Chap 11 Properties of Solutions #1 1

Table 11.1 Various Types of solutions

11.1 Solution Composition

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⋮

11.6 Osmotic Pressure

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§ 11.1 Solution Composition

$$\text{mass percent} = \frac{\text{mass of Solute}}{\text{mass of solution}} \times 100$$

mole fraction of A $= \chi_A = \dfrac{n_A}{n_A + n_B}$ for a two-component sol'n

molality (m) $= \dfrac{\text{mole of solute}}{\text{Kilogram of solvent}}$

(m) → (M) molarity $= \dfrac{\text{mole of solute}}{\dots}$

normality: number of equivalents per liter of solution (N) 10-2

Ex. 11.1 & 11.2

1.00 g ethanol w/ 100.0 g water

final volume = 101 mL

calculate the molarity, mass percent, mole fraction, and molarity.

molality (m) $= \dfrac{\text{mole of solute}}{\text{kg solvent}}$

$= \dfrac{\dfrac{1.00\text{ g}}{46.07\text{ g/mol}}}{}$

molarity (M)

m : molality

M : molarity

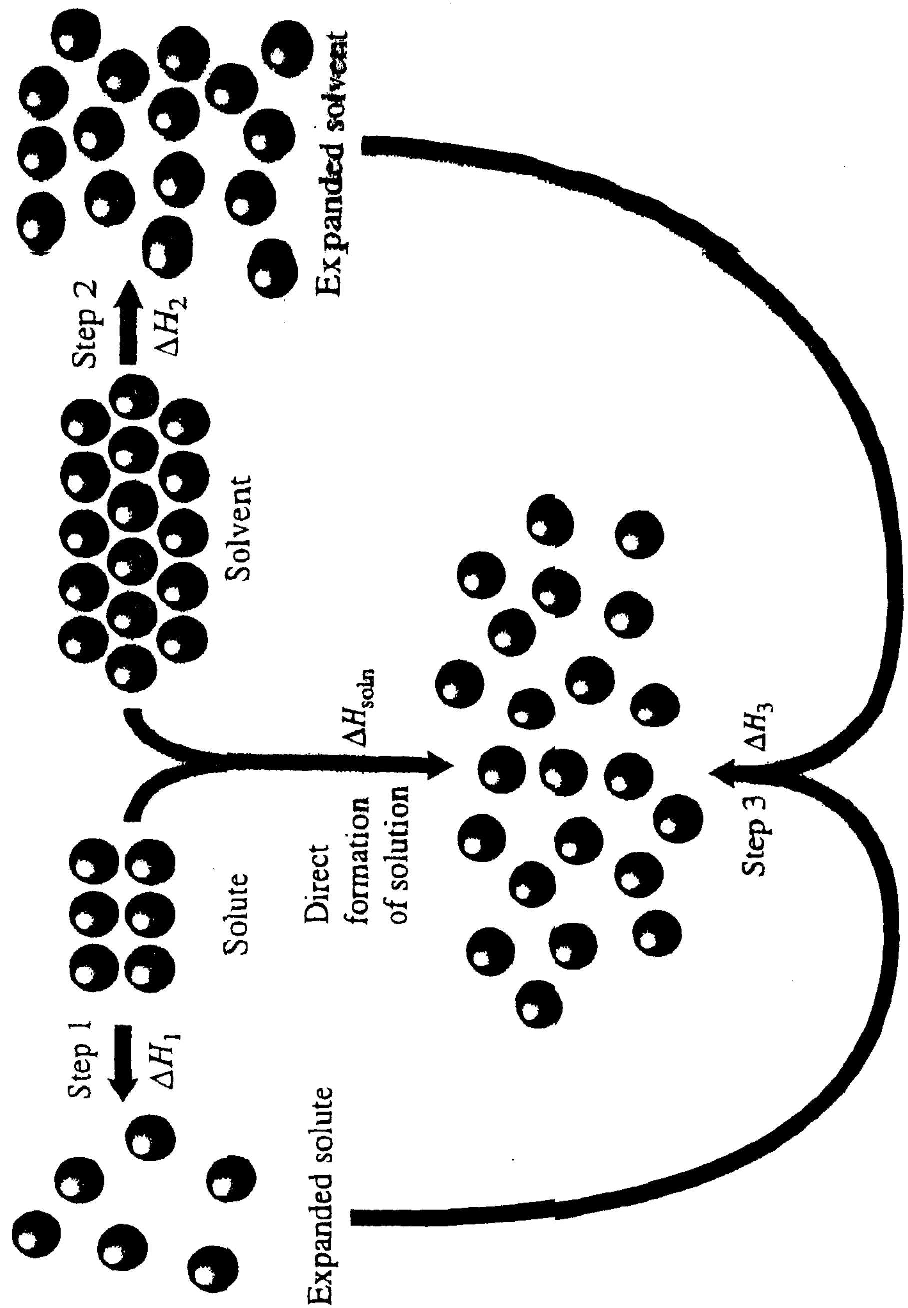


Figure 11.1
The steps in the dissolving process
Steven S. Zumdahl, *Chemistry*,

§11.2 The Energies of Solution Formation

DTT：在体内不易代謝. fat-soluble

$BaSO_4$: X-ray 顯相劑

影響 solubility 的因素

like dissolves like

Formation of a liquid solution

1. Breaking up the solute into individu[al] components (expanding the solute). ΔH_1
2. Overcoming intermolecular forces in the solvent to make room for the solu[te] (expanding the solvent). ΔH_2
3. Allowing the solute and solvent to interact to form the solution. ΔH_3

Fig. 11.1 & Fig 11.2

enthalpy of solution $= \Delta H_1 + \Delta H_2 + \Delta H_3$
(ΔH_{sol})

3

Fig. 11.2

(a) $\Delta H_{sol} < 0$ (放熱)

(b) $\Delta H_{sol} > 0$ (吸熱)

Enthalpy of hydration (ΔH_{hyd})

$= \Delta H_2 + \Delta H_3$

以 NaCl 溶於水為例

$NaCl_{(s)} \rightarrow Na^+_{(g)} + Cl^-_{(g)} \quad \Delta H_1 = 786\ kJ/mol$

$H_2O_{(l)} + Na^+_{(g)} + Cl^-_{(g)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)}$

$\Delta H_{hyd} = \Delta H_2 + \Delta H_3$

$= -783\ kJ/mol$

$\Delta H_{sol} = \Delta H_1 + \Delta H_{hyd}$

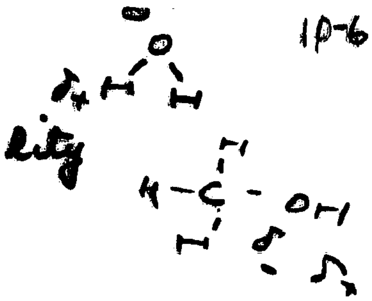
$= 3\ kJ/mol$

§ Ex 11.3.

C_6H_{14} (hexane) 己烷 } solvent
CH_3OH (methanol)

$C_{20}H_{42}$ } solute
KI

Table 11.3.



§ 11.3 Factors Affecting Solubility

structure effect

以維他命為例

Vitamins: fat-soluble (A. D. E. K)
water-soluble (B. C)

See Fig. 11.4.

vitamin A: hydrophobic

vitamin C: hydrophilic

pressure effect

汽水

Henry's law:

$P = k\,C$ → concentration of dissolved gas

↑ gas pressure

(對 dilute solutions of gases that do not dissociate in or react w/ the solvent)

$HCl_{(g)} \xrightarrow{H_2O} H^+_{(aq)} + Cl^-_{(aq)}$ 不適用

Ex 11.4 Calculations Using Henry's Law

The Henry's law const for CO_2 = $32 \ L\cdot atm/mol$

$P_{CO_2} = 4.0 \times 10^{-4}$ atm at 1 atm F

Sol: unopened:

$P_{CO_2} = k\, C_{CO_2}$

$\frac{P_{CO_2}}{k} = C_{CO_2} = \frac{5.0\ atm}{32\ L\cdot atm/mol} = 0.16\ mol/L$

opened:

$\frac{P_{CO_2}}{k} = C_{CO_2} = \frac{4.0\times10^{-4}\ atm}{32\ L\cdot atm/mol} = 1.2\times10^{-5}\ mol/L$

Temperature effect

溶解度与温度的関係

Fig 11.6 & 11.7

thermal pollution 影響 溶氧量

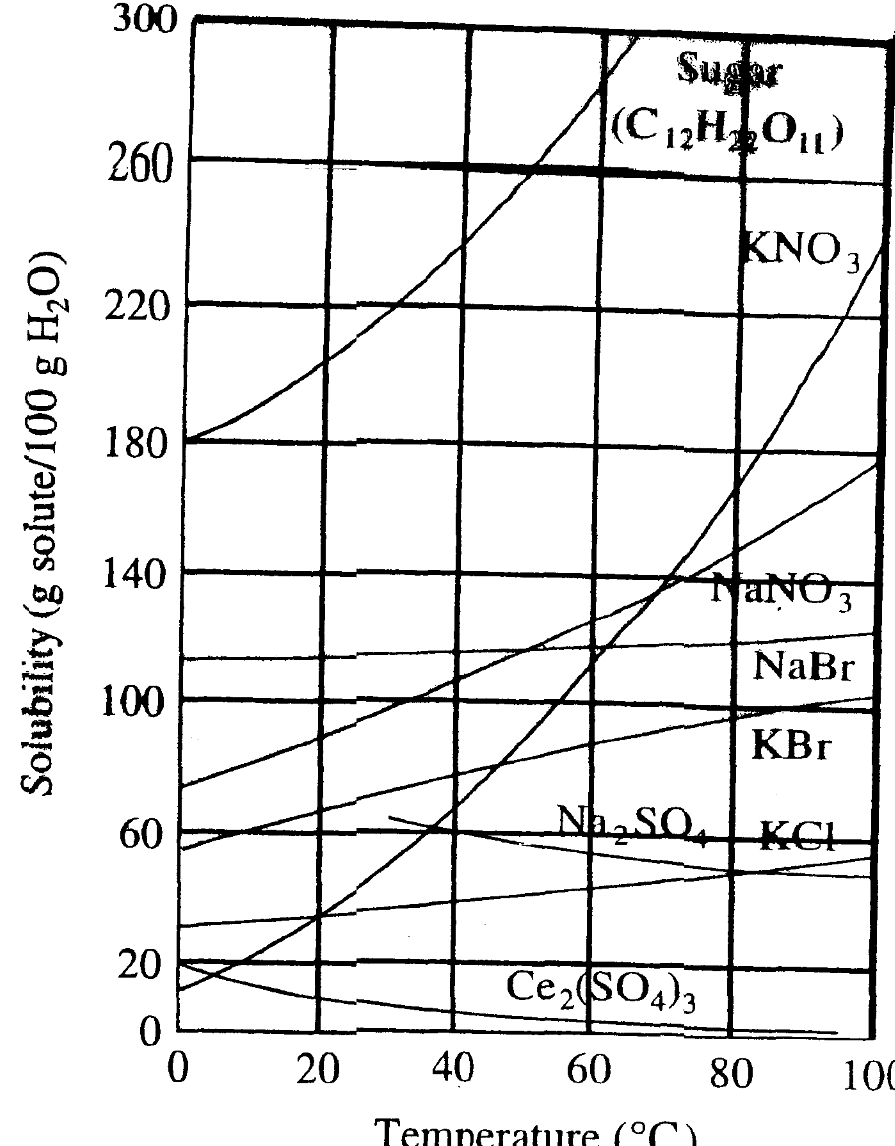


Figure 11.6
The temperature dependence of solubility for various solids

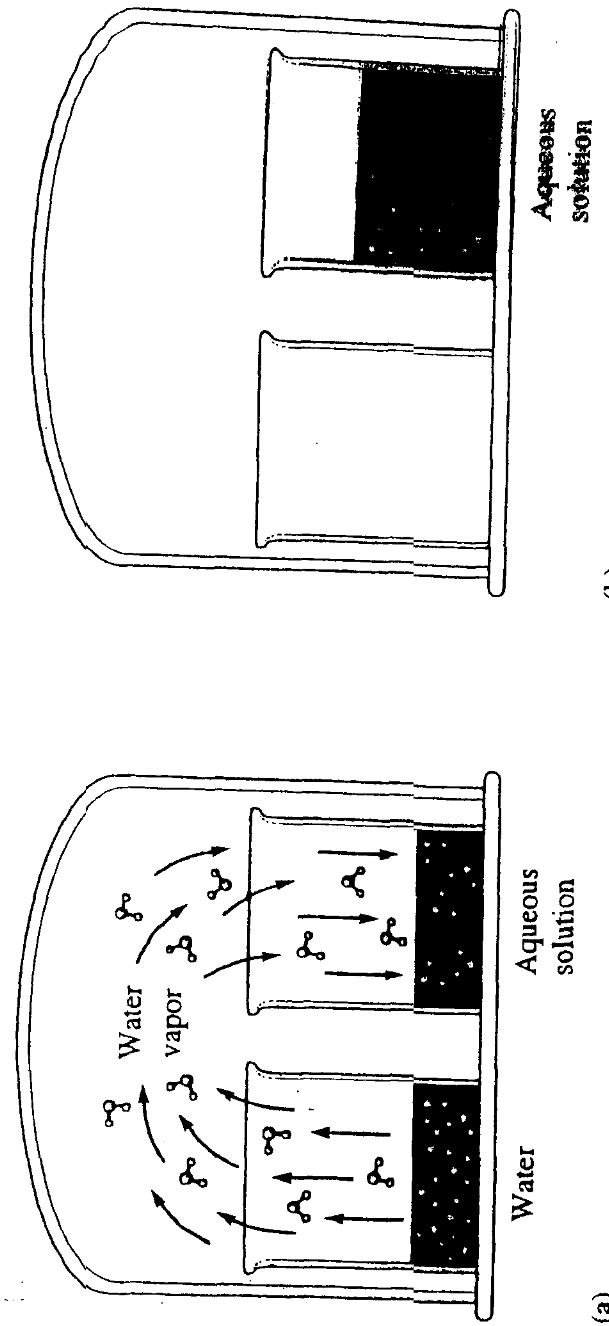


Figure 11.9
An aqueous solution and pure water in a closed environment
Steven S. Zumdahl, *Chemistry*,

§ 11.4 The vapor Pressures of solutions

Fig 11.9 (P-1...

non-volatile solute lowers the vapor pressure of a solvent

Raoult's law:

$$P_{sol} = \chi_{solvent} P^{\circ}_{solvent} + \chi_{solute} P^{\circ}_{sol...}$$

$\chi_{solvent}$ ↑ ~~molar~~ mole fraction of solvent; $\chi_{solute} P^{\circ}_{sol...}$ ↓ ≈ 0

Ex. 11.5

158.0g sugar in 643.5 cm³ water

at 25°c, H_2O density 0.9971 g/cm³

vapor pressure = 23.76...

Sol:

$$\chi_{solvent} = \frac{n_{solvent}}{n_{solute} + n_{solvent}} = \frac{\frac{643.5 \cdot 0.9971}{18}\ mol}{\frac{158.0}{342.3} + \frac{643.5 \cdot 0.9971}{18}} = 0.987...$$

$$P_{sol} = \chi_{solvent} \cdot P^{\circ}_{solvent} = 0.9873 \cdot 23.76\ torr = 23.46\ torr$$

Ex 11.6.

35.0 g solid Na_2SO_4 w/ 175 g water

$P^\circ_{H_2O}$ = 23.76 torr at 25°C

$n_{H_2O} = 175\,g\,H_2O \times \frac{1\,mol\,H_2O}{18.0\,g\,H_2O} = 9.72\,mol\,H_2O$

$n_{Na_2SO_4} = 35.0\,g \times \frac{1\,mol\,Na_2SO_4}{142\,g\,Na_2SO_4} = 0.246\,mol\,Na_2SO_4$

$n_{solute} = n_{Na^+} + n_{SO_4^{2-}} = 3 \times n_{Na_2SO_4}$

$= 3 \times 0.246 = 0.738\,mol$

$\chi_{H_2O} = \frac{9.72\,mol}{9.72\,mol + 0.738\,mol} = 0.929$

$P_{soln} = \chi_{H_2O} \cdot P^\circ_{H_2O} = (0.929)(23.76\,torr)$

$= 22.1\,torr$

Nonideal Solutions

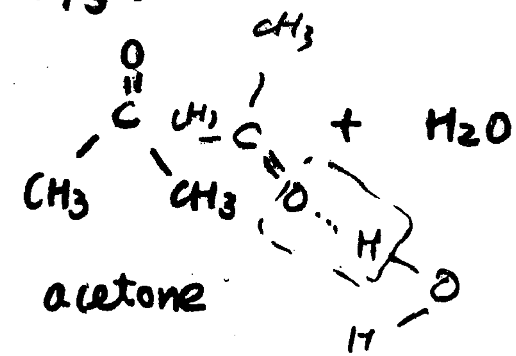
$P_{Total} \neq P_A + P_B = \chi_A P_A^\circ + \chi_B P_B^\circ$

Fig. 11.12 & 11.13.

(a) ideal solution

Non-ideal solutions <
(b) solvent-solute 引力 ↑
(c) solvent-solute 引力 ↓

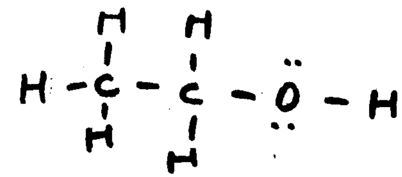
例子：

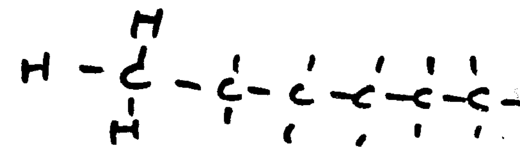


acetone

氫鍵形成

enthalpy of solution < 0
negative deviation from Raoult's law





enthalpy of solution > 0
positive deviation from Raoult's law

very similar, enthalpy of solution ~ 0 ideal solution

Table 11.4.
Summary of the behavior of various types of solutions.

Ex. 11.7

10-13

5.81 g acetone (M.W. = 58.1 g/mol)

11.9 g chloroform (M.W = 119.4 g/mol)

at 35°C, the solution has a total vapor pressure of 260. torr. Is the solution ideal?

$P^{0}_{acetone}$ = 345 torr

$P^{0}_{chloroform}$ = 293 torr

$$P_{Total} = x_A P_A^0 + x_B P_B^0$$

A : acetone

B : chloroform

$$x_A = \frac{\frac{5.81}{58.1}\text{ mol}}{\frac{5.81}{58.1} + \frac{11.9}{119.4}} = 0.5$$

$$x_B = \frac{\frac{11.9}{119.4}}{\frac{5.81}{58.1} + \frac{11.9}{119.4}} = 0.5$$

P_{total} = 0.5 × 345 + 0.5 × 293

= 319 torr

260 (observed) < 319 torr

10-1

n_{solute} = 0.10 mol = $\frac{18.00\text{g}}{\text{molar mass}}$

molar mass of solute (glucose)

$$= \frac{18.00\text{g}}{0.10\text{mol}} = 180 \text{ g/mol}$$

Freezing-Point Depression

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

K_f : molal freezing-point depression constant

§ 11.5 Boiling-point Elevation and

Freezing-point Depression

$$\Delta T = K_b \, m_{solute}$$

K_b : molal boiling-point elevation const

m_{solute} = molarity of the solute in the solution

Fig. 11.14 & Table 11.5

Ex. 11.8

a solution was prepared by 18.00 g glucose in 150.0 g water. The resulting solution was found to have a boiling point = 100.34°C. Calculate the molar mass of glucose.

Sol:

$$\Delta T = K_b \, m_{solute}$$

$$0.34^{\circ}C = K_b \; 0.51 \; {}^{\circ}C \; kg/mol \cdot m_{solute}$$

$$m_{(solute)} = 0.67 \; mol/kg = \frac{n_{solute}}{\ldots}$$

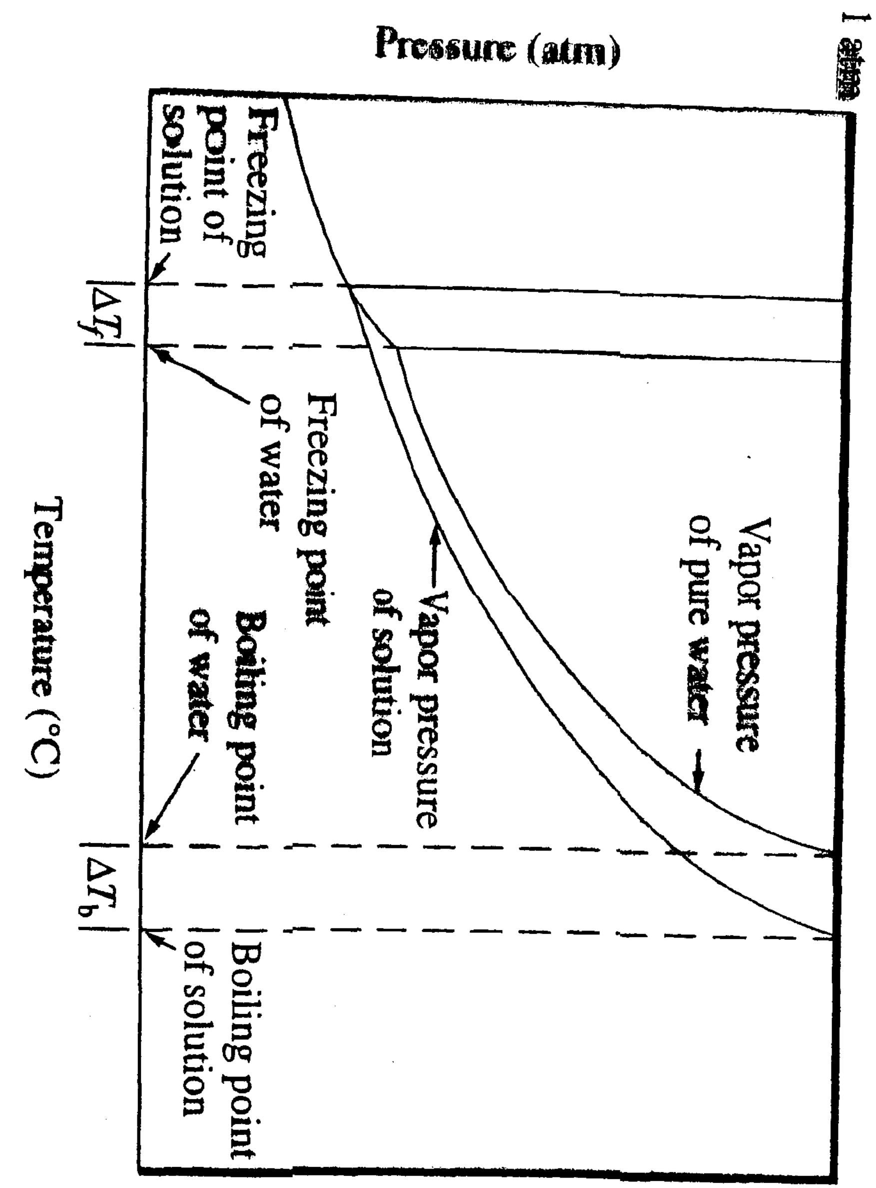


Figure 11.14 Vapor diagram for an aqueous solution

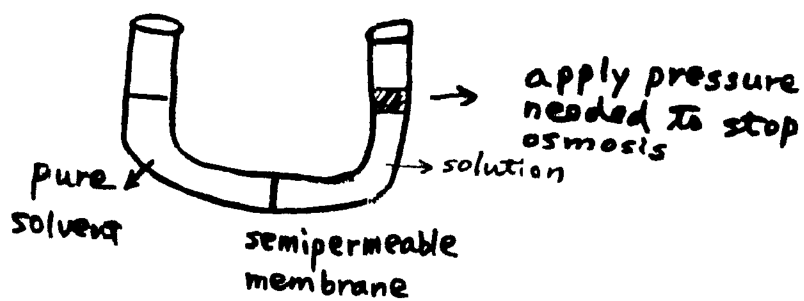
§ 11.6 Osmotic Pressure (滲透壓) 10-17

semipermeable membrane (半透膜):

allow solvent but not solute molecules to pass through.

See Fig 11.16 & 11.17

As time passes, the volume of the solution increases and that of the solvent decreases.



$$\pi = MRT$$

- π → osmotic pressure (in atm)
- M → molarity (M)
- R → gas law ~~pressure~~ const
- T → kelvin temp

See Fig 11.18

10-18

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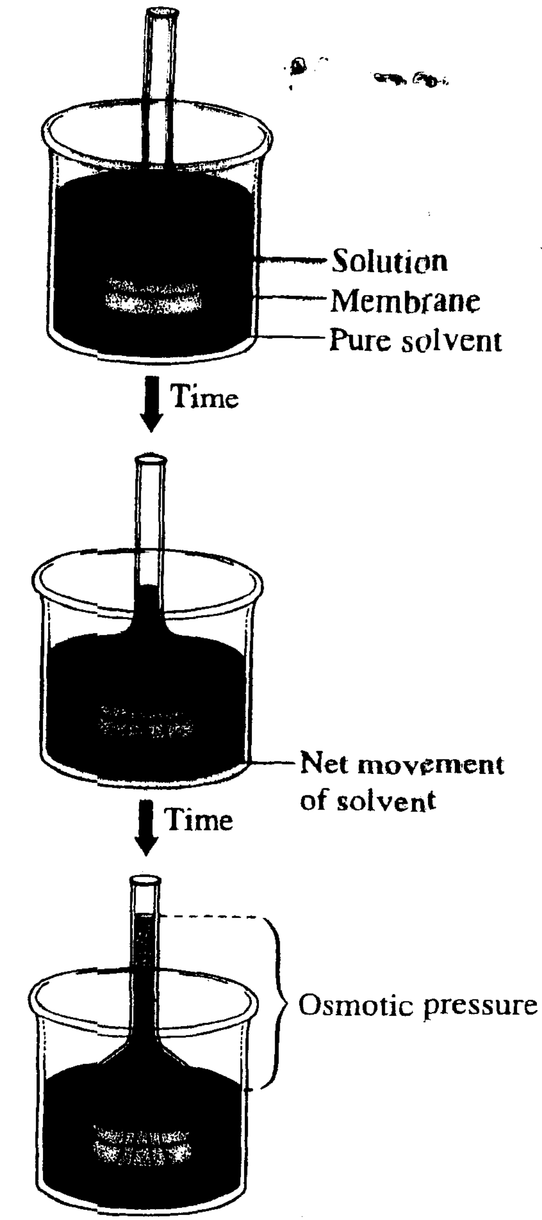


Figure 11.14
The development of osmotic pressure

Ex. 11.11 10-19

To determine the molar mass of a certain protein. 1.00×10^{-3} g in 1.00 ml of solution

osmotic pressure = 1.12 torr at 25.0°c

→ calculate the molar mass of the protein

Sol.

$$\pi = MRT$$

$$\frac{1.12\ torr}{760\ \frac{torr}{atm}} = M \cdot 0.082 \frac{L \cdot atm}{K \cdot mol} \cdot (273 + 25.0)$$

$$M = 6.01 \times 10^{-5}\ mol/L$$

$$= \frac{\frac{1.00 \times 10^{-3} g}{M.W}}{1.00 \times 10^{-3} l}$$

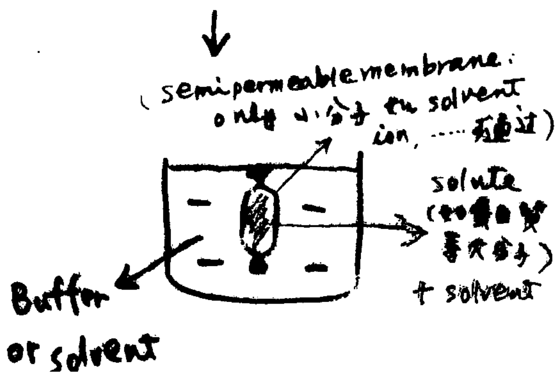
$$\therefore MW = 1.66 \times 10^{4}\ g/mol$$

應用：洗腎机 & 透析 (dialysis)

see Fig. 11.19

(清洗 or filter out waste molecule)

小分子



Isotonic solutions : solutions that [illegible]
(等滲壓溶液)
identical osmotic pressure.

Ex. 1. 靜脈注射 (必須與血液是 isoton[ic])

If hypertonic (osmotic pressure > 紅血球的 osmotic pressure)

→ 血球内 solvent and small molecules 会流出 → 血球乾扁 (crenation)

If hypotonic (osmotic pressure < 紅血球的 osmotic pressure)

→ solvent and small molecules 会流入紅血球 → 紅血球会漲破. (hemolysis)

Ex. 2. 保存食物. 高鹽 or 高糖.

Ex. 11.12

如何 make isotonic solution using NaCl and let $\pi = 7.70$ atm at 25°c (血液)

Sol.

$$\pi = MRT$$

$$7.70\ atm = M \cdot 0.082 \frac{atm \cdot l}{mole \cdot K} \cdot (273 + 25)$$

$$M = 0.315\ M.$$

0.315M

Reverse Osmosis (逆渗透): 10-21

如果溶液外加一个大於它渗透压的压力，此時溶剂会由溶液穿过 semi-permeable membrane 到(经)溶剂。

应用：淡化海水 → 食用水

see Fig 11.20 & 11.21 & 11.22

Apply 800 lb/in² 的压力

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§11.7 Colligative Properties of Electrolyte Solutions

$\Delta T_f = K_f \cdot m \quad = K_f \cdot i \cdot m$

$\Delta T_b = K_b \cdot m \quad = K_b \, i \cdot m$

$\pi = MRT \quad = iMRT$

但此時 m & M 皆为溶液中的 "solute particles" 的浓度

∴ 再乘一个 i (Van't Hoff factor)

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

see Table 11.6

§11.8 Colloids 胶体 10-22

A suspension of tiny particles in some medium is called a colloidal dispersion or a colloid.

Ex. 泥土加水搅拌

→ 光会散射 (scatter)

又称 Tyndall effect

(The scattering of light by particles)

see Fig 11.24 The Tyndall effect

Table 11.7 Types of colloids

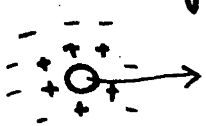
Colloid : the suspended particles

大约 1 to 1000 nm.

particles 形成原因与悬浮原因:

electrostatic repulsion

see Fig 11.25



→ 小晶体 or 分子聚集

→ 被一层离子包围

→ 被第二层离子包围

Colloid 可被 heating
or adding an electrolyte } 破壞

→ coagulation 凝結

如： 1. 帶泥河流注入海 ∵ 碰到 electrolyte
→ coagulation 形成三角洲

2. 煤灰形成 (see Fig 11.26)
→ use charged plates to attract the colloidal particles
→ remove colloidal particles from smoke