO_2} = \left(3.1 \times 10^{-2} \frac{\text{mol}}{\text{L} \cdot \text{atm}}\right)(4.0 \times 10^{-4} \text{ atm}) = 1.2 \times 10^{-5} \text{ mol/L}$$

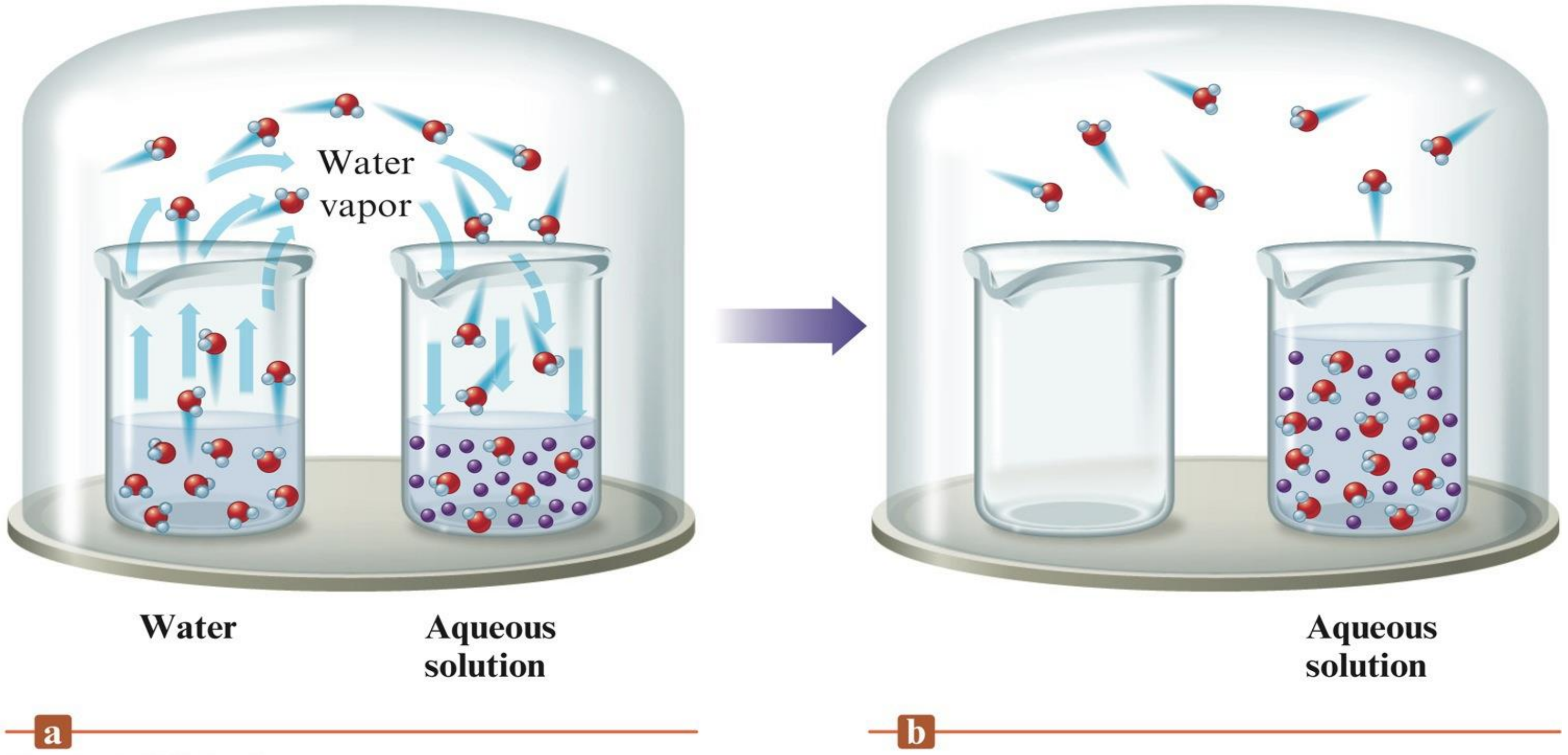
Note the large change in concentration of CO_2. This is why soda goes "flat" after being open for a while.

- **The Vapor Pressures of Solutions**
- Liquid solutions have physical properties significantly different from those of the pure solvent, a fact that has great practical importance.

- For example, we add antifreeze to the water in a car's cooling system to prevent freezing in winter and boiling in summer.

- We also melt ice on sidewalks and streets by spreading salt. These preventive measures work because of the solute's effect on the solve

- An Aqueous Solution and Pure Water in a Closed Environment



• Vapor Pressures of Solutions

- Nonvolatile solute lowers the vapor pressure of a solvent.
- Raoult's Law:

$$P_{soln} = X_{solvent} P^0_{solvent}$$

P_{soln}	=	observed vapor pressure of solution
X_{solv}	=	mole fraction of solvent
P^0_{solv}	=	vapor pressure of pure solvent

❑ A liquid–liquid solution that obeys **Raoult's law** is called **an ideal solution**.

Section 9.3
The Vapor Pressure of Solution

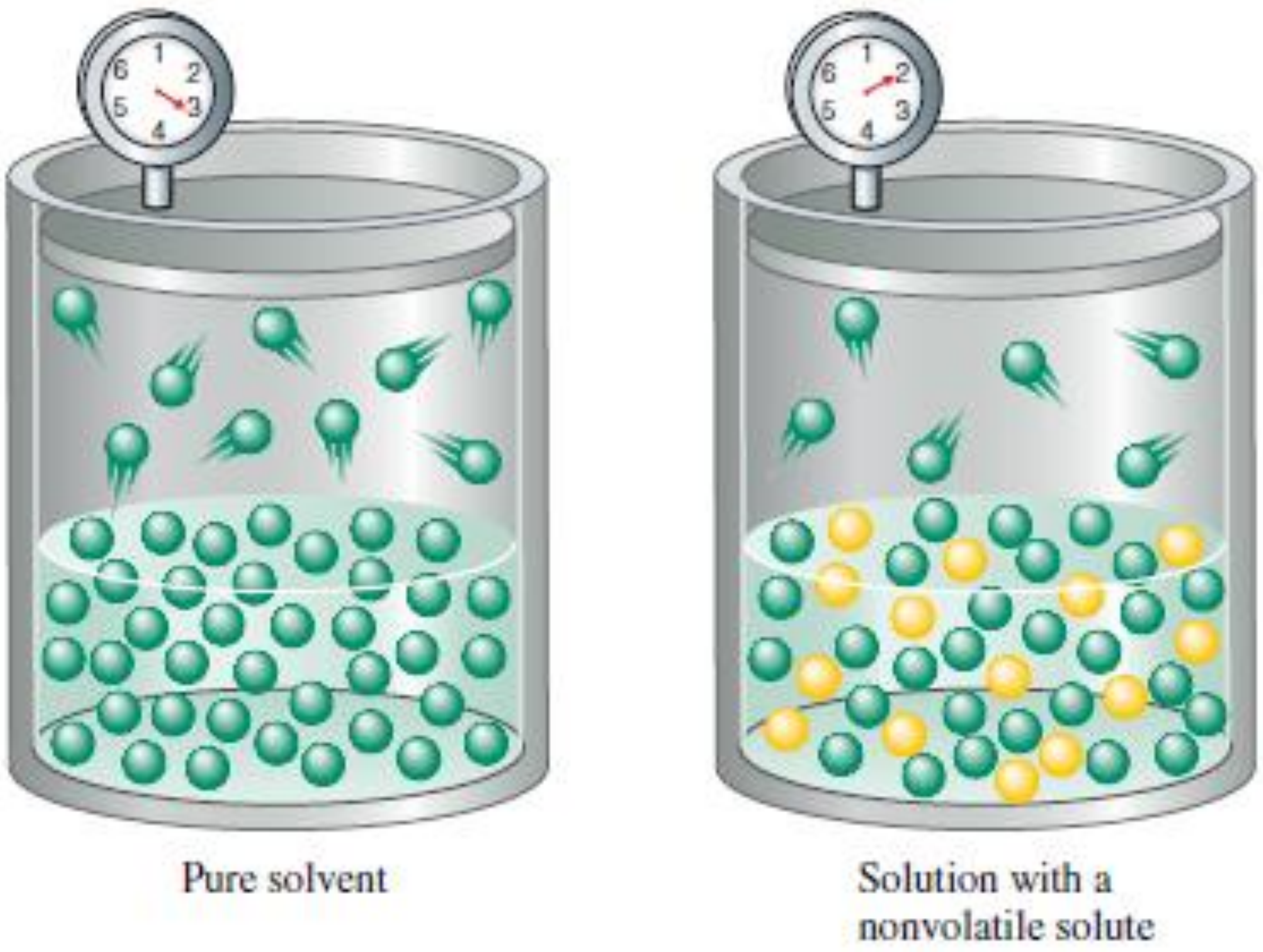
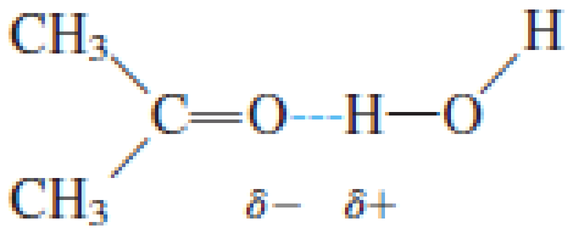


FIGURE 11.10
The presence of a nonvolatile solute inhibits the escape of solvent molecules from the liquid and so lowers the vapor pressure of the solvent.

Nonideal Solution

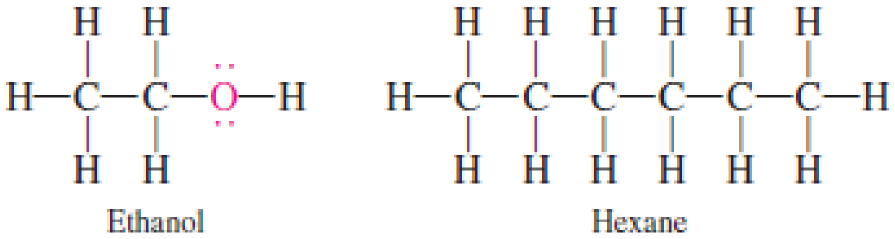
- Strong solute–solvent interaction gives a vapor pressure lower than that predicted by Raoult's law. Thus there will be a *negative deviation from Raoult's law.*

• example



- In contrast, a weak solute–solvent interaction gives a vapor pressure higher than that predicted by Raoult's law. Thus there will be a *positive deviation from Raoult's law.*

• example



Sample Exercise 9.3

Calculate the expected vapor pressure at 25°C for a solution prepared by dissolving 158.0 g of common table sugar (sucrose, molar mass = 342.3 g/mol) in 643.5 cm^3 of water. At 25°C, the density of water is 0.9971 g/cm^3 and the vapor pressure is 23.76 torr.

- ***Solution***
- We will use Raoult's law in the form

$$\rightarrow \quad P_{soln} = \chi_{H_2O} P^0_{H_2O}$$

- Moles of sucrose = $\frac{mass}{molar\ mass} = \frac{158}{342.3}$ = 0.46 mol
- Mass of water = volume x density = 643.5 x 0.9971 = 641.6g, and molar mass of water H_2O=2+16=18g/mol
- Moles of water = $\frac{mass}{molar\ mass} = \frac{641.6}{18}$ = 35.63 mol
- then $$\chi_{H_2O} = \frac{\text{mol } H_2O}{\text{mol } H_2O + \text{mol sucrose}} = \frac{35.63 \text{ mol}}{35.63 \text{ mol} + 0.4616 \text{ mo}} = \frac{35.63 \text{ mol}}{36.09 \text{ mol}} = 0.9873$$

$$\rightarrow \quad P_{soln} = \chi_{H_2O} P^0_{H_2O} = (0.9873)(23.76 \text{ torr}) = 23.46 \text{ torr}$$

- Thus the vapor pressure of water has been lowered from 23.76 torr to 23.46 torr., means that lowered by 0.3 torr

- Colligative Properties
  - Boiling-point elevation
  - Freezing-point depression
  - Osmotic pressure

➢Depend only on the number, not on the identity, of the solute particles in an ideal solution

Boiling-Point Elevation

- Nonvolatile solute elevates the boiling point of the solvent
  - $\Delta T = K_b m_{solute}$

    ΔT = boiling-point elevation

    K_b = molal boiling-point elevation constant

    m_{solute} = molality of solute

Sugar dissolved in water to make candy causes the boiling point to be elevated above 100°C.

Freezing-Point Depression

- When a solute is dissolved in a solvent, the freezing point of the solution is lower than that of the pure solvent.

- $\Delta T = K_f m_{solute}$

  ΔT = freezing-point depression

  K_f = molal freezing-point depression constant

  m_{solute} = molality of solute

The addition of antifreeze lowers the freezing point of water in a car's radiator.

Section 9.5
Osmotic Pressure

- Osmosis – flow of solvent into the solution through a semipermeable membrane.

  there is a greater hydrostatic pressure on the solution

  than on the pure solvent. This excess pressure

  is called the osmotic pressure.

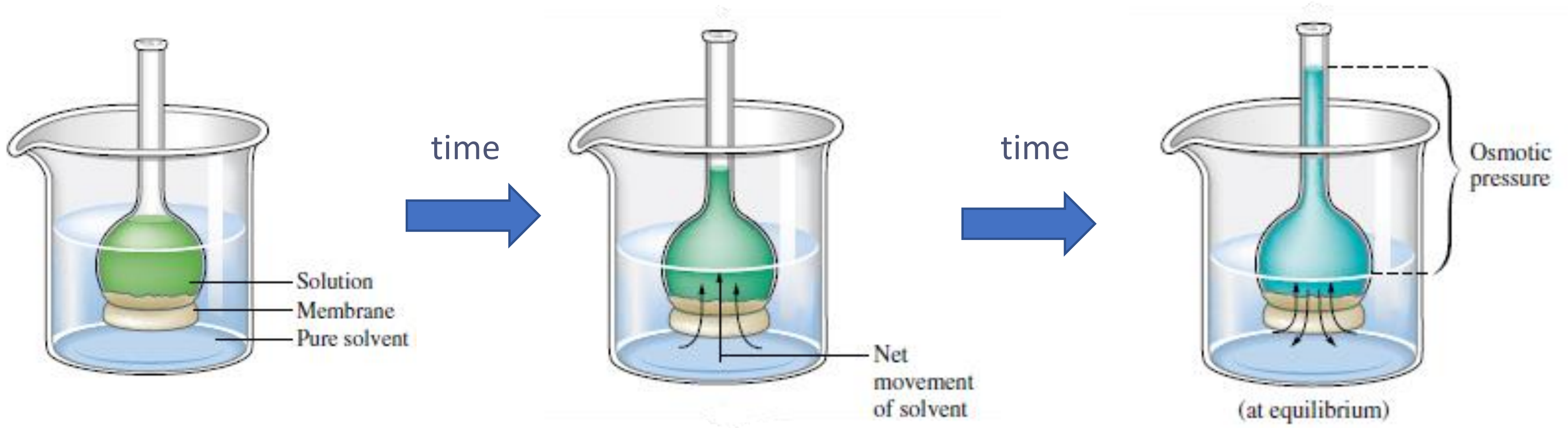


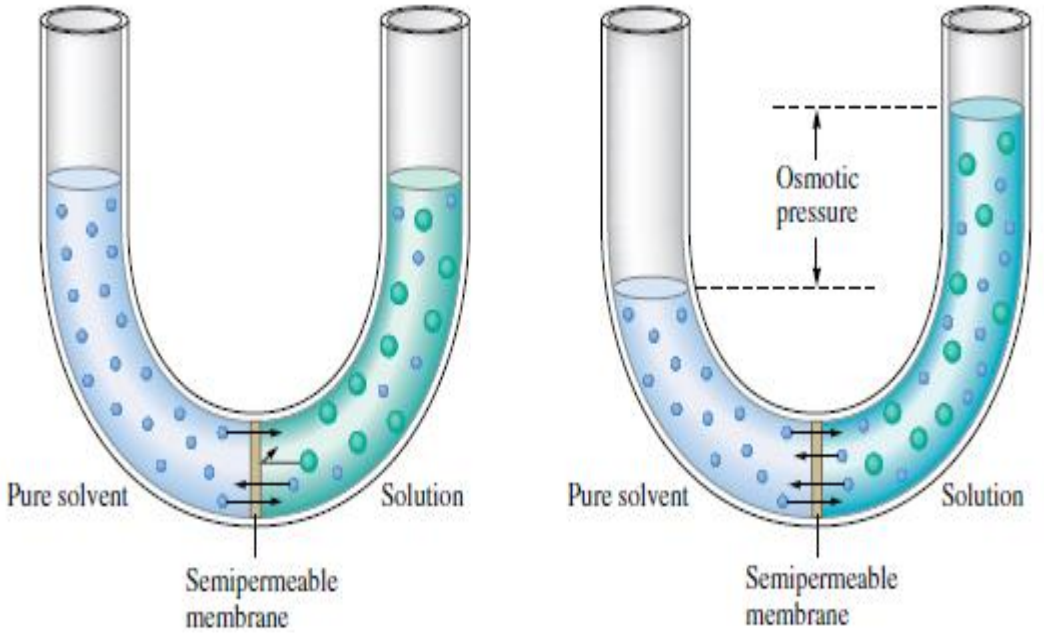
FIGURE 11.16
A tube with a bulb on the end that is covered by a semipermeable membrane. The solution is inside the tube and is bathed in the pure solvent. There is a net transfer of solvent molecules into the solution until the hydrostatic pressure equalizes the solvent flow in both directions.

Section 9.5
Osmotic Pressure

- Osmotic pressure
- *The minimum pressure that stops the osmosis is equal to the osmotic pressure of the solution.*

$$\Pi = MRT$$

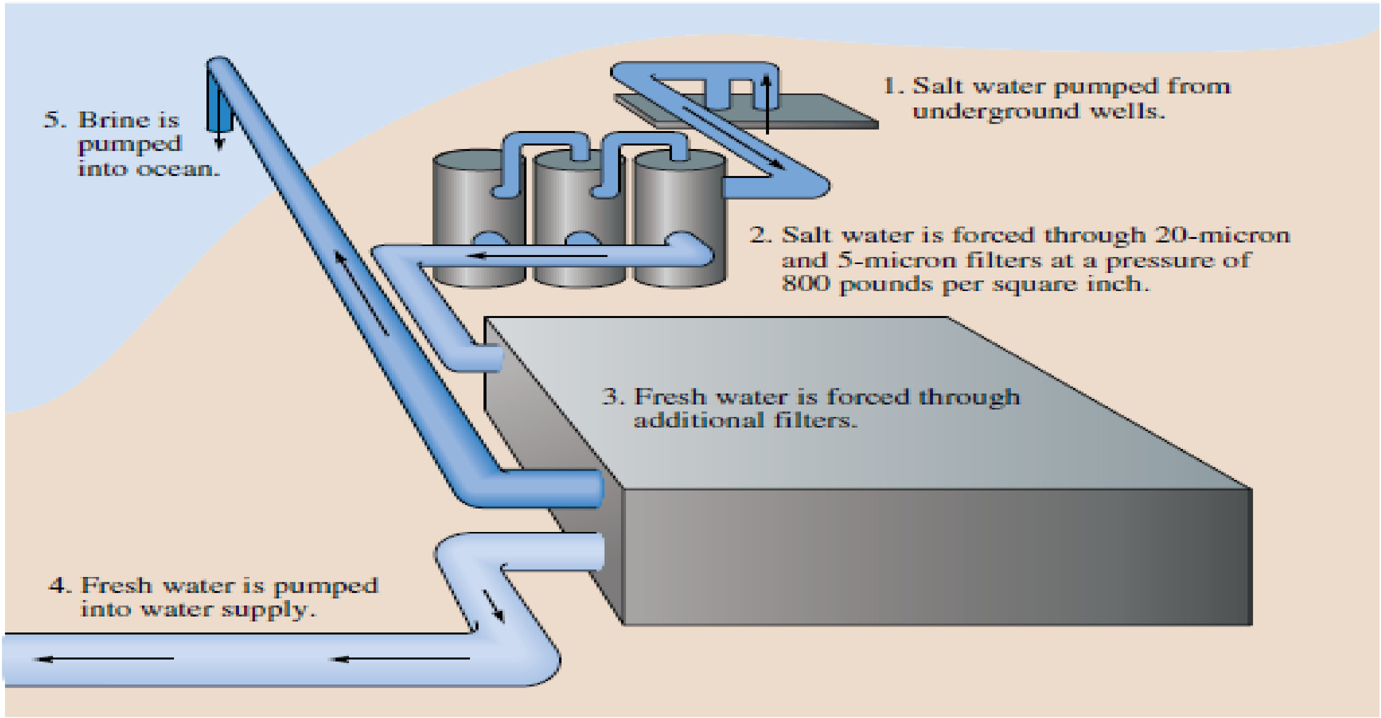
Π	=	osmotic pressure (atm)
M	=	molarity of the solution
R	=	gas law constant
T	=	temperature (Kelvin)

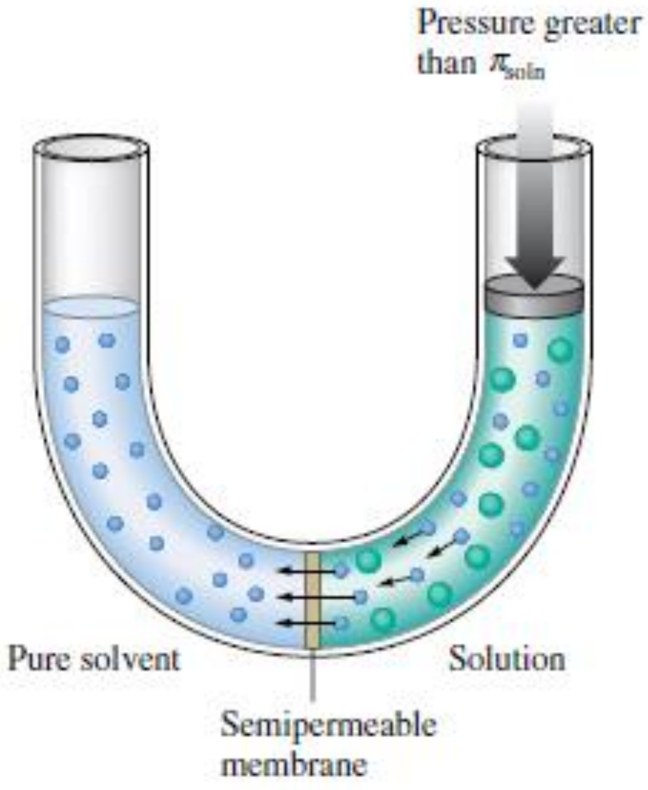


➢ Solutions that have identical osmotic pressures are said to be **isotonic solutions**

- Reverse osmosis
- Occurs when the solution in contact with pure solvent across a semipermeable membrane is subjected to an external pressure larger than its osmotic pressure

➢**desalination** (removal of dissolved salts) of seawater



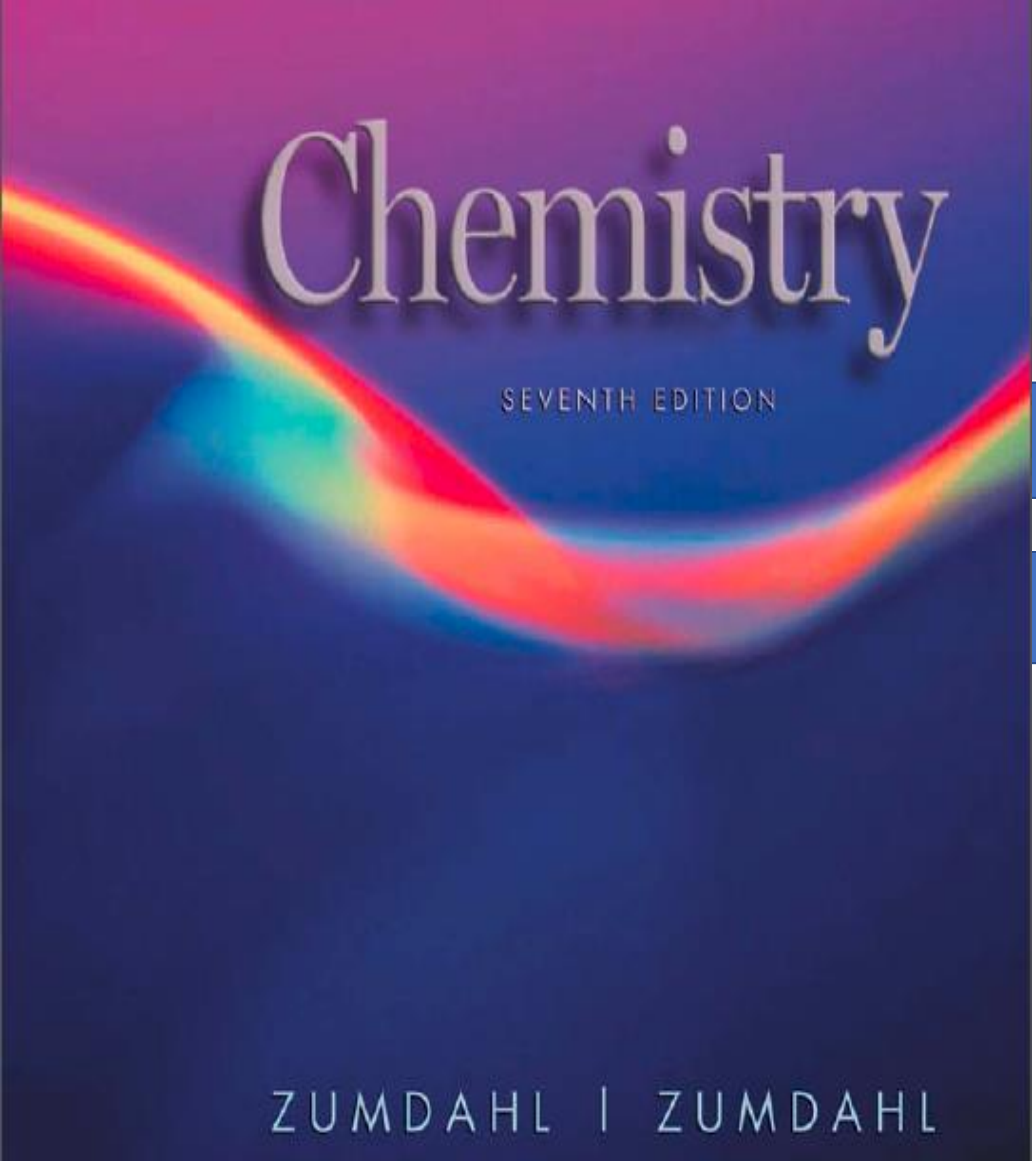


- van' t Hoff Factor, *i*
  - The relationship between the moles of solute dissolved and the moles of particles in solution is usually expressed as:

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

- Colloidal dispersion or Colloide - A suspension of tiny particles in some medium.
- Tyndall effect – scattering of light by particles. and is often used to distinguish between a suspension and a true solution

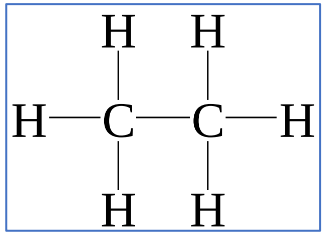
FIGURE 11.23
The Tyndall effect.



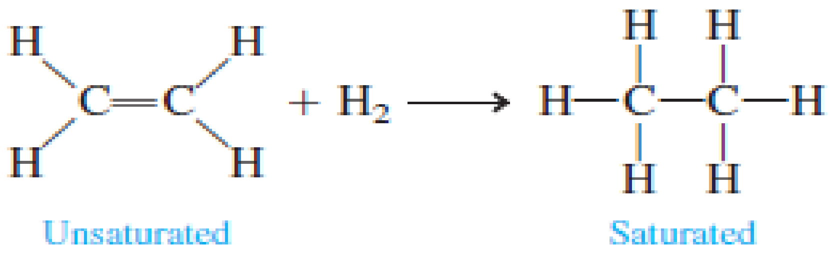
Chapter 10

Organic and Biological Molecules

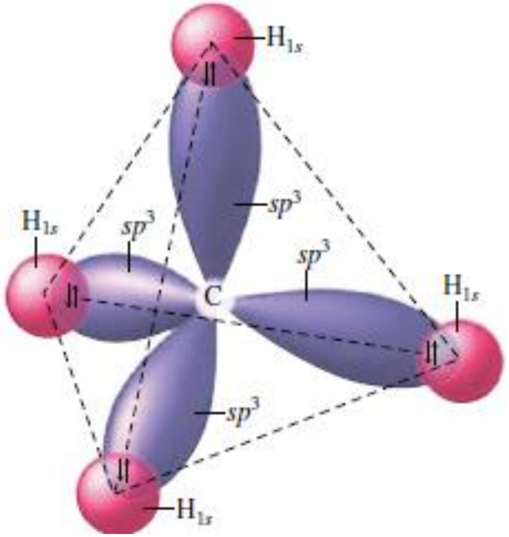
- Organic Chemistry
  - The study of carbon-containing compounds and their properties.
- Hydrocarbons
- Compounds composed of carbon and hydrogen.
- Saturated: C—C bonds are all single bonds.



- Unsaturated: contains carbon–carbon multiple bonds.



- The simplest member of the **saturated hydrocarbons(alkanes),** is *methane* (CH_4). Methane has a tetrahedral structure



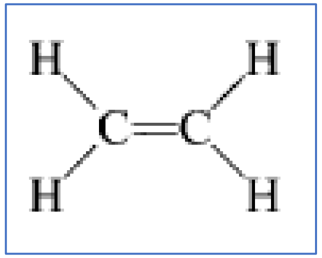
- The next members of the series are *ethane* (C_2H_6), *propane* (C_3H_8) and *butane* (C_4H_{10}).
- Alkanes in which the carbon atoms form long "strings" or chains are called **normal, straight-chain**, or **unbranched hydrocarbons**
- Alkanes can be represented by the general formula C_nH_{2n+2}.

- Multiple carbon–carbon bonds result when hydrogen atoms are removed from alkanes

- **Alkenes**: Hydrocarbons contain at least one carbon–carbon double bond

- The general formula of alkenes is C_nH_{2n}

- The simplest alkene is (C_2H_4), commonly known as *ethylene*



❖ Rules for Naming Alkenes

- Root hydrocarbon name ends in –*ene*.

  thus the systematic name of C_2H_4 is ethene, and C_3H_6 is propene

- With more than 3 carbons, double bond is indicated by the lowest–numbered carbon atom in the bond.

$CH_2{=}CH{-}CH_2{-}CH_3$	$CH_2\text{-}CH{=}CH_2{-}CH_3$
1 2 3 4	1 2 3 4
1–butene	2–butene

- **Alkynes:** are unsaturated hydrocarbons containing at least one triple carbon–carbon bond.

- The simplest alkyne is C_2H_2 (commonly called *acetylene*), the systematic name is *ethyne.*

- **REFERENCE TEXTBOOK**

Chemistry - Steven S. Zumdahl, Susan A. Zumdahl, 7th edition, 2007.

THANK YOU