# Chapter 13---Properties of Solutions

Review
Definitions:

- **The ability of substances to form solutions depends on：**
1) natural tendency toward mixing;
2) intermolecular forces (dispersion force, dipole-dipole force, hydrogen bond, ion-dipole force);
  ✓ Solute–solute interactions between solute particles must be overcome to disperse the solute particles through the solvent.
  ✓ Solvent–solvent interactions between solvent particles must be overcome to make room for the solute particles in the solvent.
  ✓ Solvent–solute interactions between the solvent and solute particles occur as the particles mix.
- **Enthalpy changes:**

Exothermic solution process   Endothermic solution process
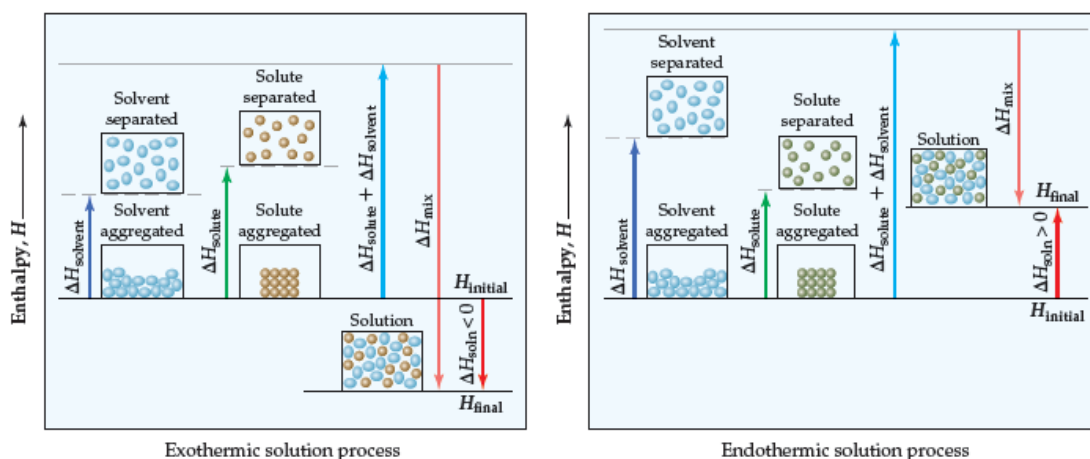
- **Hydrate:** compounds that have a defined number of water molecules in the crystal lattice.

- **Crystallization**: the process where a solid forms where the atoms or molecules are highly organized in a structure known as a crystal.

$$\text{Solute + solvent} \underset{\text{crystallize}}{\overset{\text{dissolve}}{\rightleftharpoons}} \text{solution}$$
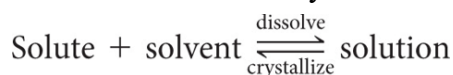
- **Saturated**: a solution that is in equilibrium with undissolved solute is saturated.
- **Unsaturated**: if we dissolve less solute than the amount needed to form a saturated solution, the solution is unsaturated.
- **Supersaturated**: under suitable conditions, it's possible to form solution that contain a greater amount of solute than needed to form a saturated solution, it's supersaturated.
- **Solubility**: the amount of solute needed to form a saturated solution in a given quantity of solvent.

● **Factors affecting solubility**

1) **Solute–Solvent Interactions**: "**like dissolves like.**" Substances with similar intermolecular attractive forces tend to be soluble in one another.

2) **Pressure Effects**------ **Henry's Law**: $S_g = kP_g$

 a) the solubility of the gas in a liquid solvent increases in a direct proportion to the partial pressure of the gas above the solution;

 b) P_g is the equilibrium partial pressure of the gas when it reaches equilibrium;

 c) The molecular state of the solute should be the same in gas phase and solution;

 d) The lower the solution concentration is, the more suitable the law is;
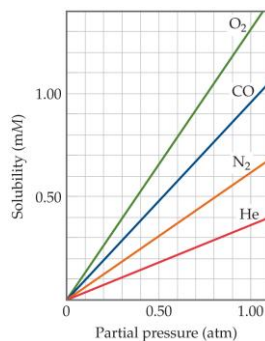
3) **Temperature Effects**

 a) Usually, dissolution of inorganic salt in liquid is a endothermic process;

 b) Usually, dissolution of gas in liquid is a exothermic process;
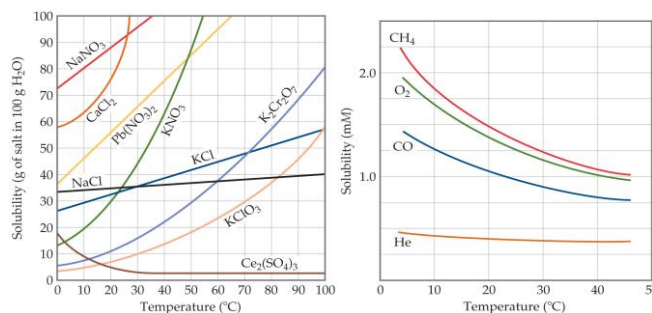
● **Units of Concentration**:

 1) Mass percentage: mass % of component $= \dfrac{mass\ of\ component\ in\ solution}{total\ mass\ of\ solution} \times 100$

 2) Parts per million (ppm): ppm of component $= \dfrac{mass\ of\ component\ in\ solution}{total\ mass\ of\ solution} \times 10^6$

 3) Parts per billion (ppb): ppb of component $= \dfrac{mass\ of\ component\ in\ solution}{total\ mass\ of\ solution} \times 10^9$

 4) Mole fraction (X): mole fraction of component $= \dfrac{moles\ of\ component}{total\ moles\ of\ all\ components}$

 5) Molarity (M): molarity $= \dfrac{moles\ of\ solute}{liters\ of\ solution}$ (do vary with temperature)

 6) Molality (m): molality $= \dfrac{moles\ of\ solute}{kilograms\ of\ solvent}$ (do not vary with temperature)

● **Colligative properties:** physical properties of solutions that depend on the quantity

(concentration) but not on the kind or identity of the solute particles.

1) **Vapor Pressure Lowering:** the vapor pressure of the solution is lower than that of the pure solvent.


Solvent molecules

Nonvolatile solute molecules

A   B
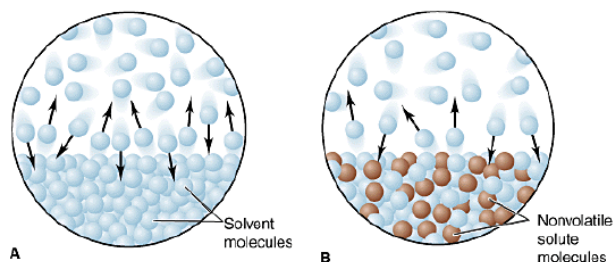
$$P_{solution} = X_{solvent} \cdot P^o_{solvent} \text{ (\textbf{Raoult's Law})}$$
$$\triangle P_{solution} = X_{solute} \cdot P^o_{solvent}$$

a) The vapor pressure of a volatile solvent above a solution containing a nonvolatile solute is proportional to the solvent's concentration in the solution.

b) The law is only suitable for the ideal solutions (the size and force of the solute and solvent molecules are similar to each other) and dilute solutions.

2) **Boiling-Point Elevation:** the boiling point of the solution is higher than that of the pure solvent.
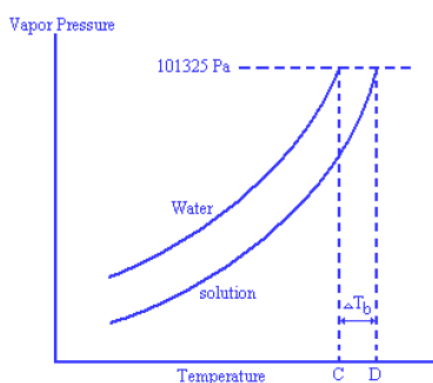
$$\Delta T_b = T_b \text{ (solution)} - T_b \text{ (solvent)} = i \cdot K_b \cdot m;$$

a) T_b (solution): the boiling point of the solution;
b) T_b (solvent): the boiling point of the pure solvent;
c) m: the molality of the solute;
d) K_b: the molal boiling-point-elevation constant for the solvent ($K \cdot kg \cdot mol^{-1}$);
e) i: van't Hoff factor (for a nonelectrolyte, i=1; for a electrolyte, i will depend on how the substance ionizes in that solvent)
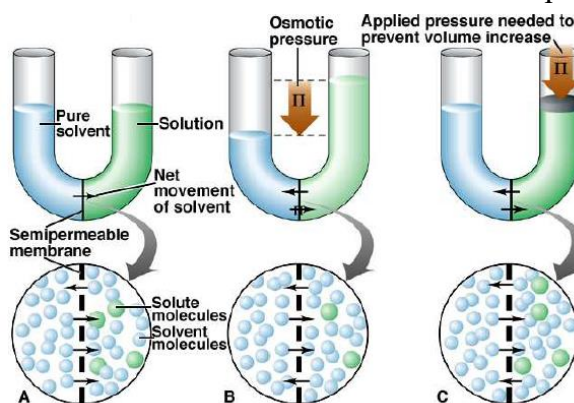
3) **Freezing-Point Depression:** the freezing-point of the solution is lower than that of the pure liquid.
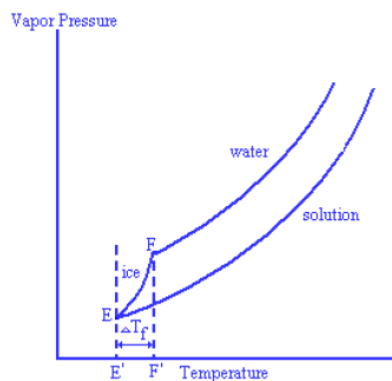
$\boldsymbol{\Delta T_f = T_f\ (solution)\text{-}T_f\ (solvent) = \text{-}\ i \cdot K_f \cdot m;}$

K_f: the molal freezing-point-depression constant $(K \cdot kg \cdot mol^{-1})$

4) **Osmotic Pressure:** the minimum pressure which needs to be applied to a solution to prevent the inward flow of water across a semipermeable membrane.

$\boldsymbol{\Pi = i(\frac{n}{V})RT = iMRT;}$

a) Π: the osmotic pressure;
b) V: the volume of solution;
c) i: van't Hoff factor;
d) n: the number of moles of solute;
e) R: ideal-gas constant;
f) T: the absolute temperature
g) M: the molarity of the solute

- **Colloids**: the intermediate types of dispersions are called colloids.
  1) Particle size can be used to classify a mixture as colloid or solution. Colloid particles range in diameter from 5 to 1000 nm; solute particles are smaller than 5 nm in diameter.
- **Hydrophilic:** a molecule or other molecular entity that is attracted to water molecules and tends to be dissolved by water.
- **Hydrophobic:** a molecule or other molecular entity that is not attracted to water and may seem to be repelled by it.
- **Tyndall Effect**: the scattering of light by colloidal particles.
- **Brownian motion**: collisions that cause a random motion of the entire colloidal particle.