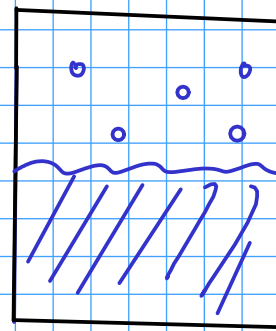


VAPOR PRESSURE LOWERING

- Described by **RAOULT'S LAW**



P_A = partial pressure of the VAPOR of solvent molecules.

$$P_A = P_A^* \times X_A$$

mole fraction of component A

vapor pressure of pure component A (depends on temperature)

partial pressure of component A in a solution

... but component "A" above is actually the SOLVENT. If we want to describe this as a colligative property, we want to express Raoult's law in terms of the SOLUTE! Assuming a two-component mixture, we get...

$$\Delta P = P_A^* \times X_B$$

mole fraction of component B (the SOLUTE in a two-component mixture)

Vapor pressure lowering. This is the DECREASE in the vapor pressure of the solvent due to the presence of solute.

BOILING POINT ELEVATION

- Since the vapor pressure is lowered by the presence of a solute, AND since boiling occurs when the vapor pressure of a liquid equals the external pressure - solutes also cause BOILING POINT ELEVATION.

- The equation for boiling point elevation looks almost exactly like the equation for the freezing point depression, and is used in almost the same way.

$$\Delta T_b = K_b \times C_m$$

└ concentration of solute (molality)

└ Boiling point elevation constant (for SOLVENT)

└ Boiling point elevation: The amount the boiling temperature is RAISED by the solute.

What is the boiling point of a solution that contains 2.817 g of molecular sulfur (S_8) dissolved in 100.0 grams of acetic acid?

$$T_b = 118.5^\circ\text{C} \quad K_b = 3.08^\circ\text{C}/m \quad \leftarrow \text{from pSol}$$

$$\Delta T_b = \underbrace{K_b}_{3.08^\circ\text{C}/m} \times C_m \quad C_m = \frac{\text{mol } S_8}{\text{kg AA}}$$

$$2.817 \text{ g } S_8 \times \frac{\text{mol } S_8}{256.48 \text{ g } S_8} = 0.0109833 \text{ mol } S_8$$

$$\frac{0.0109833 \text{ mol } S_8}{0.1000 \text{ kg AA}} = 0.109833 \text{ m} = C_m$$

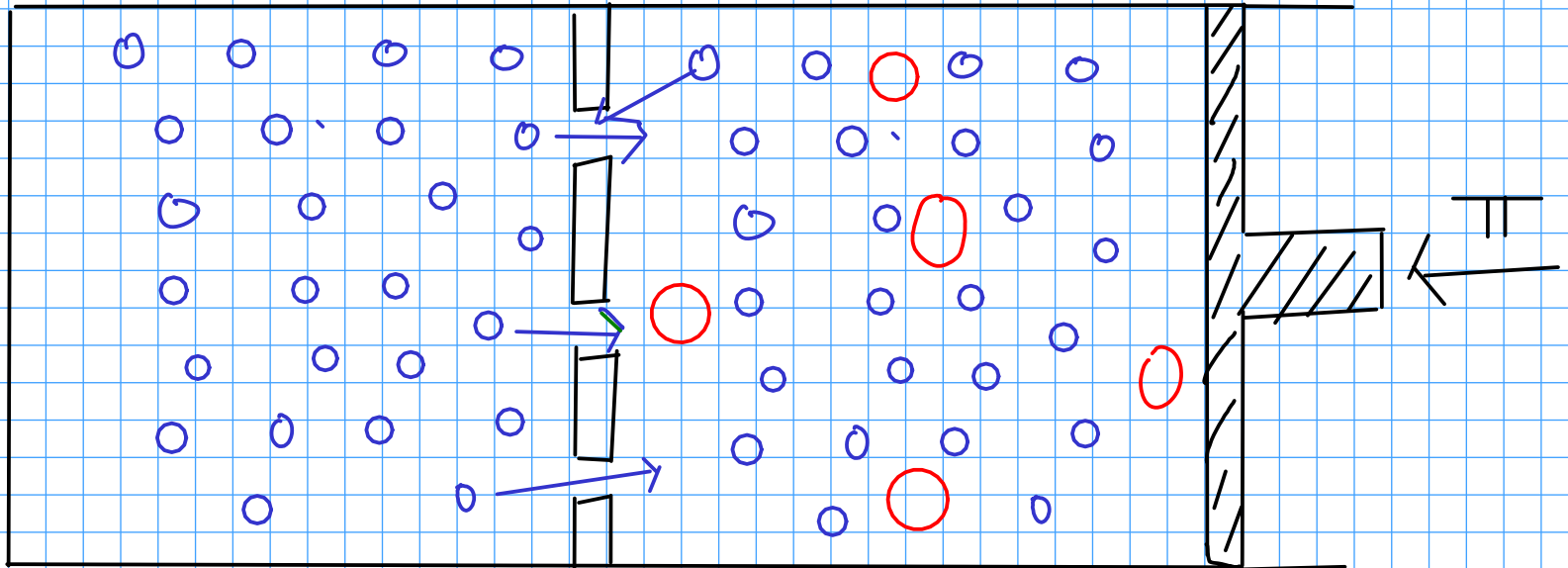
$$\Delta T_b = (3.08^\circ\text{C}/m) \times (0.109833 \text{ m}) = 0.338^\circ\text{C}$$

$$\text{new } T_b = 118.5^\circ\text{C} + 0.338^\circ\text{C} = \boxed{118.8^\circ\text{C}}$$

OSMOTIC PRESSURE

permits flow of solvent, but not solute particles

- OSMOSIS: the flow of solvent molecules through a SEMIPERMEABLE membrane to equalize concentration of solute on each side of the membrane.



The rate of solvent migration towards the RIGHT is greater than that towards the LEFT.

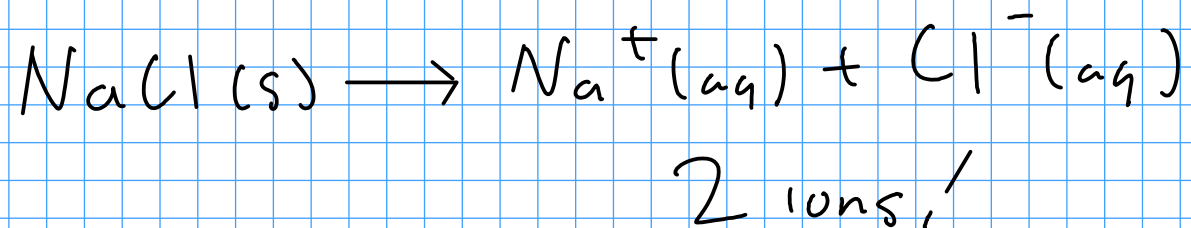
If you apply enough pressure to the piston, osmosis will not occur. This pressure is called the OSMOTIC PRESSURE

$$\pi = M \times R \times T$$

temperature
ideal gas constant
molar concentration of solute

IONIC COMPOUNDS and colligative properties

- Ionic compounds DISSOCIATE in water into their component ions. Each ion formed can act as a solute and influence the colligative properties!



... so the concentration of IONS here is TWICE the nominal NaCl concentration.

- Ions interact with each other in solution, so unless an ionic solution is DILUTE, the effective concentrations of ions in solution will be less than expected. A more advanced theory (Debye-Huckel) covers this, but we'll assume that our solutions are dilute enough so that we can use the concentration of the ions in solution to determine the colligative properties!

If you are at an altitude high enough for the boiling point of water to be 95.00 C, what amount of sodium chloride would you need to add to 1.000 kg of water to raise the boiling point to 100.00 C?

$$K_b = 0.512 \text{ } ^\circ\text{C}/m$$

$$\frac{\Delta T_b}{5.00^\circ\text{C}} = \frac{K_b \times C_m}{0.512 \text{ } ^\circ\text{C}/m} \quad C_m = \frac{\text{moles ions}}{\text{kg H}_2\text{O}}$$

$$5.00^\circ\text{C} = (0.512 \text{ } ^\circ\text{C}/m) \times C_m$$

$$C_m = 9.765625 \text{ } m$$

$$1.000 \text{ kg H}_2\text{O} \times \frac{9.765625 \text{ mol ions}}{\text{kg H}_2\text{O}} = 9.765625 \text{ mol ions}$$

Sodium chloride dissociates into TWO ions when it dissolves. So the nominal NaCl concentration will be HALF of the concentration of the individual ions.

$$9.765625 \text{ mol ions} \times \frac{1 \text{ mol NaCl}}{2 \text{ mol ions}} \times \frac{58.443 \text{ g NaCl}}{\text{mol NaCl}} = \boxed{285 \text{ g NaCl}}$$

EXTERNAL FACTORS AFFECTING SOLUBILITY

- There are a few external factors that affect the solubility. (By external, we mean other than the chemical identity of the solute and solvent).

① TEMPERATURE

- For gases dissolved in liquids, the solubility DECREASES as the temperature INCREASES
 - This is why THERMAL POLLUTION is bad! Hot water holds less oxygen than cooler water.
- For solids dissolved in liquids, solubility USUALLY increases with temperature. This is not true for ALL solid/liquid solutions.

② PRESSURE

- For gases dissolved in liquids, solubility INCREASES when the partial pressure of the solute gas over the solution INCREASES.
 - Consider soft drinks. They go flat after opening because the pressure of carbon dioxide over the liquid goes down.
- No significant pressure effects for solid/liquid solutions.

#12.83, p 520 8th ed

An aqueous solution is 8.50% ammonium chloride by mass. The density of the solution is 1.024 g/mL

Find: molality, mole fraction, molarity.

$$\text{NH}_4\text{Cl} : 53.491 \text{ g/mol} \quad \text{H}_2\text{O} : 18.016 \text{ g/mol}$$

$$\frac{8.50 \text{ g NH}_4\text{Cl}}{100 \text{ g solution}} \longrightarrow \frac{\text{mol NH}_4\text{Cl}}{\text{kg H}_2\text{O}} \quad 8.50 \text{ g NH}_4\text{Cl} \times \frac{\text{mol}}{53.491 \text{ g}} = 0.15891 \text{ mol}$$

$$\text{mass H}_2\text{O} = 100 \text{ g solution} - 8.50 \text{ g NH}_4\text{Cl} = 91.5 \text{ g H}_2\text{O}$$

$$= 0.0915 \text{ kg H}_2\text{O}$$

$$m = \frac{0.15891 \text{ mol}}{0.0915 \text{ kg}} = \boxed{1.74 \text{ m NH}_4\text{Cl}}$$

$$\rightarrow \frac{\text{mol NH}_4\text{Cl}}{\text{mol total}}$$

$$= \frac{.15891}{5.237729}$$

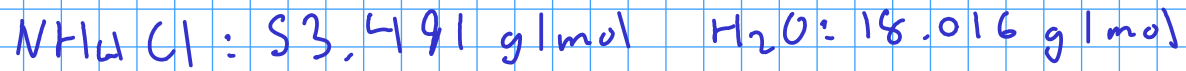
$$91.5 \text{ g H}_2\text{O} \times \frac{\text{mol}}{18.016 \text{ g}} = 5.0788 \text{ mol H}_2\text{O}$$

$$+ .15891 \text{ mol NH}_4\text{Cl}$$

$$\underline{\underline{5.237729 \text{ mol total}}}$$

$$= \boxed{0.0303 = X_{\text{NH}_4\text{Cl}}}$$

An aqueous solution is 8.50% ammonium chloride by mass. The density of the solution is 1.024 g/mL
Find: molality, mole fraction, molarity.



$$\frac{8,50 \text{ g NH}_4\text{Cl}}{100 \text{ g solution}} \longrightarrow \frac{\text{mol NH}_4\text{Cl}}{\text{L solution}} \quad 0,15891 \text{ mol NH}_4\text{Cl}$$

$$100 \text{ g solution} \times \frac{\text{mL}}{1,024 \text{ g}} \times \frac{10^{-3} \text{ L}}{\text{mL}} = 0,09765625 \text{ L}$$

$$\underline{M} = \frac{0,15891 \text{ mol NH}_4\text{Cl}}{0,09765625 \text{ L}} = \boxed{1,63 \underline{M} \text{ NH}_4\text{Cl}}$$