

## IV) Factors Affecting Solubility

### A) Nature of Solute & Solvent

Solute & solvent must possess similar I.A.F.

“ Like Dissolves Like ”

Polar Solvents ( $H_2O$ ,  $C_2H_5OH$ , etc.)

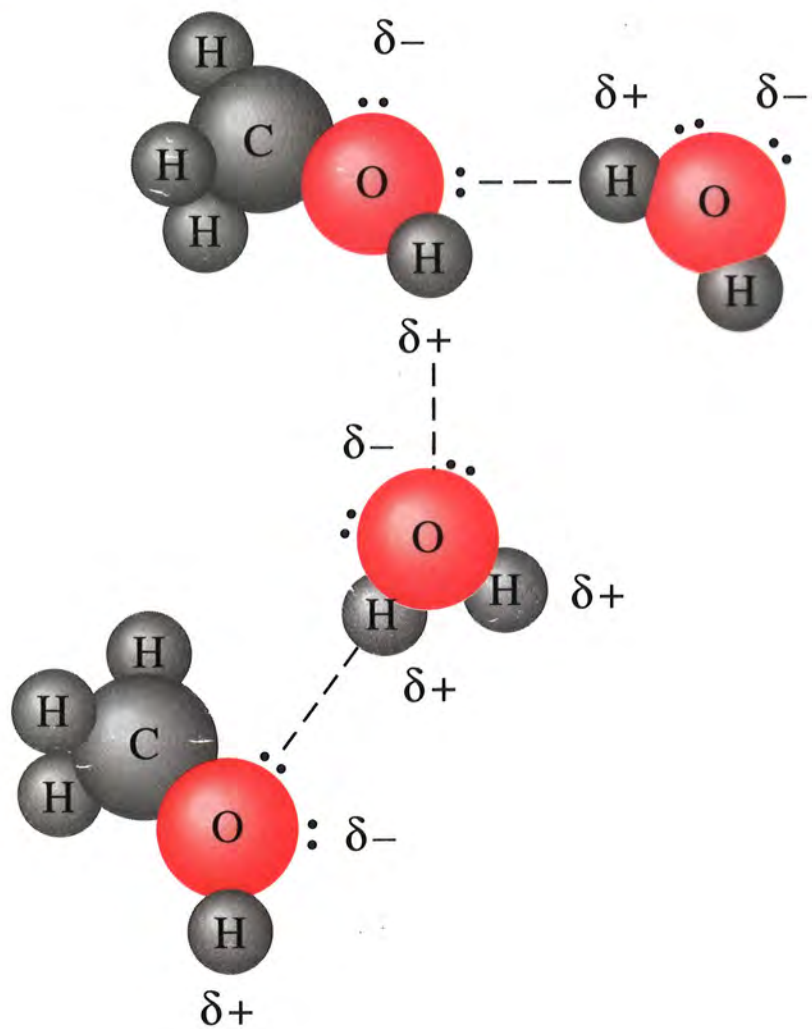
dissolve polar & ionic solutes  
( $NH_3$ ,  $NaCl$ ,  $C_2H_5OH$ , etc.)

Non polar Solvents ( $CCl_4$ ,  $C_6H_6$ , etc.)

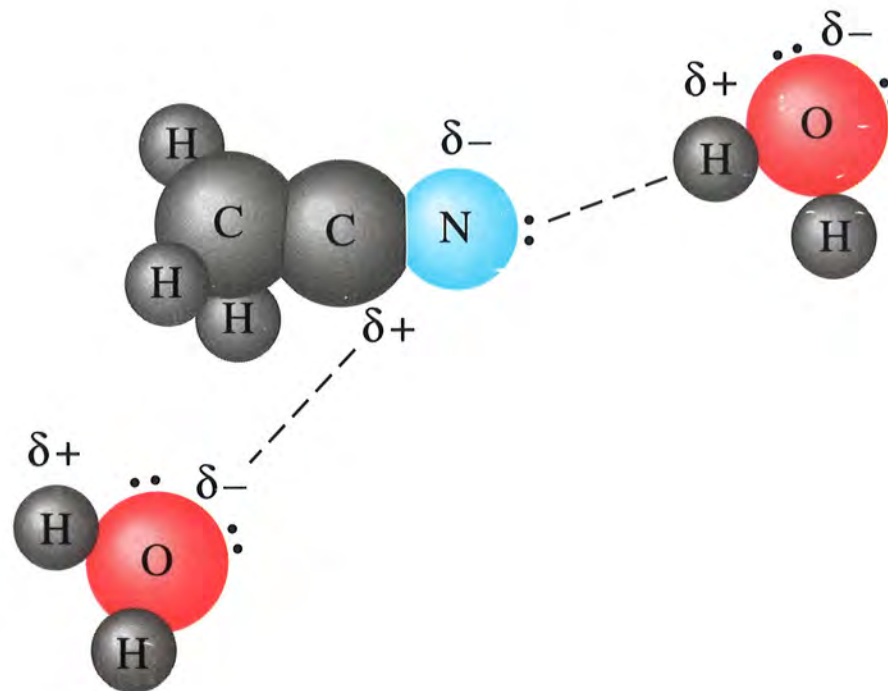
dissolve non polar solutes

(grease, fats, oils, hydrocarbons)





(a)

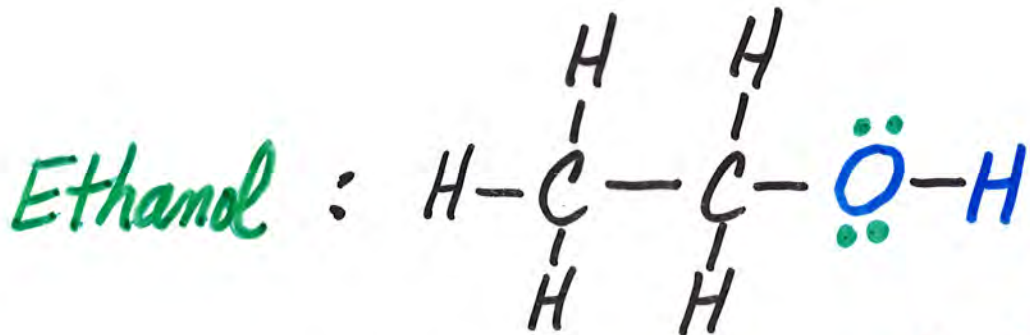


(b)

1) Ex 1: Which is **more** soluble in  $H_2O$ ; ethanol ( $C_2H_5OH$ ) or hexane ( $C_6H_{14}$ ).

$H_2O$  : L.F., D-D, H-bonding

Polar solvent



L.F., D-D, H-bonding

Polar solute

Hexane :  $C_6H_{14}$

L.F.

Non polar solute



2) Ex 2: I have a test tube containing a  $H_2O$  layer + a hexane ( $C_6H_{14}$ ) layer. In which layer(s) will  $I_2$  +  $CuCl_2$  dissolve?



## B) Pressure Effects

Mainly effects solubility of **gases**



**Dynamic Equil.**

What happens if  $P$  inc.?

## Le Chatelier's Principle

Apply a "stress" (change in  $T, P, C$ ) to a system at **equil.** the system **shifts** to a **new position** of **equil.** to **minimize** the "stress".

stress : Inc. P

counteract : wants to reduce P  
force gas molecules  
into soln.

- shifts to right

result : Inc. solubility

Inc. P , Inc. solubility

- True for ALL gases

1) Henry's Law

$$S_g = k_H P_g$$

$$\frac{S_2}{S_1} = \frac{P_2}{P_1}$$



## C) Temperature Effects

### 1) Gases

ALL gases dissolve in  $H_2O$  w.  
evolution of heat



Inc.  $T$ , Dec. solubility

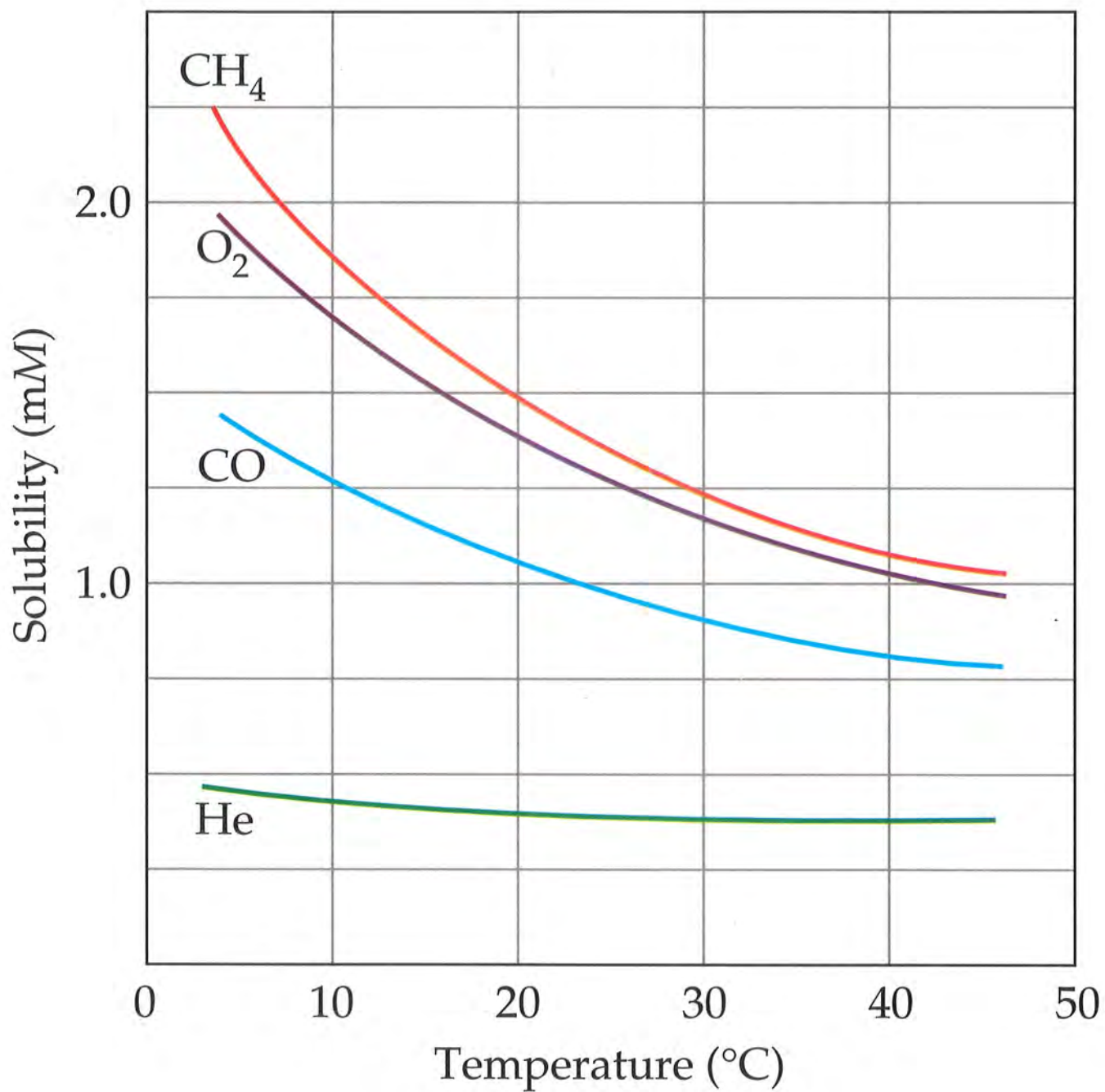
### 2) Solids

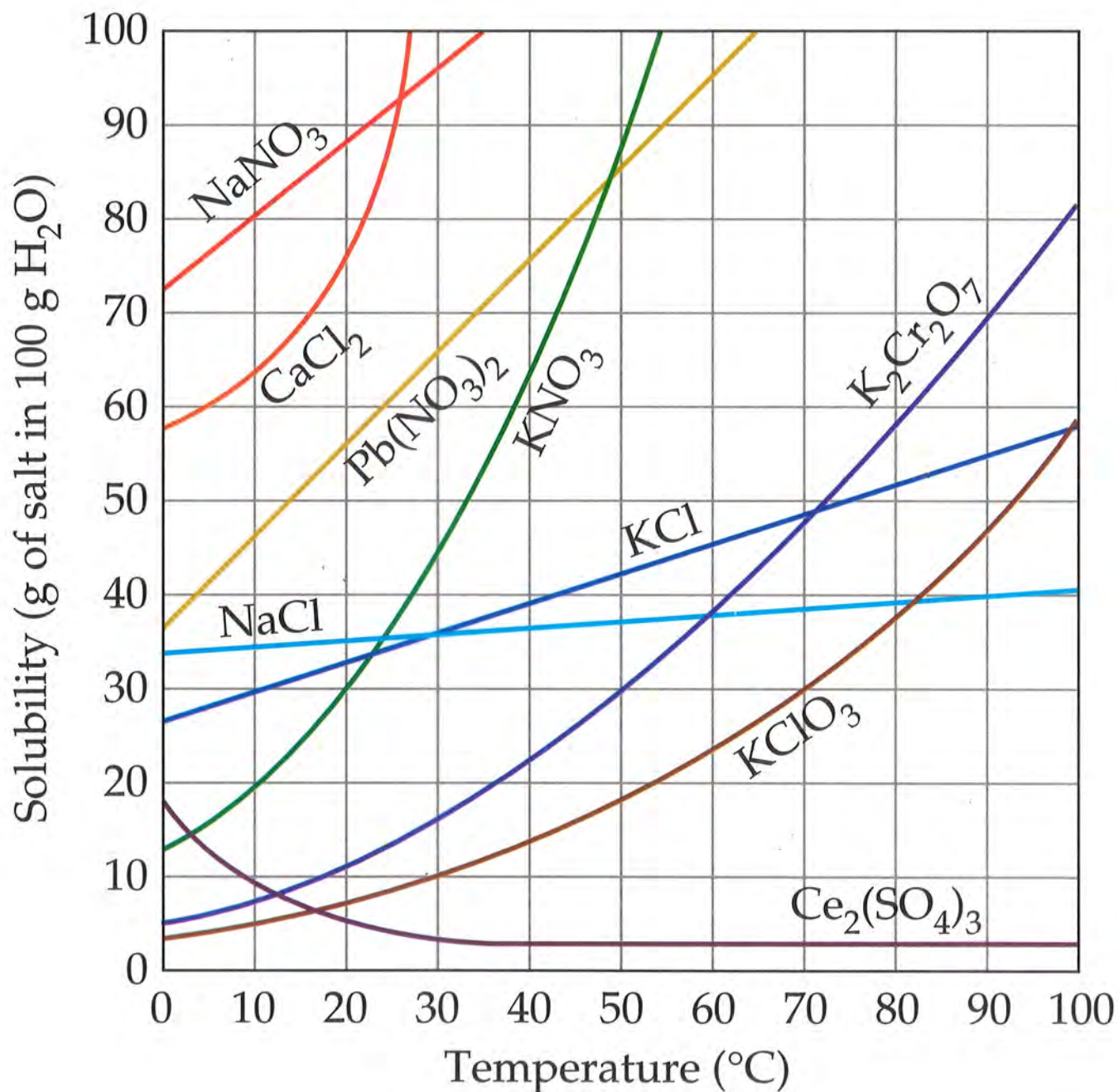
For most ionic solids:



Inc.  $T$ , Inc. solubility

Are exceptions







## III) Colligative Properties

Prop. of a soln. that depend **only** on **number** of **solute** particles (**conc.**) & **NOT** on their **identity**

### A) Vapor Pressure Lowering

#### 1) Non volatile solutes

V.P. above soln. due **only** to **solvent**

**Replace** some **solvent** molecules at **surface** w. **solute** molecules



fewer solvent molec.  
escape into gas phase  
than for pure solvent

∴ Lower V.P.

greater  
solute  
conc.



greater  
dec.  
V.P.

NOT dependent on type of particle

1 M sugar soln.  $\equiv$  0.5 M NaCl soln

## a) Raoult's Law

For **volatile** substance

$$P_A = \chi_{A_l} P_A^{\circ}$$

$P_A$  = V.P. of **A** above **soln**

$\chi_{A_l}$  = **mole fraction** of **A** in  
**liquid phase**

$P_A^{\circ}$  = V.P. of **pure A**

$$P_{\text{soln}} = P_{\text{solvent}} + P_{\text{solute}}$$

For a **soln.** of **nonvolatile solute**

$$P_{\text{soln}} = P_{\text{solvent}}$$

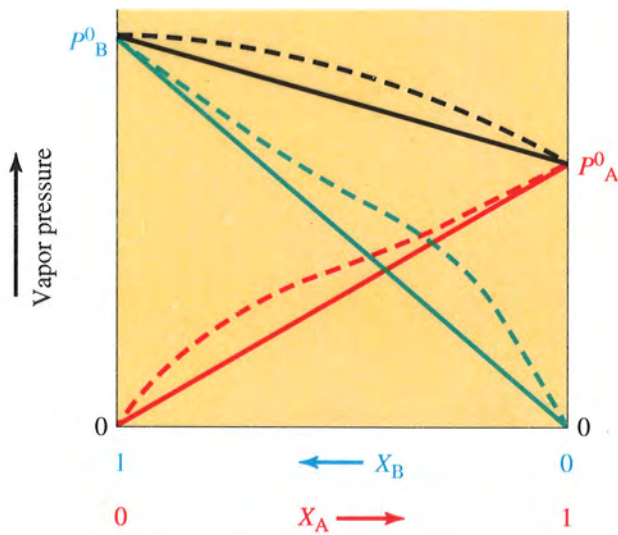
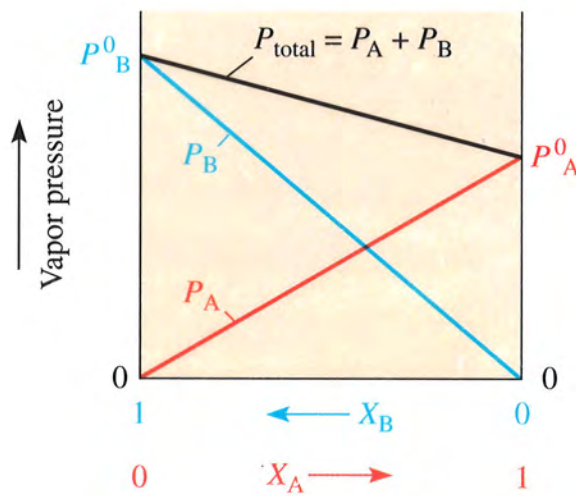
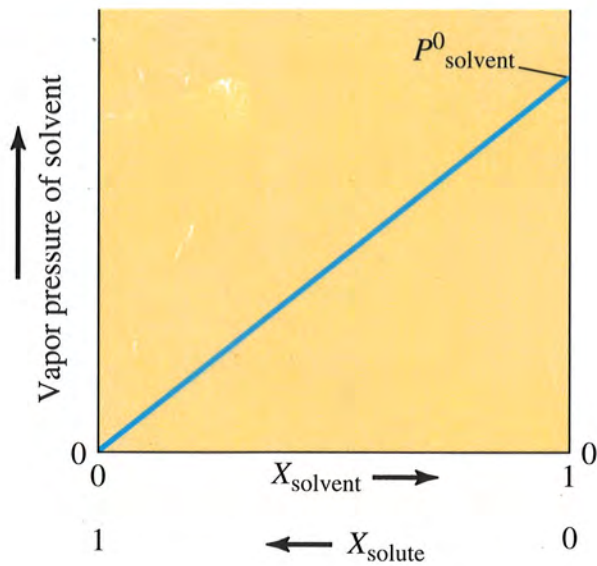
Ideal soln's obey Raoult's Law

Real soln's  $\Rightarrow$  Ideal soln's

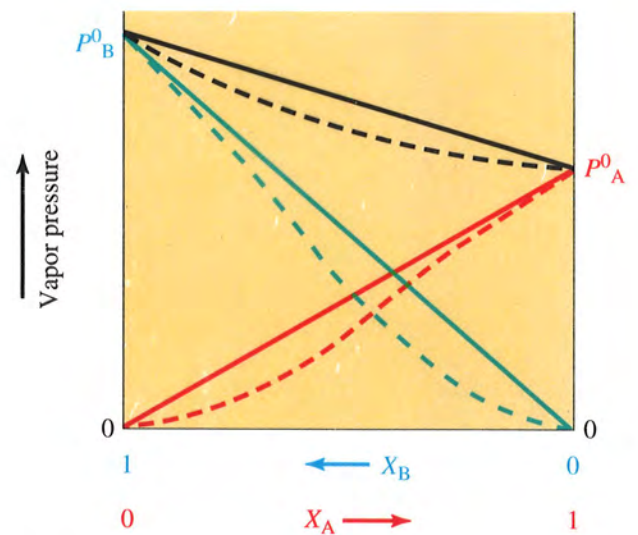
low solute conc.

&

Similar solute & solvent



(a)



(b)



b) Expression for V.P. Lowering

$$P_A < P_A^{\circ}$$

$$\Delta P = P_A^{\circ} - P_A$$

$$= P_A^{\circ} - \chi_{A_l} P_A^{\circ}$$

$$\Delta P = (1 - \chi_{A_l}) P_A^{\circ}$$

But, for a 2 component soln:

$$\chi_{A_l} + \chi_B = 1$$

∴

$$\Delta P = \chi_B P_A^{\circ}$$

V.P. lowering due to solute in soln.

c) Ex: What is the V.P. lowering & V.P. of a soln. containing 8.56g of eugenol ( $C_{10}H_{12}O_2$ ) in 50.0g of ethanol ( $C_2H_5OH$ ), at  $20.0^\circ C$ .

The V.P. of ethanol at  $20.0^\circ C$  is 44.6 torr.



## 2) Volatile solutes

Both solute & solvent have appreciable V.P.

Also, suppose A & B form ideal soln.

i.e. both A & B follow

Raoult's Law & obey

Dalton's Law

$$P_A = \chi_{A_l} P_A^{\circ}$$

$$P_B = \chi_{B_l} P_B^{\circ}$$

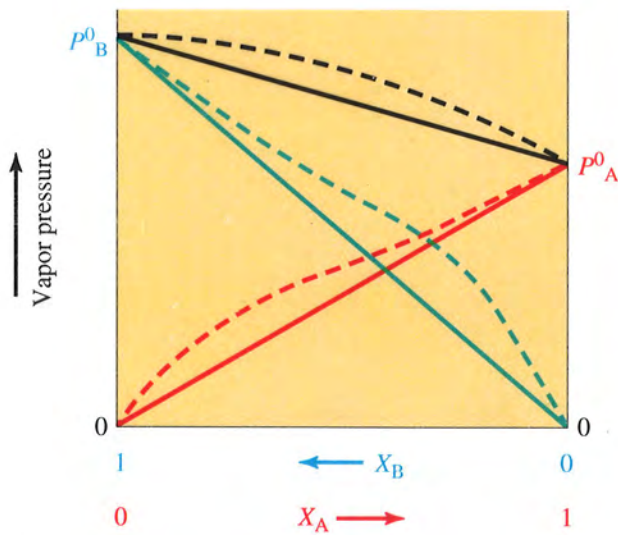
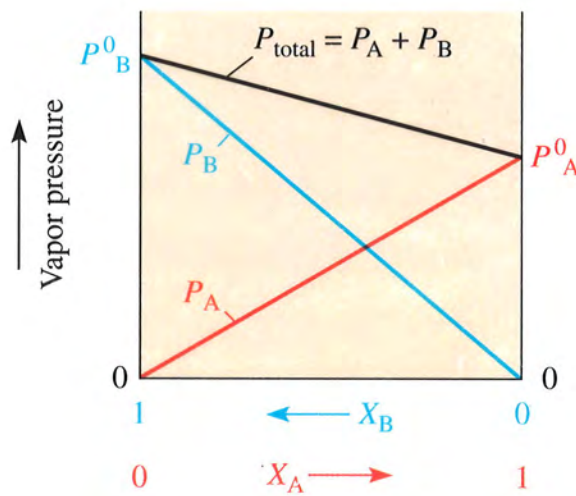
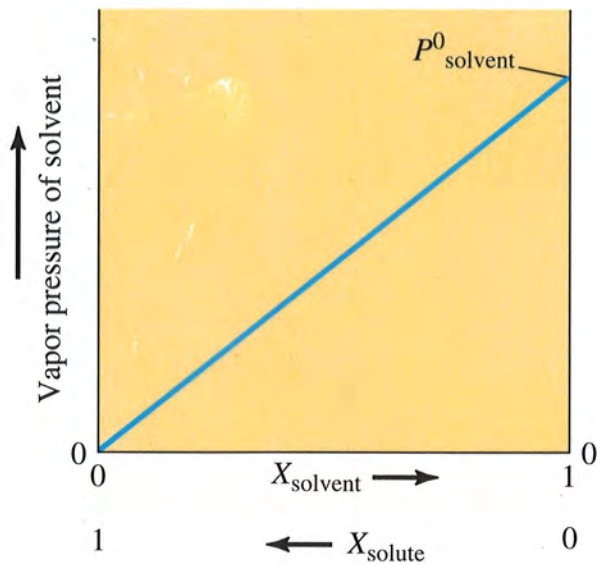
$$P_T = P_A + P_B$$

$$P_T = \chi_{A_l} P_A^{\circ} + \chi_{B_l} P_B^{\circ}$$

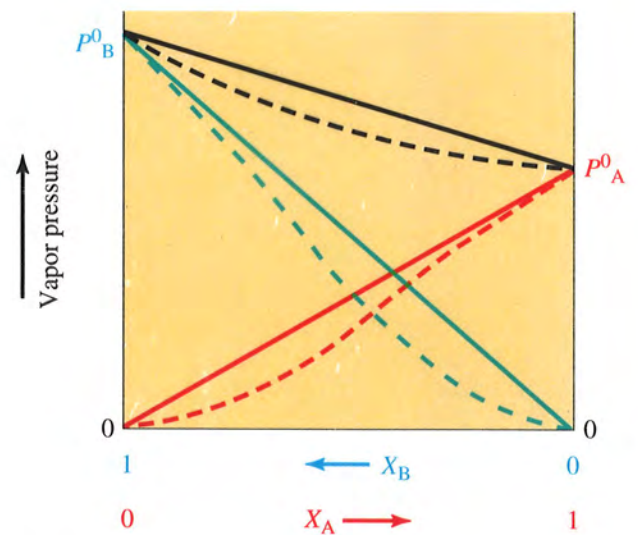


a) Ex: What is the V.P. of a soln. of 0.250 mole of heptane ( $C_7H_{16}$ ) + 0.306 mole of octane ( $C_8H_{18}$ ) at  $100^\circ C$ ?

$$P_{\text{hep}}^\circ = 791 \text{ torr} \quad P_{\text{oct}}^\circ = 352 \text{ torr}$$



(a)



(b)

b) Ex: What is the composition of the vapor in the previous example?

## B) Boiling Point Elevation

Soln. will **not** boil at **normal** b.p. of solvent since **V.P.** of soln. is **not** **1 atm** at this temp.

Must **raise** temp. to bring **V.P.** of soln. to **1 atm**.

$$\Delta T_b = K_b m_{\text{particles}} = K_b (i m_{\text{stated}})$$

$K_b \equiv$  molal b.p.-elevation constant

$i \equiv$  # particles in soln.

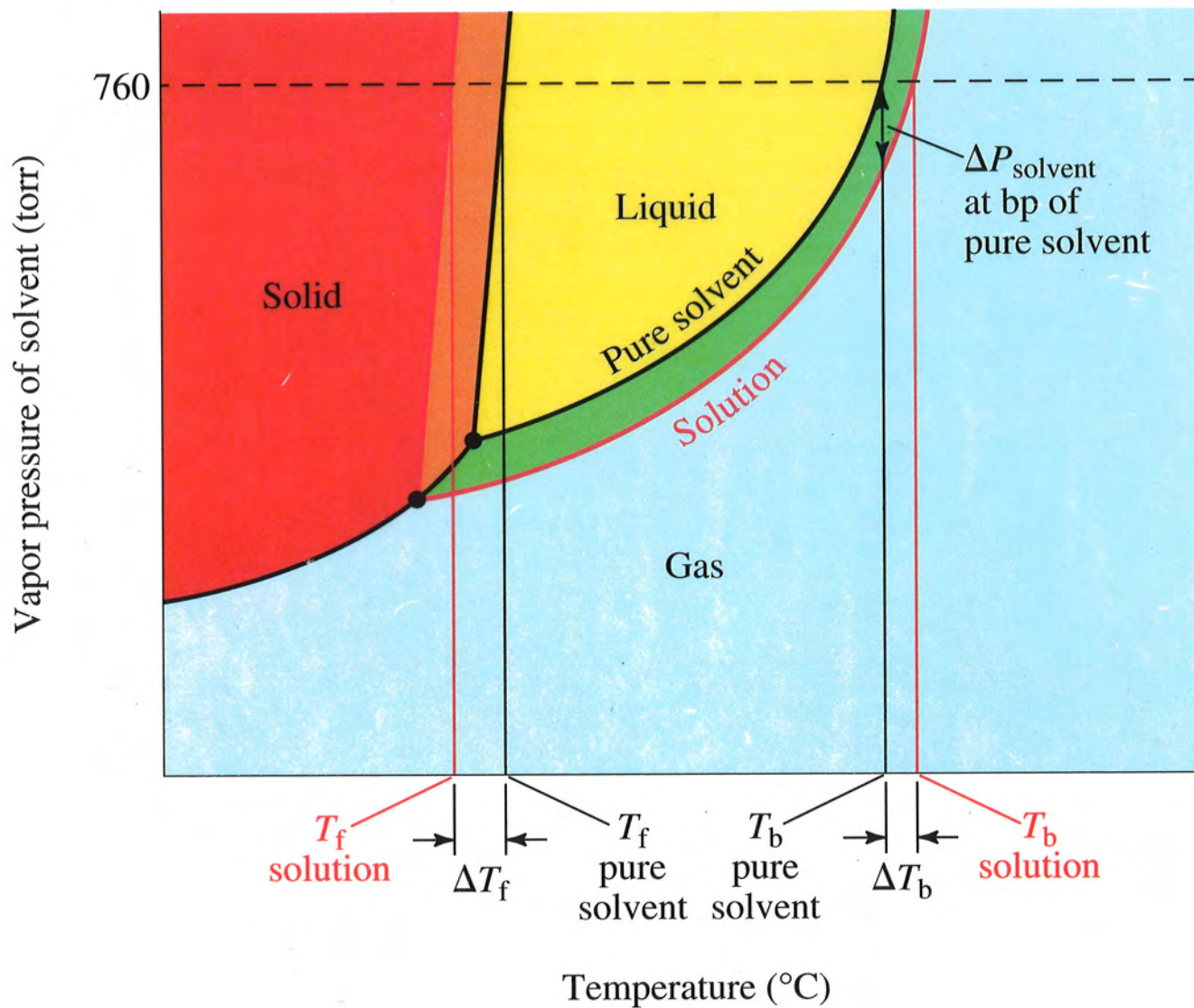
- integer for **ideal** behavior

$i = 1$  for **non ionizing** solutes

$i =$  # ions resulting from **f.u.**

$$m_{\text{particles}} = i m_{\text{stated}}$$





1) Ex: What is the b.p. of a soln. of 35.0g of a nonionizing solute (MW=210 amu) in 450.0g of benzene?

$$K_b = 2.61 \text{ } ^\circ\text{C}/m \quad n.b.p. = 80.1^\circ\text{C}$$

## C) Freezing Point Depression

Solute is **not** normally soluble in **solid solvent**.

∴ **solid** in equil. w. **soln.** is essentially **pure solvent**

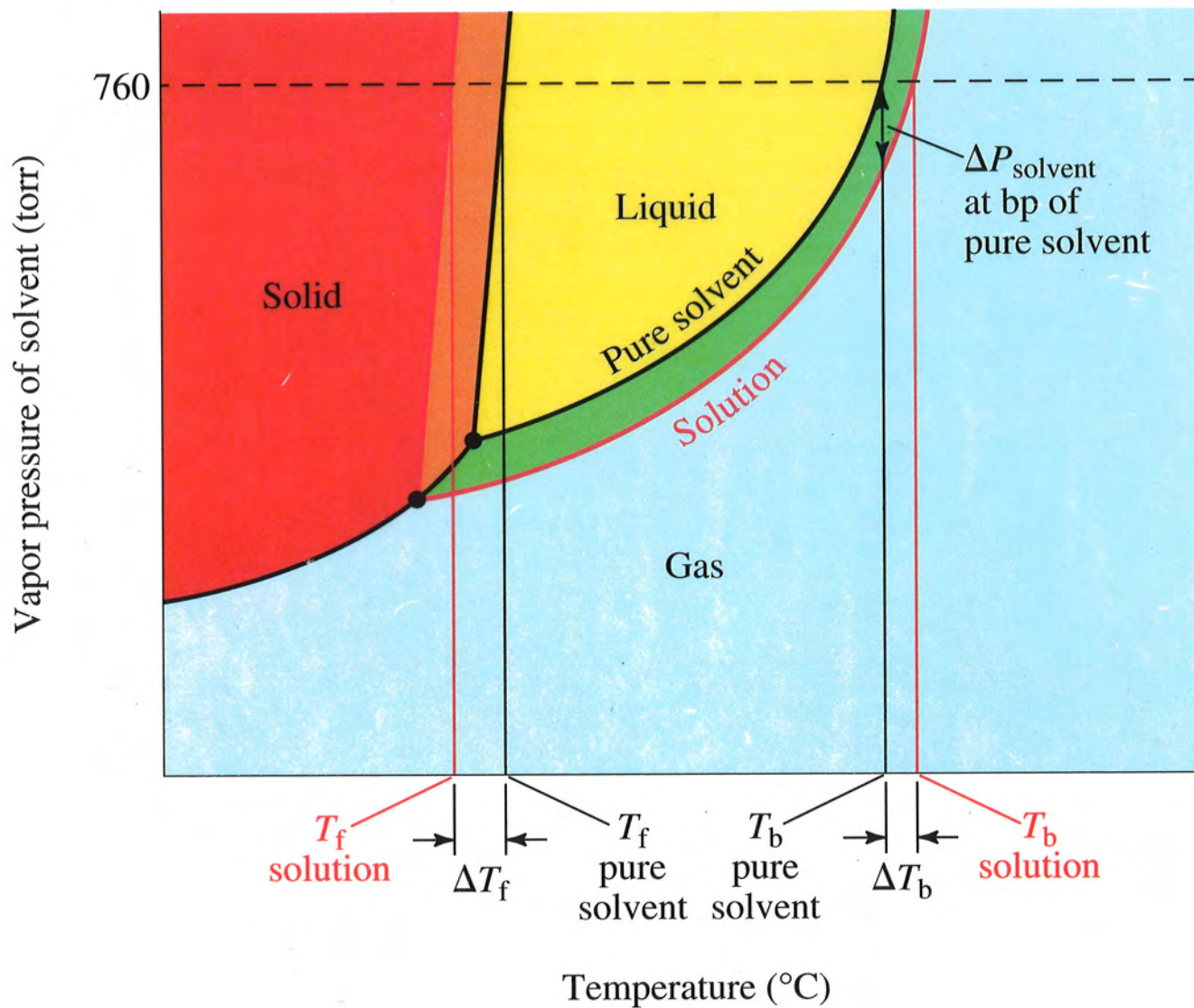
V.P. of **solid** is **unaffected** while that of **soln.** is **reduced**

**solid solvent**  $\xrightleftharpoons[\text{freezing}]{\text{melting}}$  **liquid soln.**

Must **lower f.p.** to reestablish equil.

$$\Delta T_f = K_f m_{\text{part}} = K_f (i m_{\text{stated}})$$







1) Ex: A soln. containing 16.9 g of a nonionizing solute in 250.0 g  $H_2O$  freezes at  $-0.744^\circ C$ .

What is the solute's M.W.?

## D) Osmotic Pressure

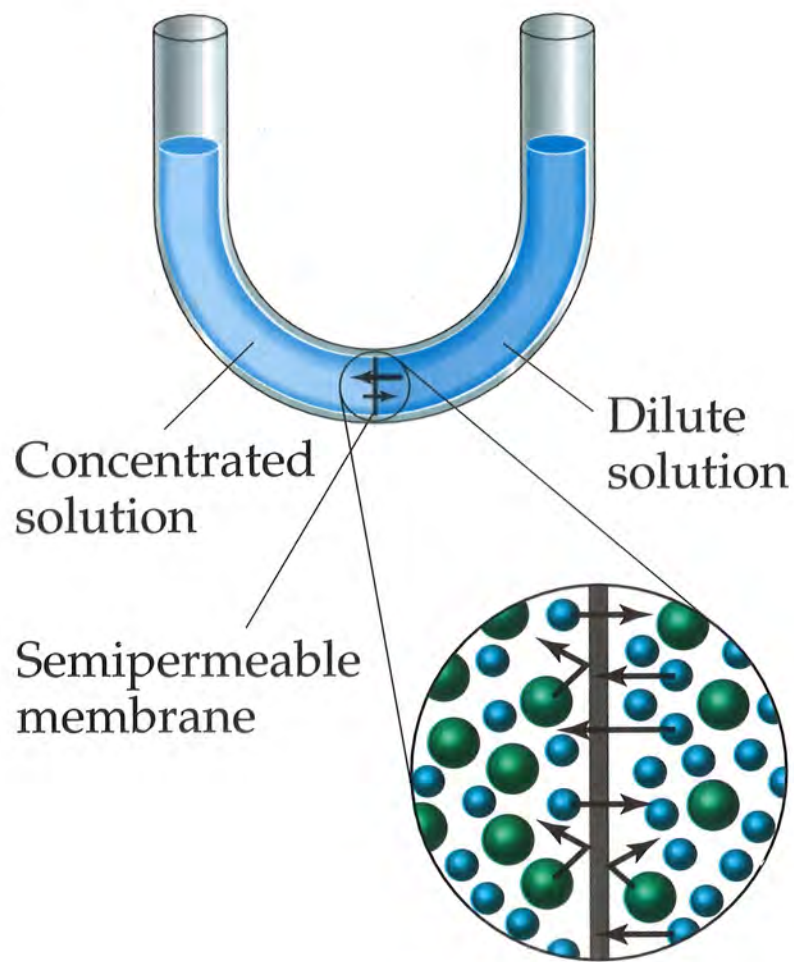
### Semipermeable membrane

permits passage of some molecules (solvent) but **not** others (solute)

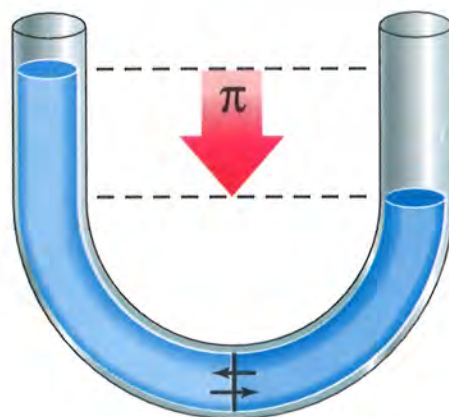
### Osmosis

Passage of solvent through a semipermeable membrane from a region of low solute conc. (high solvent conc.) to a region of high solute conc. (low solvent conc.)

NOTE: net movement of solvent is always toward more conc. soln.



(a)



(b)



## Osmotic Pressure, $\pi$

Pressure that must be supplied to prevent osmosis

$$\pi = i M R T$$

or

$$\pi = n_{\text{particles}} R T$$

Also write as,

$$\pi = \frac{n_{\text{part}}}{V} R T$$

Used to determine M.W. from very dilute soln.

$$\pi \gg \Delta T_f > \Delta T_b$$



1) Ex: Calc. the freezing pt. depression & osmotic pressure for a 0.00054 m aqueous soln. (use 25°C to calc  $\pi$ )

$$K_f = 1.858 \text{ } ^\circ\text{C}/m$$

2) Ex 2: A soln. contains 0.070g of insulin in 10.0 mL of soln. It has an osmotic pressure of 23 torr at 25°C. What is the approx. MW. of insulin?

## E) Colligative Prop. of Electrolytes



a) If Ideal

$$i = 3$$

0.01 m  $\text{K}_2\text{SO}_4 \Rightarrow$  0.03 moles of ions  
per kg  $\text{H}_2\text{O}$

$$\Delta T_f = i_{\text{ideal}} \cdot K_f \cdot m$$

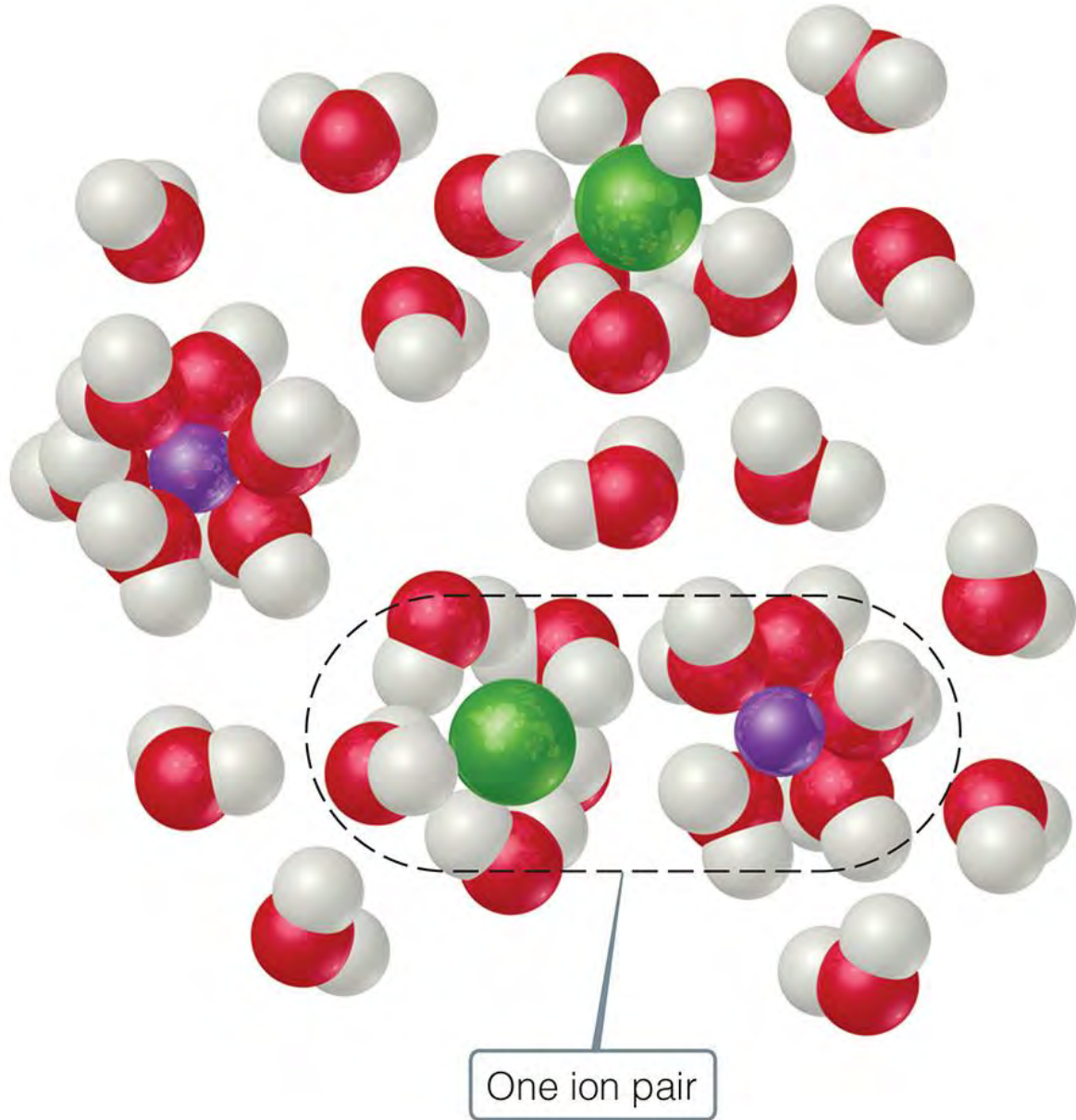
$$= 3 (1.858 \text{ } ^\circ\text{C}/m) (0.01 m)$$

$$= 0.0558 \text{ } ^\circ\text{C} \quad \text{expected}$$

$$\Delta T_{f_{\text{obs}}} = 0.0500 \text{ } ^\circ\text{C} \quad \text{observed}$$

Discrepancy due to:

**Interionic Attractions**



One ion pair



b) Non ideal ionic soln.

get ion pairs

- Number of independent particles is reduced

$$i_{obs} = \frac{\Delta T_{f_{obs}}}{K_f m}$$
$$= \frac{\text{observed collig. prop}}{\text{calc. prop. (assuming } i = 1)}$$

van't Hoff factor

$i_{obs}$  is diff. for each conc.  
+ approaches # ions per f.u.  
for very dilute soln.

$i_{obs} \longrightarrow i_{ideal}$

**TABLE 13.4 Measured and Expected van't Hoff Factors for Several Substances at 25 °C**

Compound	Concentration			Expected Value
	0.100 <i>m</i>	0.0100 <i>m</i>	0.00100 <i>m</i>	
Sucrose	1.00	1.00	1.00	1.00
NaCl	1.87	1.94	1.97	2.00
K <sub>2</sub> SO <sub>4</sub>	2.32	2.70	2.84	3.00
MgSO <sub>4</sub>	1.21	1.53	1.82	2.00



c) Ex: For a 0.0100 m  $K_2SO_4$  soln.  $\Delta T_f$  is measured to be  $0.0500^\circ C$ . What is the van't Hoff factor?

## F) Osmotic Pressure & Cells

### 1) Isotonic Soln.'s

soln.'s of identical osm. press.

### 2) Hypotonic Soln.

a soln. w.  $\pi$  less than  
the more conc. soln.

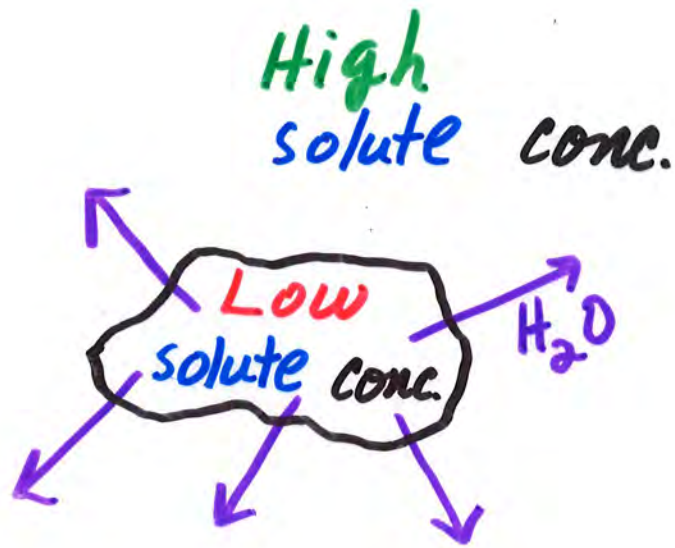
i.e. - the dilute soln. is  
hypotonic w. respect to  
the more conc. soln.

### 3) Hyper tonic Soln.

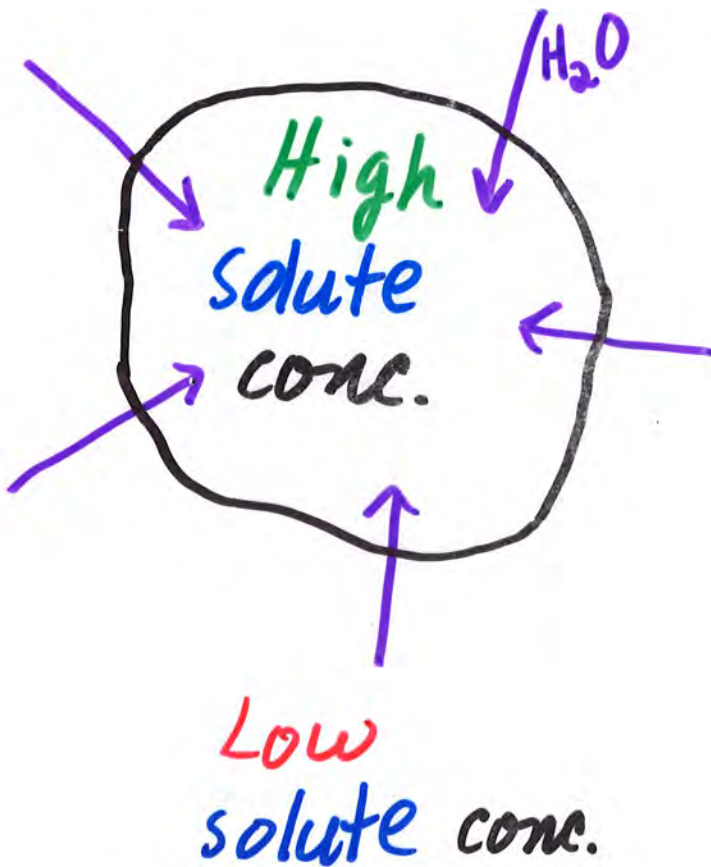
a soln. w.  $\pi$  greater than  
the less conc. soln.



## 4) Living Systems - Cells



soln. is  
hypertonic  
to cell fluid  
- crenation



soln. is  
hypotonic  
to cell fluid  
- hemolysis

## VIII) Colloids

Mixtures in which solute particles are larger than in a soln. but not large enough to settle out.

- colloidal dispersion

Particle size : 10 - 2,000 Å

Scatter light - Tyndall Effect

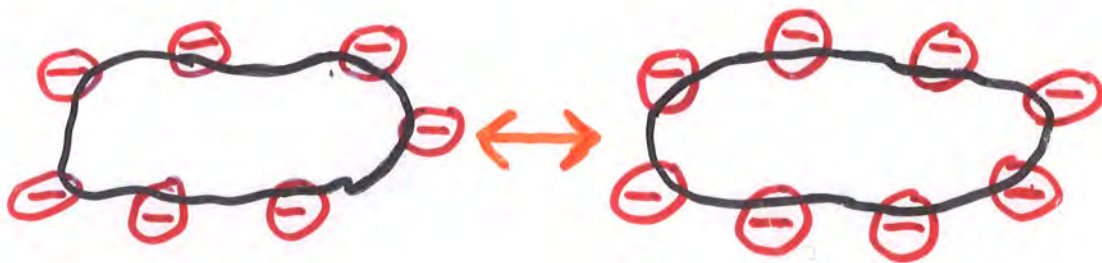


A) Hydrophilic Colloids: "water-loving"

- generally stay in soln.
- have polar groups that interact w.  $H_2O$

B) Hydrophobic Colloids: "water-hating"

- must be stabilized to stay dispersed
- absorb ions on surface
  - causes particles to not aggregate



stabilize w. molecules of form,



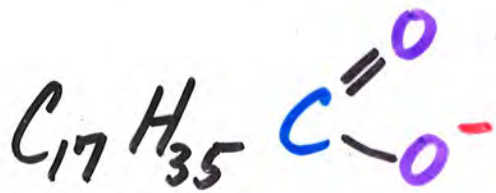
non polar

polar or charged

## C) Association Colloids (Micelles)

Micelle: colloid-sized particle formed in water by the association of molecules that have both hydrophilic & hydrophobic ends

Association Colloid: the dispersed phase consists of micelles



stearate ion



lauryl sulfate

