11

CHAPTER

SOLUTIONS

✓**Solution**: homogeneous mixing two or more pure substances (liquid solid, or gas) whose molecules interact directly in the mixed state.

- **Solvent**: the major component
- **Solute**: the minor component

Molecules experience new intermolecular forces in moving from pure solute or solvent into the mixed state.

Chap. 11 How are the properties and reactions of the pure solute modified when it is dispersed in the solvent?

11.1 COMPOSITION OF SOLUTIONS

➢ Percent composition

$$\text{Mass (or Weight)}\,\% = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100$$

$$\text{Vol}\ \% = \frac{\text{vol of solute}}{\text{vol of solution}} \times 100$$

➢ Parts per million & parts per billion

$$\text{ppm} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 10^6 \approx \mathrm{O(mg\,L^{-1})}$$

$(\mathrm{mg\ kg^{-1}})$

$$\text{ppb} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 10^9 \approx \mathrm{O(\mu g\,L^{-1})}$$

$(\mathrm{\mu g\ kg^{-1}})$

for water (d= 1 $\mathrm{g/cm^3}$)

474

➢ Mole Fraction

$$X_1 = \frac{n_1}{n_1 + n_2}, \quad X_2 = \frac{n_2}{n_1 + n_2} = 1 - X_1 \quad \text{(for a binary mixture)}$$

➢ Molarity & Molality

$$\text{Molarity (M)} = \frac{\text{moles solute}}{\text{liters solution}} = \mathrm{mol\,L^{-1}}$$

✓ Molarity depends on temperature.

$$\text{Molality (m)} = \frac{\text{moles solute}}{\text{kilograms solvent}} = \mathrm{mol\,kg^{-1}}$$

✓ Molality is independent of temperature!

General Chemistry I

KAIST CHEMISTRY

Example 11.1

A solution is prepared by dissolving 22.4 g of $MgCl_2$ in 0.200 L of water. Taking the density of pure water to be 1.00 g/cm^3 and the density of the resulting solution to be 1.089 g/cm^3, calculated the mole fraction, molarity and molality of $MgCl_2$ in this solution.

Example 11.2

A 9.386 M aqueous solution of sulfuric acid has a density of 1.5091 g/cm^3. Calculate the molality, the percentage by mass, and the mole fraction of sulfuric acid in this solution.

(a) (b) (c) (d) (e)

Preparing a solution of $NiCl_2$ using a volumetric flask

➢ Dilution of solution

Chemical amount conserved.

$$n = c_i V_i = c_f V_f \longrightarrow \boxed{c_f = \frac{\text{moles solute}}{\text{final solution volume}} = \frac{c_i V_i}{V_f}}$$

n: number of moles of solute

$c_{i(f)}$: initial (final) concentration in molarity

$V_{i(f)}$: initial (final) solution volume in liters

Example 11.3

(a) Describe how to prepare 0.500 L of a 0.100 M aqueous solution of potassium hydrogen carbonate ($KHCO_3$).

(b) Describe how to dilute this solution to a final concentration of 0.0400 M $KHCO_3$.

11.2 NATURE OF DISSOLVED SPECIES

Original phases (solvent-to-solvent and solute-to-solute attractions) are broken up and replaced, at least in part, by new solvent-to-solute attractions.

Intermolecular forces

-Water molecule-molecular solutes

-Water molecule-ionic solutes

11.2 NATURE OF DISSOLVED SPECIES

◆ Aqueous Solutions of Molecular Species

- **Polar** molecules dissolved by **water** ~ "Like dissolves like"
- Sugars: $C_m(H_2O)_n$

  ~ Sucrose ($C_{12}H_{22}O_{11}$), Fructose ($C_6H_{12}O_6$), Ribose ($C_5H_{10}O_5$)

  ~ Do not contain water molecules

  ~ Include polar –OH groups

  ~ Dipole-dipole interaction between –OH groups
  and water molecules → *hydrogen bonds*

* Nonpolar molecule in water: oil w/water → do not dissolve significantly.

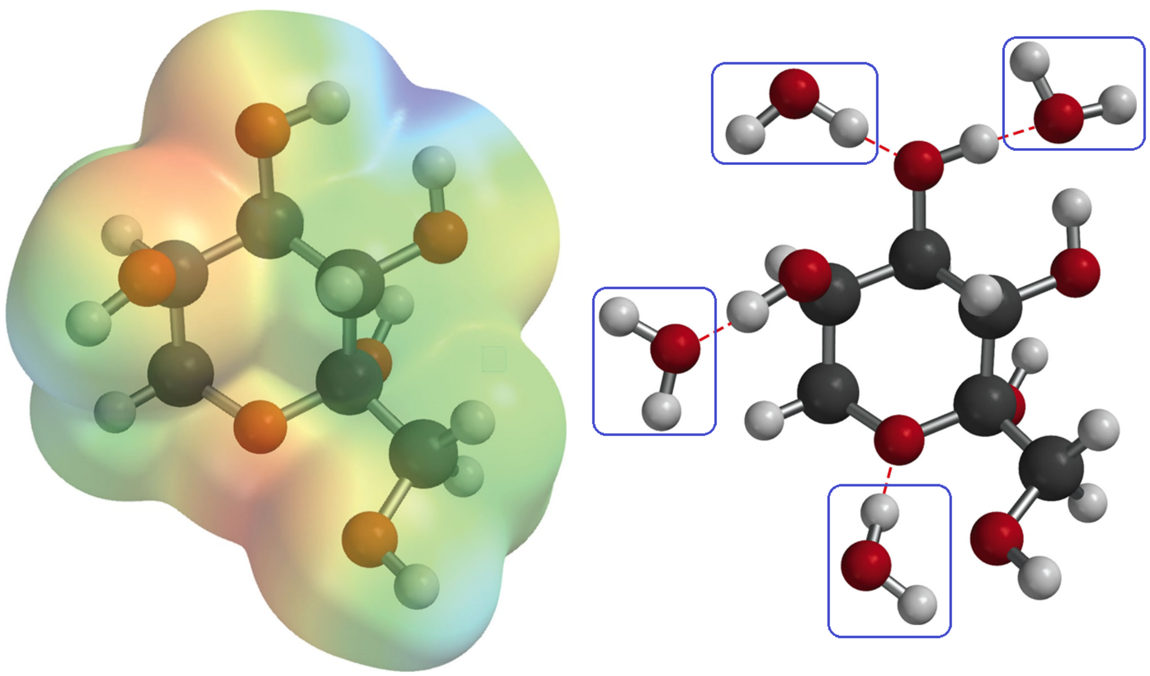
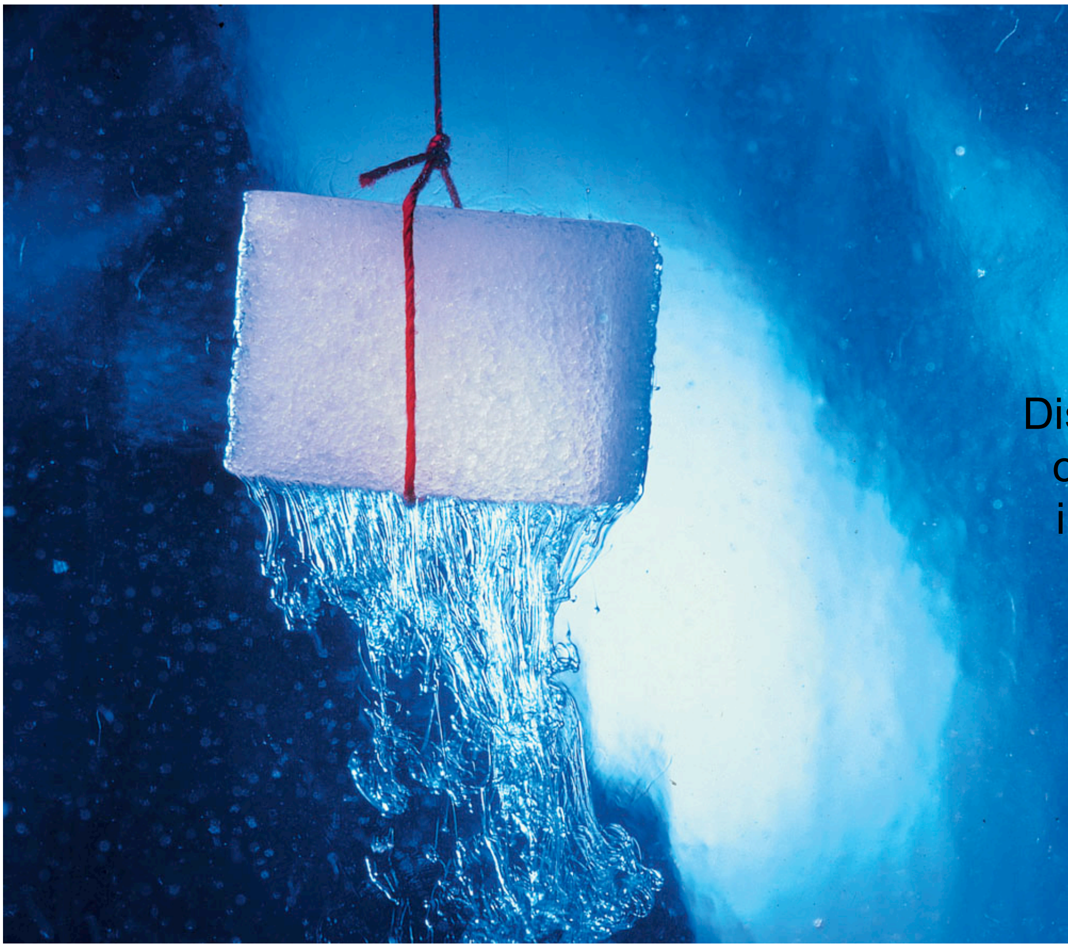


Fig. 11.2 Electrostatic potential energy surface of a fructose molecule and its hydrated form in aqueous solution. Four water molecules are bonded with hydrogen bondings.



Dissolution of sugar in water

◆ Aqueous Solutions of Ionic Species (Electrolytes)

➢ **Solubility**: Maximum mass dissolved in 1 L at 25 ºC

$K_2SO_4(s) \rightarrow 2\,K^+(aq) + SO_4^{2-}(aq)$,

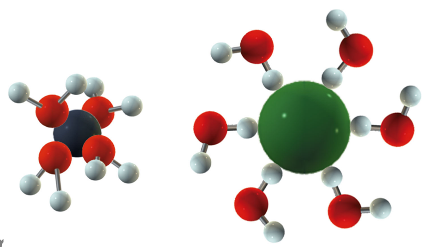
Solubility of K_2SO_4: 120 g L^{-1} at 25ºC

Dissolution of ionic species → Ion-dipole forces

Each ion is surrounded by an intact solvation shell of water molecules.

~ Good conductor, strong electrolyte

~ Electrophoresis under an electric field



Na^+ ion　　Cl^- ion

Cl–H–O

➔ Hydrogen bond is more dominant than ion-dipole force.

➢ Potassium sulfate (K_2SO_4)

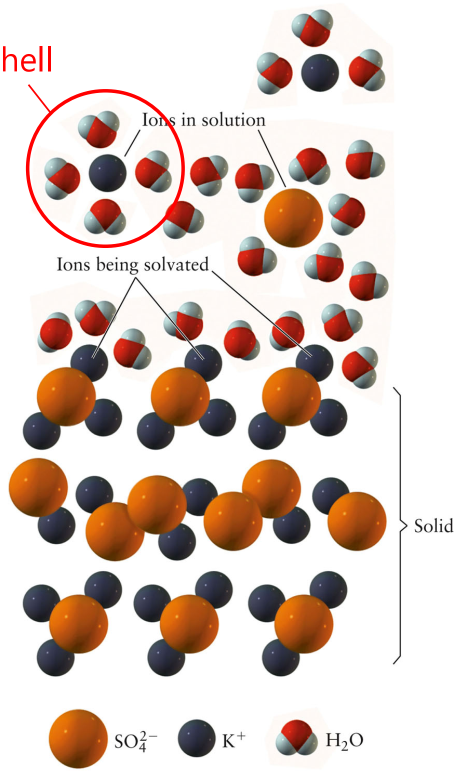
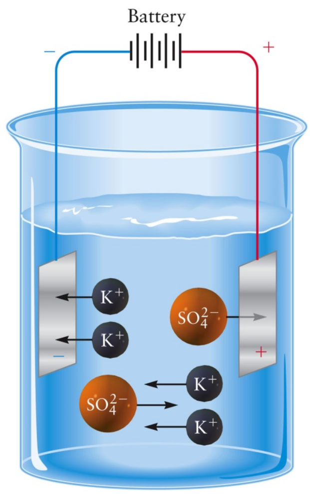


Fig. 11.3 Dissolves in water.



Solvated ions

Conducts electricity.

Fig 11.4

❖ Insoluble salts

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

Solubility of $BaSO_4$: 0.0025 g L^{-1} at 25ºC

➢ Precipitation reaction

$\cancel{BaCl_2(aq) + K_2SO_4(aq) \rightarrow BaSO_4(s) + 2\,KCl(aq)}$

$Ba^{2+}(aq) + 2\,Cl^-(aq) + 2\,K^+(aq) + SO_4^{2-}(aq)$

$\rightarrow BaSO_4(s) + 2\,K^+(aq) + 2\,Cl^-(aq)$

❖ Net ionic equation

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

Spectator ions: Cl^- and K^+