

A solution of 2.500g of unknown dissolved in 100.0 g of benzene has a freezing point of 4.880 C.

What is the molecular weight of the unknown?

$$K_{f, \text{benzene}} = 5.065 \text{ } ^\circ\text{C}/m, \quad T_{f, \text{benzene}} = 5.455 \text{ } ^\circ\text{C} \quad \left(\begin{array}{l} \text{see} \\ \text{p500 9th} \\ \text{p509, 10th} \end{array} \right)$$

$$\underbrace{\Delta T_f}_{5.455 \text{ } ^\circ\text{C} - 4.880 \text{ } ^\circ\text{C} = 0.575 \text{ } ^\circ\text{C}} = \underbrace{K_f}_{5.065 \text{ } ^\circ\text{C}/m} \times C_m = 5.065 \text{ } ^\circ\text{C}/m \quad \left| \quad C_m = \frac{\text{mol unknown}}{\text{kg benzene}} \right.$$

Solving for C_m (molality) will allow us to calculate how many moles of unknown are dissolved in the benzene. Since we already know the mass of unknown, we'll then be able to find the molecular weight (grams/moles).

$$0.575 \text{ } ^\circ\text{C} = 5.065 \text{ } ^\circ\text{C}/m \times C_m$$

$$C_m = 0.1135241856 \text{ m unknown} = 0.1135241856 \frac{\text{mol unk}}{\text{kg benzene}}$$

To get moles, multiply the molality by the kilograms benzene!

$$0.1000 \text{ kg benzene} \times 0.1135241856 \frac{\text{mol unk}}{\text{kg benzene}} = 0.0113524186 \text{ mol unk}$$

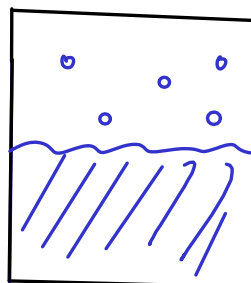
(100.0g)

Now, find molecular weight.

$$MW = \frac{\text{g unknown}}{\text{mol unknown}} = \frac{2.500 \text{ g}}{0.0113524186 \text{ mol}} = \boxed{220 \text{ g/mol}}$$

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 Raolt'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.

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

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

K_b — Boiling point elevation constant (for SOLVENT)

C_m — concentration of solute (molality)

(pS0C, 9th
pS09, 10th)

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?

$$T_b = 118.5^\circ\text{C}$$

$$K_b = 3.08^\circ\text{C}/m$$

(see p500 for data)
p509, 10th

$$\Delta T_b = \underbrace{K_b}_{3.08^\circ\text{C}/m} \times C_m \quad \text{---} \quad C_m = \frac{\text{mol } S_8}{\text{kg } HC_2H_3O_2}$$

Find C_m by changing the 2.817 grams of sulfur to moles, then dividing by the kg of acetic acid!

$$S_8: S - 8 \times 32.07 = 256.56 \text{ g/mol}$$

$$2.817 \text{ g } S_8 \times \frac{\text{mol } S_8}{256.56 \text{ g } S_8} = 0.0109798877 \text{ mol } S_8$$

$$C_m = \frac{0.0109798877 \text{ mol } S_8}{0.1000 \text{ kg } HC_2H_3O_2 \text{ (100.0 g)}} = 0.1097988775 \text{ m } S_8$$

Now calculate delta T_b ...

$$\Delta T_b = (3.08^\circ\text{C}/m)(0.1097988775 \text{ m } S_8) = 0.338^\circ\text{C}$$

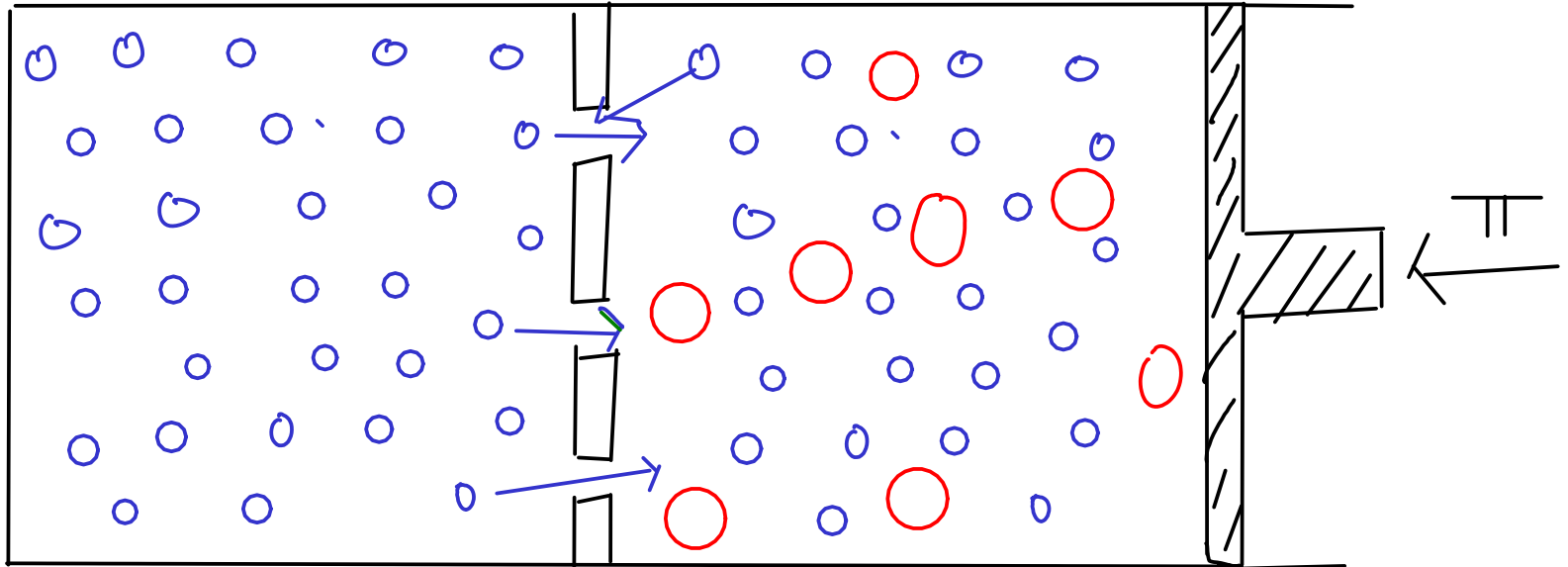
Finally, calculate boiling point.

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

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.

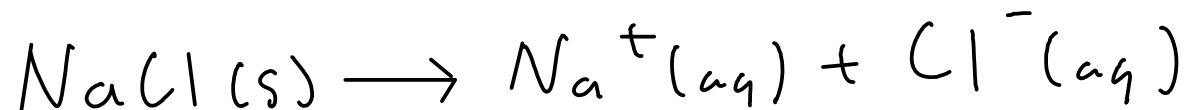
If you apply enough pressure to the piston, osmosis will not occur. This pressure is called the OSMOTIC PRESSURE

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

temperature
ideal gas constant
molar concentration of solute

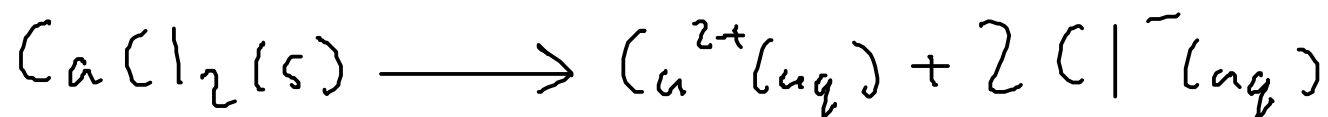
IONIC COMPOUNDS and colligative properties

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



2 ions!

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



3 ions!

... so the concentration of IONS here is THREE TIMES the nominal calcium chloride 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?

$$K_b = 0.512 \text{ } ^\circ\text{C}/m \quad \text{NaCl: } 58.443 \text{ g/mol}$$

$$\Delta T_b = K_b \times C_m \quad C_m = \frac{\text{mol ions}}{\text{kg H}_2\text{O}} \quad \leftarrow \text{NaCl is ionic, so the colligative properties are based on total concentration of IONS}$$

$100.00^\circ\text{C} - 95.00^\circ\text{C} = 5.00^\circ\text{C}$
 $0.512^\circ\text{C}/m$

Find C_m ...

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

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

Find moles ions...

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

but $\text{NaCl} \rightarrow \text{Na}^+ + \text{Cl}^-$ (2 ions); $\text{mol NaCl} = 2 \text{ mol ions}$

$$9.765625 \text{ mol ions} \times \frac{\text{mol NaCl}}{2 \text{ mol ions}} = 4.8828125 \text{ mol NaCl}$$

Find mass NaCl

$$4.8828125 \text{ mol NaCl} \times \frac{58.443 \text{ g NaCl}}{\text{mol NaCl}} = \boxed{285 \text{ g NaCl}}$$

KINETICS

- the study of the RATE of chemical reactions. Or, the study of the factors affecting how fast chemical reactions proceed.

DEFINING RATE

- RATE is defined as the change in the molar (M) concentration of a reactant or product over time. Usually, rate is defined in terms of one of the REACTANTS



...Let's look at a simple combination

$$\text{Rate} = \frac{-\Delta[A]}{\Delta t}$$

$[A]$ = "molar concentration of substance "A".

Square brackets () are used to denote MOLAR concentration

change in time

$$\text{Rate} = \frac{\Delta[C]}{\Delta t}$$

You could ALSO define the rate in terms of the disappearance of B or the appearance of C over time! Our choice of A was arbitrary,

Negative sign because we define the rate as a POSITIVE number, and (A) will decrease over time!