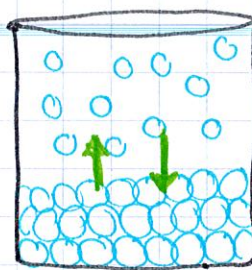


• Colligative Properties - properties that are dependent on the number of particles (atoms/ions) that are in solution!

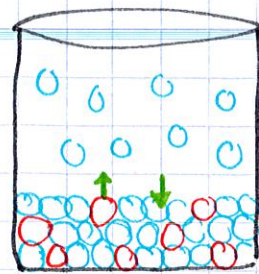
↳ Vapor Pressure Lowering

- due to IMFs between the solute & solvent,
 (nonvolatile)

the solvent particles do NOT escape as a vapor as much. ∴ vapor pressure for the solution is lower than for just the pure solvent.



solvent only



solute + solvent

- Raoult's Law

$$P_A = X_A P_A^{\circ}$$

P_A = vapor pressure of solvent in solution

X_A = mole fraction of solvent

P_A° = vapor pressure of pure solvent

Ex (7) The vapor pressure of pure water at 110°C is 1070 torr. A solution of ethylene glycol and water has a vapor pressure of 1.00 atm at 110°C. What is the mole fraction of ethylene glycol in the solution?

$$P_A^{\circ} = 1.41 \text{ atm}$$

$$1.00 = X_A (1.41 \text{ atm})$$

$$.709 = X_A$$

Ex (8) Calculate the vapor pressure of water above a solution prepared by dissolving 22.5 g of lactose ($C_{12}H_{22}O_{11}$) to 200.0 g of water at 338 K. (Vapor pressure for water is given in Appendix B) $\hookrightarrow 187.5 \text{ torr}$

$$22.5 \text{ g } C_{12}H_{22}O_{11} \left(\frac{1 \text{ mol}}{342 \text{ g}} \right) = .0658 \text{ mol } C_{12}H_{22}O_{11}$$

$$200.0 \text{ g } H_2O \left(\frac{1 \text{ mol}}{18 \text{ g}} \right) = 11.11 \text{ mol } H_2O$$

$$P_a = (.0658 \text{ mol}) (187.5 \text{ torr})$$

$$P_a = 12.33 \text{ torr}$$

\hookrightarrow Boiling Point Elevation - adding a solute (nonvolatile) raises the boiling point of the solution.

- why? IMFs between solute & solvent take more energy to break before substance can boil.

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

ΔT_b = change in boiling pt.
 K_b = boiling pt. constant (p 549)
 i = # particles in solution
 m = molality

\hookrightarrow Freezing Point Depression - adding a solute lowers the freezing point of the solution

- why?

Freezing a solution means crystals of pure solvent usually separate out. It takes a colder temp. to stop the IMFs from interfering w/ the crystal formation in the pure solvent.

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

ΔT_f = change in freezing pt.
 K_f = freezing pt. constant (p 549)
 i = # particles in solution
 m = molality

i is called van't Hoff factor

Ex (8) Calculate the freezing point of a solution containing .600 kg CHCl_3 and 42.0 g of eucalyptol ($\text{C}_{10}\text{H}_{18}\text{O}$), the fragrance found in the leaves of the eucalyptus tree.

$\Delta T_f^\circ = -63.5^\circ\text{C}$ - normal fr. pt.

$\Delta T_f = ?$

$K_f = 4.68^\circ\text{C}/m$

$i = 1$

$m = ?$

$\Delta T_f = (4.68^\circ\text{C}/m)(1)(.455m) = 2.13^\circ\text{C}$

$T_{f \text{ solu}} = -63.5^\circ\text{C} + 2.13^\circ\text{C}$

$= -65.63^\circ\text{C}$

$K_f = p.549$
for the solvent

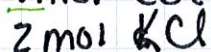
$n = 42.0\text{g} / (1\text{mol C}_{10}\text{H}_{18}\text{O} / 154\text{g}) = .273\text{mol}$

$m = .273\text{mol} / .600\text{kg} = .455m$

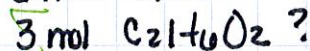
Ex (9) which of the following solutes will produce the largest increase in boiling point upon addition to 1kg of water:



$i = 3$ $m = 1$



$i = 2$ $m = 2$ ✓



$i = 1$ $m = 3$

$\Delta T_b = K_b \cdot i \cdot m$
Same

Ex (10) Calculate the freezing and boiling pts. for these solutions.
See Table 13.4 (p 549).

A. .22m glycerol ($\text{C}_3\text{H}_8\text{O}_3$) in ethanol

$\Delta T_f = ?$

$K_f = 1.99^\circ\text{C}/m$

$i = 1$

$m = .22m$

$\Delta T_f = .438^\circ\text{C}$ $T_{f \text{ solu}} = -114.6$

$+ -.438 = -115.038^\circ\text{C}$

$\Delta T_b = ?$

$K_b = 1.22$

$i = 1$

$m = .22m$

$\Delta T_b = .268$ $T_{b \text{ solu}} = 78.4$

$+ .268 = 78.6^\circ\text{C}$

b. .240 mol of naphthalene ($C_{10}H_8$) in 2.45 mol chloroform
normal bP: $\Delta T_b^\circ = 61.2^\circ C$ normal fP: $\Delta T_f^\circ = -63.5^\circ C$

$$\begin{aligned}\Delta T_b &= ? \\ k_b &= 3.63^\circ C/m \\ i &= 1 \\ m &= .830 m\end{aligned}$$

$$\begin{aligned}\Delta T_f &= ? \\ k_f &= 4.68^\circ C/m \\ i &= 1 \\ m &= .830 m\end{aligned}$$

$$\Delta T_b = 3.63(1)(.830) = 3.01^\circ C$$

$$\Delta T_f = 4.68(1)(.830) = 3.88^\circ C$$

$$k_g = 2.45 \text{ mol } CHCl_3 \left(\frac{119.5 \text{ g}}{1 \text{ mol}} \right) = 289.1 \text{ g} \rightarrow .289 \text{ kg } CHCl_3$$

$$m = .240 \text{ mol} / .289 \text{ kg} = 0.830 m$$

$$\begin{aligned}T_b^\circ &= 61.2 + 3.01 = 64.2^\circ C \\ T_f^\circ &= (-63.5) + (-3.88) = -67.4^\circ C\end{aligned}$$

c. 2.04 g KBr in 188 g of water

$$K_b = 0.51^\circ C \quad K_f = 1.86^\circ C \quad i = 2 \quad m = \frac{n}{kg} = 0.090 m$$

$$2.04 \text{ g KBr} \times \frac{1 \text{ mol}}{119.0 \text{ g}} = 0.017 \text{ mol} \quad \frac{0.017 \text{ mol}}{0.188 \text{ kg}} = 0.090 m$$

$$\Delta T_b = 0.0918^\circ C + 100^\circ C = 100.09^\circ C$$

$$\begin{aligned}\Delta T_f &= 0.3348^\circ C \\ 0^\circ C - 0.3348^\circ C &= -0.33^\circ C\end{aligned}$$

$$T_b = 100.09^\circ C \quad T_f = -0.33^\circ C$$