1412 - E1
CH 11 - Solutions & Colliods
Notes

11

What is a Solution?

"Solution"

Solute

Solvent

} Solution

Solution = Solute + Solvent

Eg: Cola → CO_2 (g) in H_2O (l)
salt water → $NaCl$ (s) in H_2O (l)
brass → Zn (s) in Cu (s)

The Dissolution Process

(endo) $S \not\equiv S$ ⓑ $\qquad$ $S - u$ (exo)

(endo) $u \not\equiv u$ ⓐ $(-CLE)$ $\qquad$ ⓒ Solvation energy
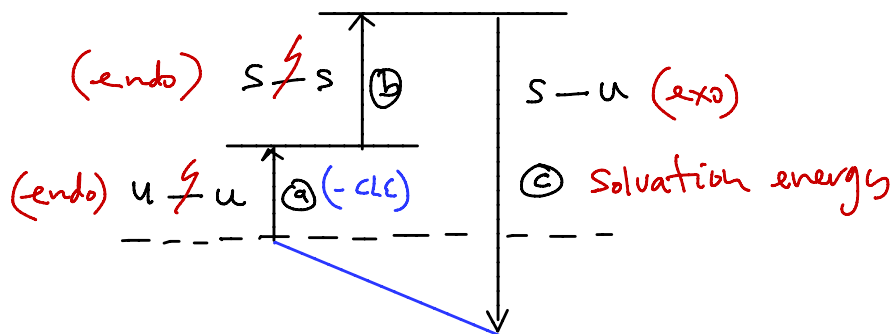
ASIDE: ⓐ $= -CLE = -\left(M^+ + X^- \xrightarrow{exo} MX + energy \right)$

$\Delta H_{soln} = \underline{b + c + a}$

$\qquad\qquad = \Delta H_{solvation} - CLE$

The Formation of Solutions

- <u>SPONTANEOUS PROCESS</u> — occurs "naturally", with<u>out</u> Energy input.

Drivers for Spontaneous Process

- Two Criteria that FAVOR (not guarantee) Soln formation:
  - ① ↓ ΔE (i.e., exo)   ② ↑ disorder   ↑ ΔS
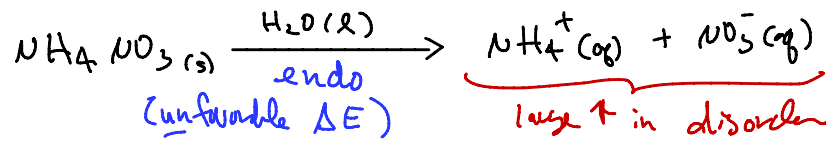
Key Concept

1. a decrease in the internal energy of the system
(an exothermic change, as discussed in the previous chapter on thermochemistry)

2. an increase in the disorder in the system
(which indicates an increase in the entropy of the system, as you will learn about in the later chapter on thermodynamics)

Competing Forces & Spontaneity

• If the two forces (internal energy vs. disorder) compete, the larger one wins…

SCENARIO	$\downarrow \Delta E$	$\uparrow$ disorder	Result
# 1	(exo) ✓	✓	spontaneous
# 2	(endo) ✗	✓	depends
# 3	(exo) ✓	✗	depends

"exo is favorable"

Case Study: Coldpack

$$NH_4NO_{3\,(s)} \xrightarrow[\text{endo}]{H_2O\,(\ell)} NH_4^+{}_{(aq)} + NO_3^-{}_{(aq)}$$

(unfavorable ΔE)   large $\uparrow$ in disorder
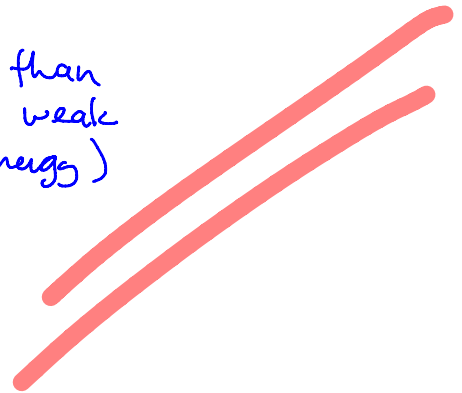
Net result:
① dissolves, b/c   unfav ΔE < fav $\uparrow$ Disorder
② cooling, b/c   endo
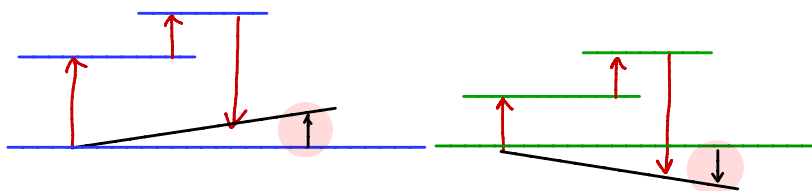
(EX) Disorder vs. Energy Gain/Loss
¿If the dissolution of NaCl in water is ENDO (unfavorable; solvation < u–u, s–s),
how is it that salt dissolves?

The gain in Disorder (Entropy) more than
compensated for the relatively weak
s–u interactions (small Solvation energy)

Less likely. The more energy required to break the u-u interactions, the less soluble the material will be:

Other Terms

• "ACID-INTO-WATER" – exothermic, but waster is the heat sink
• Hydration – solvation when water is the solvent
• Electrolyte – yields ions in solution, therefore, incr. conductivity
• Non-electrolyte – does not yield … " ….
• Strong electrolyte – nearly 100 dissoiates into inons
• Weak electrolyte – small fraction dissociates into ions
• Dissociation – water solvate the ions in an ionic solid, reducing electrostatic forces holding them together

Ionic Electrolyte: Another IMF type

•   Water is dipolar ; electrolytes are ionic ↗

    ion – dipole attraction   ⊕ ←—+ ⊖

    Na^+ $\delta^- O \overset{-H}{\underset{-H}{}} \delta^+$ Cl^-
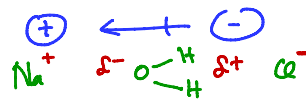
Covalent Electrolytes

•   Covalent compounds are not typically good
    electrolytes until, and if, they dissocite into
    ions:. $H_2O_{(l)}$ —   poor !!! (few ions)
                  $HCl_{(l)}$ —   poor   (few ions)
                  $HCl_{(aq)}$ —   good   (100% dissoc.Ais)

Basic Terms

- SOLUBILITY – max conc. when system is at equilibrium
- SATURATED – conc. of solute = its solubility
- UNSATURATED – conc. of solute < its solubility
- SUPERSATURATED – conc. of solute > its solubility

Superstatured – a closer look

- Non-equilibrium state
- "meta-stable"
- Cause
    ↳ solute unable to organize
    ↳ disordered, and can't get the molecules ordered (lined up)
    ↳ unfavorable entropy
- Potential remedy – "seeding"

(non-equilibrium)

Super-
saturated

— Saturated

Un-
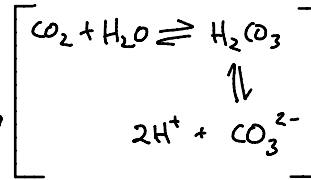saturated

(solid ⇌ liq)

Solutions of Gases in Liquids

Factors affecting solubility of (g) in (l)

① IMF : "like dissolves like"
  → where WATER is the solvent
    • Polar ($HF_{(g)}$, $HCl_{(g)}$)
    • rxn to form polar compound : ↗

$$\left[\begin{array}{c} CO_2 + H_2O \rightleftharpoons H_2CO_3 \\ \Updownarrow \\ 2H^+ + CO_3^{2-} \end{array} \right]$$

② Temp : (pCO_2)
  Ⓐ typ :   ↑ Temp, ↓ Solubility
      → THERMAL POLLUTION : ↑ Temp, ↓ Solb'ty O_2 ∴ FISH KILL
      → SOLUBILITY of WATER : $\dfrac{0.04 lg}{L}$ @ 25°C ; $\dfrac{0.027 g}{L}$ @ 50°C

③ Partial Pressure of solute : ↑ Pressure, ↑ Solubility
      → COLA CAN: ↓ Pressure, ↓ Solubility ∴ Bubbles

⇒ Henry's Law , next page ⇒

Henry's Law

$$C_g = k \; P_g$$

k = proportionality constant
C_g = [gas] __in__ liquid
P_g = Pressure(gas) __above__ liquid

Note: Interphase relationsly !!!

Crosses Gas/Liq barrier

Concept: The harder the gas pushes down on the liquid, the more gas will be pushed into the liquid.

(EX) ¿the solubility of O2 in water is 1.25E–3 M at 25°C at sea level (1.00 atm). what is the solubility in Denver, where the atmospheric pressure is only 0.800 atm?

- Relating $[\text{gas-in-liq}]$ to pressure ~ Try Henry's Law

(a) At Denver: $\boxed{C} = k\, P = \dfrac{1.25\text{E-}3M \mid 0.80\ atm}{\mid 1\ atm} = \boxed{1.00\text{ E-}3\ M}$
(start w/ answer)

(b) At sea level: $C = \dfrac{k\, P}{}$

$$k = \frac{C}{P} = \frac{1.25\text{E-}3\ M}{1.00\ atm} = \boxed{\frac{1.25\ \text{E-}3\ M}{atm}}$$

ASIDE

$P_T = \sum P_i$	Dalton
$P_i = X_i\, P_T$	Raoult
$C_{(g\text{-in-}L)} = k\, P_i$	Henry

Real world application of Henry's Law.

↳ When diving: ↑ 1 atm pressure ≈ 10 meter dive depth

dive ⟩ ...increase   increase...

$$C = k \, P_{ext}$$

ascend ⟩ ... rapid
decrease, via   rapid
decrease ...

rapid release of
gas bubbles into the blood
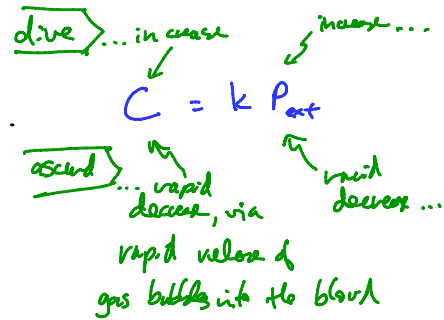
Exceptions to Henry's Law

• If a gas reacts with the solvent, this effectively decr. the gas-in-liquid concentration, but Henry's Law does NOT anticipate removal-by-reaction.

e.g. $NH_3 + H_2O \rightleftharpoons NH_4OH$

$\downarrow [NH_3]$
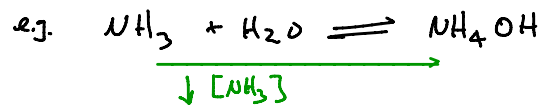
Miscible — liquids infinitely soluble
Immiscible — liquids do not appreciably mix
Partially miscible — moderate mutual solubility, depending on conditions.

General Rule of Thumb: "Like – Dissolves – Like"

• u–s interatctions stronger for similar species the dis-similar

non polar —— polar —— H-bonds —— ionic

Solutions of Solids in Liquids

- Depends highly on TEMPERATURE

Formation of Supersaturated Solutions

- Can make by cooling a saturated soln:
  - in which the solute is more stable @ elevated Temp ...
  - i.e., $\Delta H_{soln} = ENDO$

- INDUCE PPT via (a) seeding, or (b) mechanical agitation.
  - Ex: Hand Warmer Packet

$$NaAc (l) \xrightarrow[\text{or seed}]{\text{agitation}} NaAc_{(s)} + heat$$

$\xleftarrow{\text{endo}}$
$\xrightarrow{\text{exo}}$

FIG 11.17

Solubility (g solute per 100 g H$_2$O) vs Temperature (°C) for Sugar (C$_{12}$H$_{22}$O$_{11}$), KNO$_3$, NaNO$_3$, NaBr, KBr, KCl, NaCl, Ce$_2$(SO$_4$)$_3$
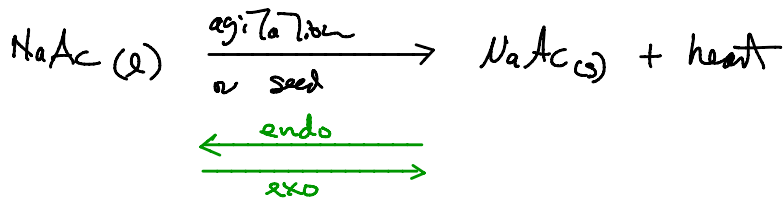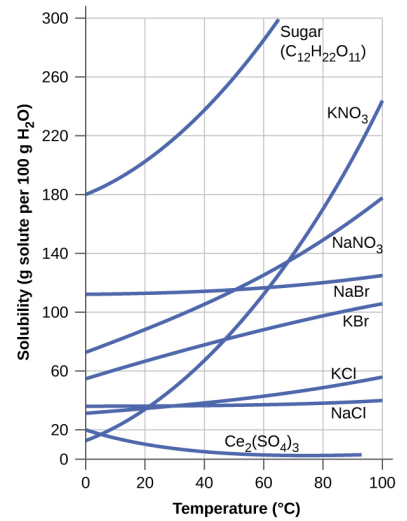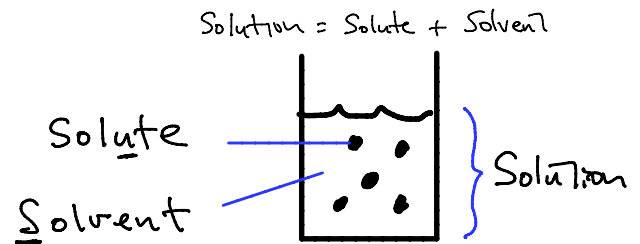
Colligative Properties [11.4]

• Colligative Properties present in solution in which the solute is non-volatile ("NVS").
• Colligative Properties = f(amt of solute) … not f(kind of solute)

4 Type of Colligative Properties
① vp ↓
② bp ↑
③ fp ↓
④ osmotic pressure Π

Solution = Solute + Solvent

Solute ————
Solvent ————

Solution

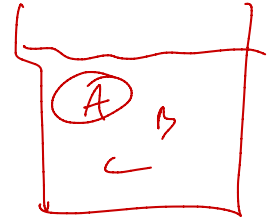• WRT Colligative Properties, amount of solute typically measured in Mole Fraction and Molality (not be be confused with Molarity)

Molarity

$$M = \frac{mol\ u}{L\ soln}$$

← change in Temp...
soln contracts/expands w/ Temp

Mole Fraction

$$X_A = \frac{mol\ A}{total\ mol\ of\ all\ components} = \frac{mol\ i}{\Sigma mol}$$

← no change w/ Temp

Molality

$$m = \frac{mol\ u}{Kg\ SOLVENT}$$

← no change w/ Temp

$$f = \frac{parts}{whole}$$

$$\% = \frac{parts}{whole} \times 100$$
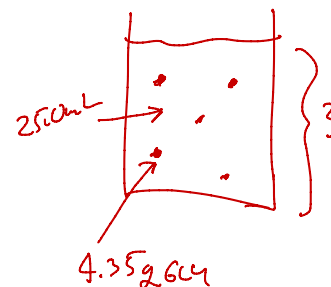
$$\% = (f_r)(100)$$

(white)

(EX) Calc Molarity **vs. Molality**

¿A solution is made by dissolving 4.35 g of glucose (MM = 180.2 g/mol) in 25.0 mL of water (d = 1.00 g/mL) at 25 °C (298 K). What is the Molarity?

ⓐ $\dfrac{\square\ mol\ glu}{L_{soln}} = \dfrac{4.35\ g_u}{} \cdot \dfrac{1\ mol_u}{180.2\ g_u} \cdot \dfrac{1}{25.0\ mL_{soln}} \cdot \dfrac{1000\ mL\ soln}{L_{soln}} = \boxed{0.966\ M}$

$M = m$ when $d = 1.0\ g/mL$

ⓑ $\dfrac{\square\ mol\ glu}{kg\ solv} = \dfrac{4.35\ g/u}{} \cdot \dfrac{1\ mol\ u}{180.2\ g/u} \cdot \dfrac{1}{25.0\ mL} \cdot \dfrac{1\ mL\ w}{1\ g/w} \cdot \dfrac{1000\ g/w}{1\ kg\ w} = \boxed{0.966\ m}$

$25.0\ mL \rightarrow$?

$4.35\ g\ glu$

$\dfrac{\square\ mol\ u}{kg_2\ s} =$

$\dfrac{\square\ mol\ u}{L\ soln} =$

★ Assume 100g sample of SOLUTION
 ↳ like density, x_{up} same as Barrel
 ↳ X_i = INTENSIVE PROP ≠ f(amt)   ★ TIP

$\left(\dfrac{36 \quad HCl}{100 \quad SOLN} \right)$
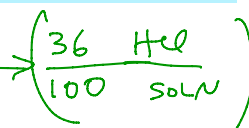
| X_i = intensive property, ∴ can use "100 g ASSUMPTION" |

$$\dfrac{\square \text{ mol } HCl}{\text{mol } soln} = \dfrac{\text{mol } HCl}{\text{mol } HCl + \text{mol } w} \Rightarrow \dfrac{0.968}{4.54} = \boxed{0.217}$$

$$\square \text{ mol } HCl = \dfrac{36.0g, HCl}{} \bigg| \dfrac{1 \text{ mol } HCl}{36.5 \, HCl} = \left(0.986 \text{ mol } HCl \right)$$

Sum + → (4.54)

$$\square \text{ mol } w = \dfrac{64.0g, w}{} \bigg| \dfrac{1 \text{ mol } w}{18.0g \, w} \approx (3.56)$$

HCl
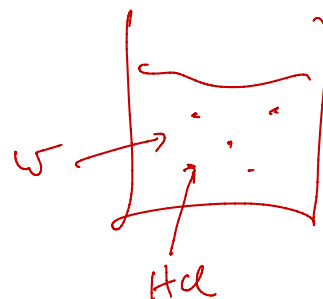
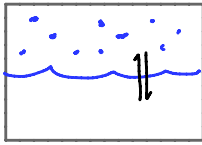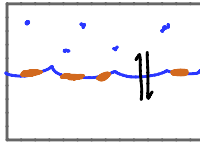## Vapor Pressure Lowering

Nonvolatile solute (NVS) — doesn't vaporize, but does take up surface area

● = NVS

No NVS — full surface area for Evap/Cond equil.

NVS present — diminished surface area for Volatile solvent, ∴ less in equilibrium vapor ∴ lower VP

"Solvent obstruction"

A more rigorous explanation involves the property of ENTROPY, a topic of discussion in a later text chapter on thermodynamics. For purposes of understanding the lowering of a liquid's vapor pressure, it is adequate to note that the greater entropy of a solution in comparison to its separate solvent and solute serves to effectively stabilize the solvent molecules and hinder their vaporization.

$$P_{SOLUTION} = \sum P_i = \sum X_i P_i^{\circ}$$

$$P_a = X_a P_a^{\circ}$$

NOTE: for a soln with a solvent and an NVS,
b/c $P_{NVS}^{\circ} = \emptyset$

$$P_{SOLN} = X_{SOLVENT} \, P_{SOLVENT}^{\circ}$$
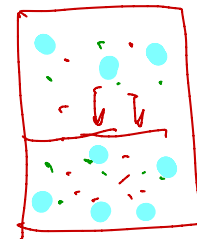
Change in P due to addition of solute (which changes $X_?$) to pure solvent

$\Delta P = P_?^{\circ} -$

$\Delta P = P_s^{\circ} - (X_s P_s^{\circ})$ [Raoult : $P_s = X_s P_s^{\circ}$]

$\Delta P = P_s^{\circ} (1 - X_s)$ [rearrange]

$\Delta P = P_s^{\circ} X_u$ [$X_u + X_s = 1 \implies X_u = 1 - X_s$]

$\boxed{\Delta P = X_u P_s^{\circ}}$ [rearrange]

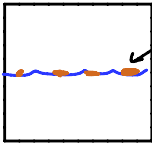¿A solution contains 5.00 g of urea, $CO(NH_2)_2$ (a nonvolatile solute) and 0.100 kg of water. If the vapor pressure of pure water at 25 °C is 23.7 torr, what is the vapor pressure of the solution?

$MW_{urea} = 60.06 \text{ g/mol}$

$5.00 \text{ g } u$
$P_w^\circ = 23.7 \text{ torr}$
$0.100 \text{ kg, } w$

$\left(\begin{array}{l} \boxed{?} \checkmark \checkmark \\ P_s = X_s P_s^\circ \leftarrow \text{either will work} \\ \boxed{?} \checkmark \checkmark \\ \Delta P = X_u P_s^\circ \leftarrow \text{(textbook uses the top as)} \end{array} \right.$

5.00g

Wed 9/11

— $\Delta P = P_s^\circ - P_s = X_u P_s^\circ$

— $n_u = \dfrac{5.00 \text{ g}}{} \bigg| \dfrac{\text{mol}}{60.06 \text{ g}} = 0.083$, $n_v = \dfrac{0.100 \text{ kg}}{} \bigg| \dfrac{1000 \text{ g}}{\text{kg}} \bigg| \dfrac{\text{mol}}{18.0 \text{ g}} = 5.56$

∴ $n_{TOTAL} = 0.083 + 5.56 = 5.64$

— $X_u = 0.083/5.64 = 0.0148$

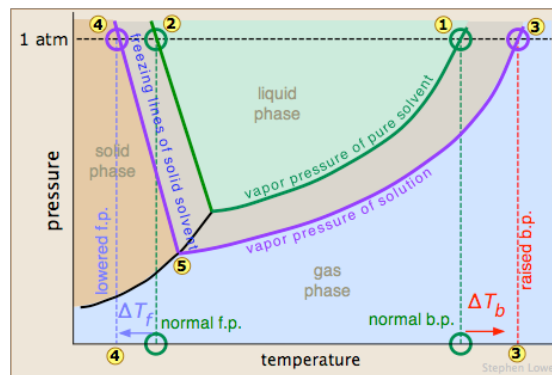— $\Delta P = (0.0148)(23.7 \text{ torr}) = 0.350 \text{ torr} = P^\circ - P$?

$P = P^\circ - 0.350$
$= 23.7 - 0.350$
$\boxed{P = 23.4 \text{ torr}}$

Boiling Point Elevation

Example : coolant in auto radiator

Rationale : ↑[NVS] ↓VP ∴ must ↑Temp to make $P_{sln} = P_{exit}$

BP constant
molality

$T_H - T_L$

$$\Delta T_b = K_b \, m$$

¿What is the boiling point of a solution of 1.0 g of glycerin, C3H5(OH)3, in 47.8 g of water?
Assume an ideal solution.

CHECKLIST
☐ NVS?
☐ Solvent?
☐ Which colligative prop?
☐ Formulas?

$MM = \dfrac{92.09 g}{mol}$

$K_b = \dfrac{0.512 \, °C}{m}$, $MM = \dfrac{18.0 g}{mol}$

Results Low:
$P_{soln} = X_s P_s°$
$P_s = X_s P_s°$
$\Delta P = X_u P°s$

ⓐ $\boxed{?}$ ✓   ✓ $\overset{NO}{\sim}$ ✓
   $T_H - T_L = \Delta T = K_b \, m^{\overset{QO}{}} ✓$

ⓑ $m_u = \dfrac{\boxed{}\, mol \, u}{\boxed{}\, kg_s} = \dfrac{1.0 g_u \, | \, mol \, u}{| \, 92.09 g_u \, | \, 47.8 g_w \, | \, 1 kg_w} \dfrac{| \, 1000 g_w}{} = 0.2272$
   $\downarrow$
   $\boxed{0.23 \, m}$

ⓒ [subst into ⓐ] : $T_H = K_b \cdot m + T_L$
   $= \dfrac{0.512 °C}{m} \, \Big| \, 0.23 \, m \; + \; 100.00 °C$
   $= 0.12 °C + 100.00 °C = \boxed{100.12 °C}$

Distillation of Solutions

- Separation Technique based on Δ BP
- <u>Simple distillation</u> — break liquid into 2 fractions
- <u>Fractional distillation</u> — " " " many fractions
  Simultaneously, using a Temperature Gradient
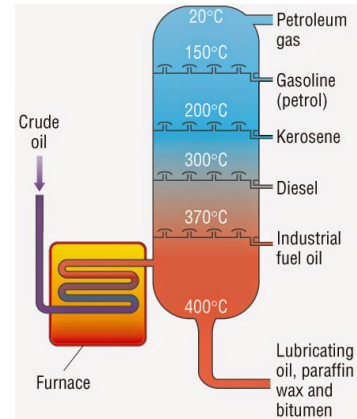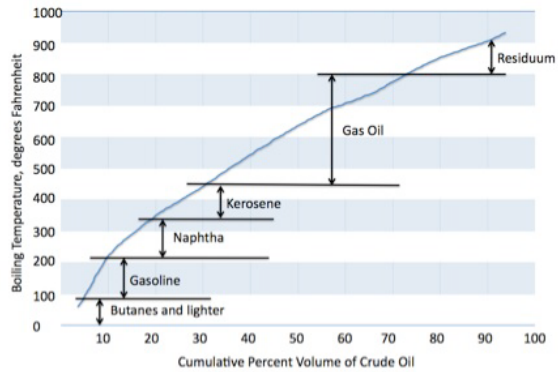
horizontal - vapor more conc. in
more volatile component than
original liquid

vertical — no chg in composition
upon condensation:
$x_A (vap) = "new" x_A (liq)$

more volatile

less volatile

Temperature

vapour mixture

$P_A = X_{A, liq} P_A^o$

$P_A = X_{A, gas} P_T$

liquid mixture / liquid

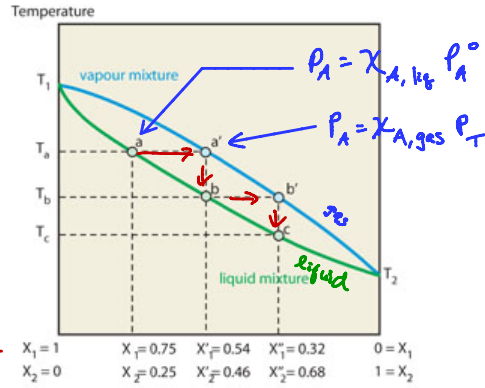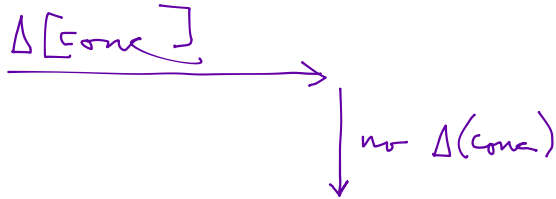| $X_1 = 1$ | $X_1 = 0.75$ | $X'_1 = 0.54$ | $X''_1 = 0.32$ | $0 = X_1$ |
| $X_2 = 0$ | $X_2 = 0.25$ | $X'_2 = 0.46$ | $X''_2 = 0.68$ | $1 = X_2$ |

Diagram: boiling point curve for an ideal, binary mixture at a constant
external pressure.

Aside cont'd ⇓

ASIDE

$P_T = \sum P_i$ Dalton
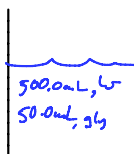$P_i = X_i P_T$ Raoult

$C_{(g-in-L)} = k P_i$ Henry

$P_i = X_i P_A^o$ Raoult

$\Delta [conc]$

no $\Delta (conc)$

(EX) Colligative Property Calculation

¿A solution is made by mixing 500.0 mL H2Oa nd 50.0 mL of gylcerine (C3H8O3; MM = 92.1 g/mol; d = 1.26 g/mL @ 25°C). Knowing P°water = 28.64 torr, and glycerine is a nonvolatile solute, what is the vapor pressure of the solution?

(a) Formulas w/ "P" as variable?

$$P_i = X_i^{Liq} P_i^°$$

$$P_i = X_i^{vap} P_T$$

(eg 1) $P_w = X_w P_w^°$

NUS

$~~~P_G \neq X_G P_G^°$

$P_T = P_w + P_G^{=0}$

(b) $X_w = \dfrac{mol_w}{mol_T}$

500.0mL, w
50.0mL, gly

(c) ☐ $mol_w = \dfrac{D_g}{MW} = \dfrac{500.0mL}{} \Big| \dfrac{1 g}{1 mL} \Big| \dfrac{mol}{18.0 g} = 27.8$ mol w

☐ $mol_G = \dfrac{D_g}{MW} = \dfrac{50.0mL}{} \Big| \dfrac{1.262}{mL} \Big| \dfrac{1 mol}{92.1 g} = +0.684$ mol_G

$\overline{28.5 \text{ mol}_{TOTAL}}$

(d) $X_w = 27.8/28.5 = 0.976$

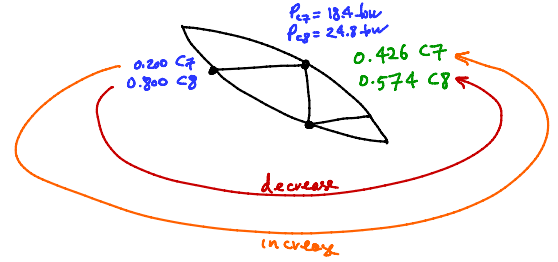(e) $P_w = X_w P_w^° = (0.976)(23.8) = \boxed{23.2 \text{ torr}}$

(EX) Calculate Distillation Curve Components   [Whitten, Examples 14.5 & 14.6]
¿A solution of C7, heptane (P°,C7 = 92.0 torr) and C8, octane (P°,C8 = 31.0 torr) is composed of 1.00 mol C7 and 4.00 mol C8.
(i) calculate the vapor pressures of C7, C8, and the solution as a whole above the solution.
(ii) calculate X,C7 and X,C8 in equilibrium.

(i) $X_{C7,liq} = 1.00/(1.00+4.00) = 0.200$ ∴ $X_{C8,liq} = 0.800$

$P_{i,vap} = X_{i,liq} P_i^°$ ← RAOULT

$P_{C7} = X_{C7} P_{C7}^° = (0.200)(92.0\ torr) = 18.4\ torr$

$P_{C8} = X_{C8} P_{C8}^° = (0.800)(31.0\ torr) = \underline{24.8\ torr}$

$P_{TOTAL} = P_{soln}$ $= 43.2\ torr$

$P_{C7} = 18.4\ torr$
$P_{C8} = 24.8\ torr$

0.200 C7
0.800 C8

0.426 C7
0.574 C8

decrease

increase

summary:
$X_{i,liq}$
↓ $P_i = X_{i,liq} P^°$
P_i in gas
↓ $P_i = X_{i,g} P_T$
$X_{i,2}$ cond.
↓ $X_{i,g} = X_{i,liq}$
$X_{i,liq,2}$

(ii) $P_{n,vap} = X_{i,vap} P_T$

$X_{C7,vap} = 18.4\ torr/43.2\ torr = 0.426$

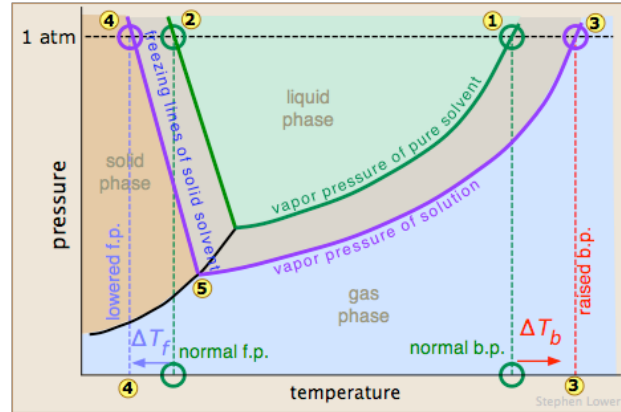$X_{C8,} = 24.8\ torr/43.2\ torr = 0.574$

↑ ASIDE ↑

Depression of the Freezing Point of a Solvent

Examples : Ice removed from (i) roads, (ii) from airplane wings (de-ice)
(iii) radiator fluid additive, (iv) home made Ice Cream

Ratonale : < see below >

$T_H - T_L$

freezing point constant
(cryoscopic constant)

molality

$$\Delta T_f = K_f \, m$$

*Note: $\Delta T_f = (f)$
$T_L = T_H - \Delta T_f$

Explain, Chemically, What Causes Freezing Point Depression?

Freezing point depression is the phenomena that describes why adding a solute to a solvent results in the lowering of the freezing point of the solvent. When a substance starts to freeze, the molecules slow down due to the decreases in temperature, and the intermolecular forces start to take over. The molecules will then arrange themselves in a pattern, and thus turn into a solid. For example, as water is cooled to the freezing point, its molecules become slower and hydrogen bonds begin to "stick" more, eventually creating a solid. If salt is added to the water, the Na+ and Cl- ions attract to the water molecules and interfere with the formation of the large network solid known as ice. In order to achieve a solid, the solution must be cooled to an even lower temperature.

The freezing point depression can also be explained in terms of vapor pressure. Adding solute to a solvent will essentially dilute the solvent molecules, and according to Raoult's law, this leads to a decrease in vapor pressure. Considering the fact that the vapor pressure of the solid and liquid forms must be the same at freezing point, because otherwise the system would not be at equilibrium, the lowering of the vapor pressure leads to the lowering of the temperature at which the vapor pressures of the liquid and frozen forms of the solution will be equal.

-- https://www.boundless.com/chemistry/textbooks/boundless-chemistry-textbook/solutions-12/colligative-properties-of-nonelectrolyte-solutions-95/freezing-point-depression-407-4701/

¿Calculate the freezing point of a 25% (wt) of ethylene glycol ($C_2H_6O_2$, MM = 62.1 g/mol) in water (MM = 18.0 g/mol, FP = 0.0 °C, Kf = 1.86 °C/m)

(eg 1) $\Delta T_f = K_f \, m = T_H - T_L \longrightarrow T_L = T_H - K_f \, m$ (eg 2)

$$T_L = 0.0°c - \frac{1.86\,°C}{m} \,\Big|\, 5.37$$

$\Delta H_f = INTENSIVE \neq f(amt)$
∴ assume 100g

% as CF ＊TIP

$= 0.0°c - 9.98°c$

$= \boxed{-9.98°c}$

(eg 3)
$$m = \frac{\square \, mol \, u}{\square \, kg, w} = \frac{25g, u}{75.0g, w} \,\Big|\, \frac{1000g, w}{kg, w} \,\Big|\, \frac{1\,mol, u}{62.1g, u}$$

$= 5.37$ calc canz

Phase Diagram for an Aqueous Solution of a Nonelectrolyte

Handwritten annotations on figure:

S-L shift →

S-g curve is not shifted (for most materials) →

L-g shift ↑

Figure labels:
1 atm
ΔT_f
ΔT_b
Liquid
Solid
ΔP
Gas
Pressure
Temperature
Freezing point of solution
Freezing point of pure solvent
Boiling point of pure solvent
Boiling point of solution

Handwritten (right side):

Ca^{2+}
Cl^-
Cl^-

$1m\ CaCl_2 \rightarrow 3m$

↓

$1m\ NaCl \rightarrow 2m$
Na^+
Cl^-
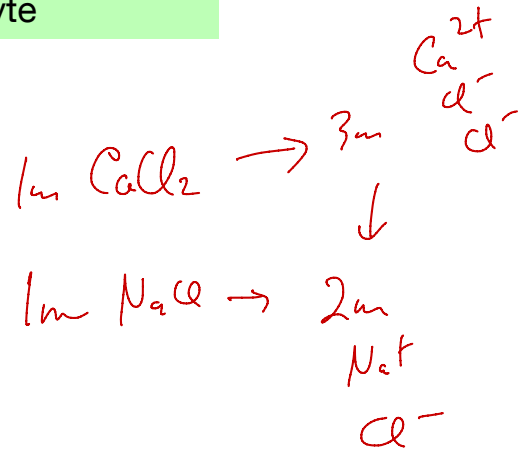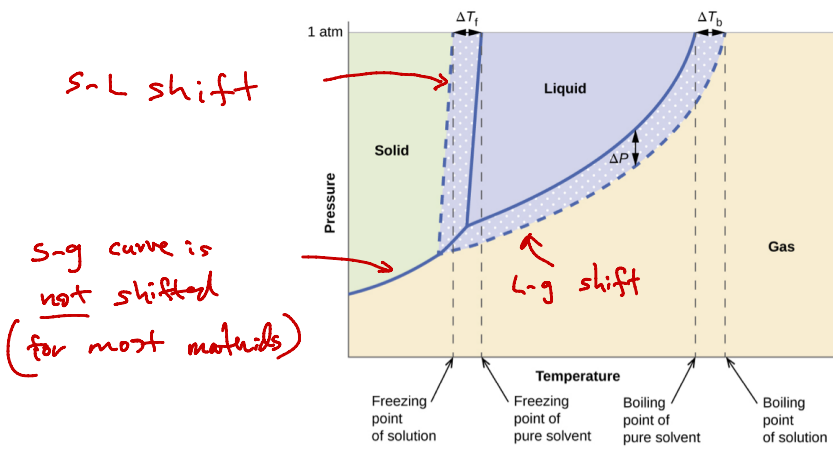
The liquid-vapor curve for the solution is located beneath the corresponding curve for the solvent, depicting the vapor pressure lowering, ΔP, that results from the dissolution of nonvolatile solute. Consequently, at any given pressure, the solution's boiling point is observed at a higher temperature than that for the pure solvent, reflecting the boiling point elevation, ΔTb , associated with the presence of nonvolatile solute. The solid-liquid curve for the solution is displaced left of that for the pure solvent, representing the freezing point depression, ΔTb , that accompanies solution formation. Finally, notice that the solid-gas curves for the solvent and its solution are identical. This is the case for many solutions comprising liquid solvents and nonvolatile solutes. Just as for vaporization, when a solution of this sort is frozen, it is actually just the solvent molecules that undergo the liquid-to-solid transition, forming pure solid solvent that excludes solute species. The solid and gaseous phases, therefore, are composed solvent only, and so transitions between these phases are not subject to colligative effects.
-- OpenStax: p621/626, sec 11.4

Examples: ① fluid movement across cell wall (e.g.: dehydration upon drinking sea water) ② reverse osmosis (apply pressure > OP)

Premise: Across a <u>semipermeable membrane</u>, fluids will move FROM MORE concentrated to LESS concentrated side.

<u>Osmosis</u>: DiFFusion-DRIVEN transfer of solvent through a semipermeable membrane.
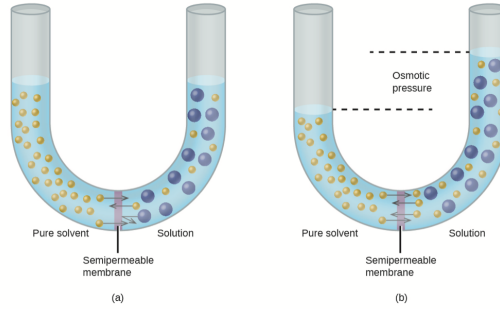
osmotic pressure

Molarity 0.08206 atm·L /mol·K

Temp

$$\pi = M R T$$

$$\pi = \frac{n}{V} R T$$

$$\pi V = n R T \qquad \pi = \left(\frac{g}{MW \cdot V}\right) R T$$

- π – Good for MW deth, as π is large for dilute soln's

Osmotic pressure

Pure solvent   Solution
Semipermeable membrane
(a)

Pure solvent   Solution
Semipermeable membrane
(b)

R	
0.0821	atm·L/mol·K
1.987	cal/mol·K
8.3145	J/mol·K

Assumptions
For dilute aq. soln $M \approx m$
b/c $d_{soln} \approx d_{solvent} \approx d_w = 1\frac{g}{mL}$
$\therefore$ 1 L $\approx$ 1 Kg

Isotonic, Hypotonic, and Hypertonic

- Solutions injected into body should have same Π as blood serum

hemolysis — expand & rupture
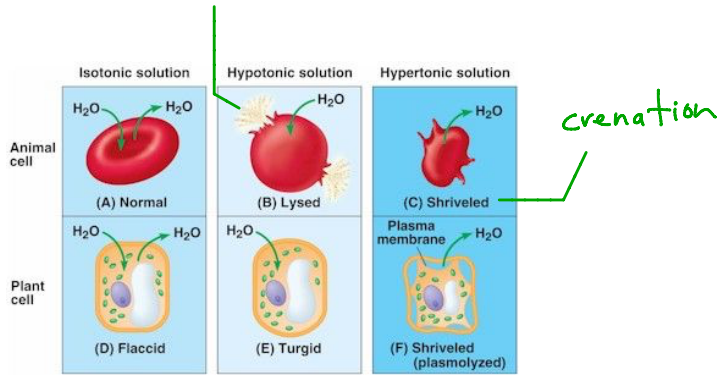
crenation

	Isotonic solution	Hypotonic solution	Hypertonic solution
Animal cell	H_2O → H_2O (A) Normal	H_2O (B) Lysed	H_2O (C) Shriveled
Plant cell	H_2O → H_2O (D) Flaccid	H_2O (E) Turgid	Plasma membrane H_2O (F) Shriveled (plasmolyzed)

Issue #1: Ion Formation Effects Concentration

- Colligative Properties $= f(\text{\# particles})$
  - ↳ Electrolytes break into 2 or more ions (cations + anions)
  - ↳ eg. 1 mol $NaCl \rightarrow$ 2 mol ions ($1\ Na^+ + 1\ Cl^-$)
          1 mol $CaF_2 \rightarrow$ 3 mol ions ($1\ Ca^{2+} + 2\ F^-$)
  - ∴ for $NaCl$: "m" of $NaCl$ must be doubled
        for CaF_2 : "m" of CaF_2 must be tripled

· van't Hoff factor $(i) = \dfrac{\text{mols particles in Soln}}{\text{mole of formula units dissolved}}$

i (predicted) = # ions from formula
i (measured) = from experiments.

activity: the effective concentration
↪ If two opposite charged ions collide, for an instant
they are 1 chg neutral species, ∴ effective conc is ↓
↪ In DILUTE solutions, collisions are more rare
↪ In very DILUTE solutions, [effective] ≈ [predicted]

(EX) Calc MW from Osmotic Pressure
¿Biochemists have discovered more than 400 mutant varieties of hemoglobin, the blood protein that carries oxygen throughout the body. To determine its MW, a scientist dissolves, at 5.0 °C, 21.5 mg in enough water to make a 1.50 mL solution, then meaures Osmotic Pressure, which is found to be 3.61 torr. What is the MW of hemoglobin?

$$\Pi = M\,RT = \dfrac{n}{L}\bigg|\ R\ \bigg|\ T = \dfrac{g}{mw\ \big|\ L}\bigg|\ R\ \big|\ T \longrightarrow$$

$$MW = \dfrac{g\ RT}{\Pi\ L} = \dfrac{0.02153}{\ }\bigg|\dfrac{0.08321\ atm \cdot L}{mol \cdot k}\bigg|278.15\,k\bigg|\dfrac{1}{3.61\ torr}\bigg|\dfrac{760\ torr}{1\,atm}\bigg|\dfrac{1}{1.50\,mL}\bigg|\dfrac{1000\,mL}{1\,L}$$

$$= 69\,840.6\ \dfrac{g}{mol} = \boxed{69,800\ g/mol}$$
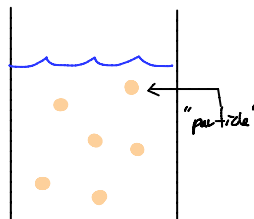
.

Colloid: mixture between homogeneous soln (clear)
    and Suspension (turbid; cloudy)
↳ Examples: salt water = homogen soln
            Milk = suspension (protein-in-water)
↳ Translates literally: "glue like"

TYNDALL EFFECT: particles are
large enough to scatter light,
∴ cloudy or opaque

"particle"

DISPERSED PHASE ≈ solute
DISPERSION MEDIUM ≈ solvent

Emulsion: colloid of two immiscible liquids using an
    emulsifying agent, a substance that inhibits

Examples of Colloidal Systems

Dispersed Phase	Dispersion Medium	Common Examples	Name
solid	gas	smoke, dust	—
solid	liquid	starch in water, some inks, paints, milk of magnesia	sol
solid	solid	some colored gems, some alloys	—
liquid	gas	clouds, fogs, mists, sprays	aerosol
liquid	liquid	milk, mayonnaise, butter	emulsion
liquid	solid	jellies, gels, pearl, opal (H_2O in SiO_2)	gel
gas	liquid	foams, whipped cream, beaten egg whites	foam

Table 11.4

Preparation of Colloid Systems

① DISPERSION METHODS — break down larger particles (eg. paint pigments)
② CONDENSATION " — growth from small particles (eg. ions)

Soaps & Detergents

non polar (oily)
hydro phobic

polar
hydrophilic

eg. sodium lauryl sulfonate

$$C_{12} - O - \overset{O}{\underset{O}{\overset{||}{S}}} - O^{\ominus} \quad Na^{\oplus}$$

Solvated cation
Ionic end
Hydrocarbon tail
Drop of oil

Electrical Properties of Colloidal Particles

· Colloidal systems often CHARGED
· Example Application: Smoke detector
  ↳ carbon & dust particles are often (-) charged
  ↳ Detector has α-source, He^{2+}, which completes a circuit
  ↳ (-) Particles interrupt He^{2+}, breaking the circuit
      and sounding alarm.

Gels

· Gel : Liquid-in-solid colloid
· Ex : Jello = water-in-solid proteins
· Solid fibers form 3-D network — a
    cage — around a liquid.
· If liquid is water, the gel is
    said to be hydrated.
· EX 2: Canned Heat = alcohol + Sat. aq. soln of $Ca(CH_3CO_2)_2$.
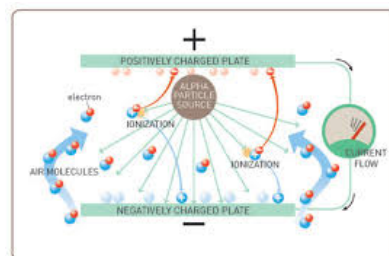
Redux: calc MW from colligative BP/MP change

(EX) Colligative Property: Calculate MW   (also a lab experiment)
¿Calculate the MW of naphthalene, basen on an experiment in which 5.2 g is dissolved in a 100. g of ethanol (BP = 78.41 °C) to produce a mixture with a boiling point of 78.90 °C? (Kb,ethanol = 1.22 °C/m)

$$\boxed{}\frac{g}{mol} = \frac{5.2\,g}{mol} = \frac{5.2\,g}{0.040\,mol} = 129.5\frac{g}{mol} = \boxed{130\,g/mol}$$

$$0.100$$

$$m = \frac{mol_{u} \quad \Longrightarrow}{kg_{v}} \qquad mol = m \cdot kg = 0.040 \quad \curvearrowright$$

$$\Delta T_{b} = K_{f} \cdot m \qquad \Longrightarrow \qquad m = \frac{\Delta T_{b}}{K_{f}} = \frac{(78.90 - 78.41)}{1.22\,°C}\bigg|\,m = 0.40\,m$$

MAP:

$$MM = \frac{g_{u}}{mol_{u}}$$

$$\frac{T_{s}}{T_{u}} \quad \nearrow \quad \Delta T = K_{f}\,m \quad \searrow \quad m = \frac{mol_{u}}{L}$$

<--
start with an expression for what you need to calculate ("I need to know molar mass"), and work backwards, calculating the things you don't know.