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?

$K_{f,\text{benzene}} = 5.065\ ^{o}C/m$, $T_{f,\text{benzene}} = 5.455^{o}C$ (see p500 9th p509, 10th)

$$\Delta T_f = \underbrace{K_f}_{5.065\ ^{o}C/m} \times C_m \qquad C_m = \frac{\text{mol unknown}}{\text{Kg benzene}}$$

$\uparrow$

$0.575^{o}C = 5.455^{o}C - 4.880^{o}C$

Solve for Cm, the MOLAL concentration.

$$0.575^{o}C = (5.065\ ^{o}C/m)C_m\ ;\ C_m = 0.1135241856 \frac{\text{mol unknown}}{\text{Kg benzene}}$$

Calculate moles unknown from MOLAL concentration and the mass of benzene used.

$100.0\text{g benzene} = 0.1000\text{ Kg benzene}$

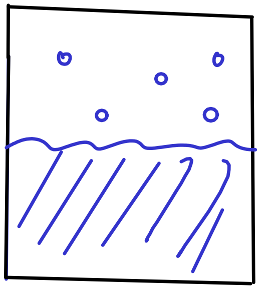
$$0.1000\text{Kg benzene} \times \frac{0.1135241856\text{ mol unknown}}{\text{Kg benzene}} = 0.0113524186\text{ mol unknown}$$

FInd molecular weight

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

VAPOR PRESSURE LOWERING

- Described by RAOULT'S LAW



P_A = partial pressure of the VAPOR of solvent molecules.

$$\underline{P_A} = \underline{P_A^*} \times \underline{X_A}$$

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...

$$\underline{\Delta P} = P_A^* \times \underline{X_B}$$

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.

$$\underline{\Delta T_b} = \underline{K_b} \times \underline{C_m}$$

C_m – concentration of solute (molality)

K_b – Boiling point elevation constant (for SOLVENT) (p500, 9th
p509, 10th)

ΔT_b – 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?

$T_b = 118.5°C$ $K_b = 3.08°C/m$ (see p500 for data)
p509, 10th

$\Delta T_b = \underbrace{K_b}_{3.08°C/m} \times C_m$

Start by calculating Cm from DATA ...

$C_m = \frac{mol\ S_8}{Kg\ HC_2H_3O_2}$ ① ②

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(1) - Calculate moles sulfur. Use FORMULA WEIGHT.

$S_8: \frac{S - 8 \times 32.07}{256.56\,g\,S_8 = mol\,S_8}$

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

(2) - Calculate kg acetic acid. Unit conversion.

$100.0\,g\,HC_2H_3O_2 = 0.1000\,Kg\,HC_2H_3O_2$

Now calculate Cm...

$C_m = \frac{0.0109798877\ mol\ S_8}{0.1000\ Kg\ HC_2H_3O_2} = 0.1097988775\ m\ S_8$

FInd delta Tb ...

$\Delta T_b = (3.08°C/m)(0.1097988775\ m\ S_8) = 0.338°C$

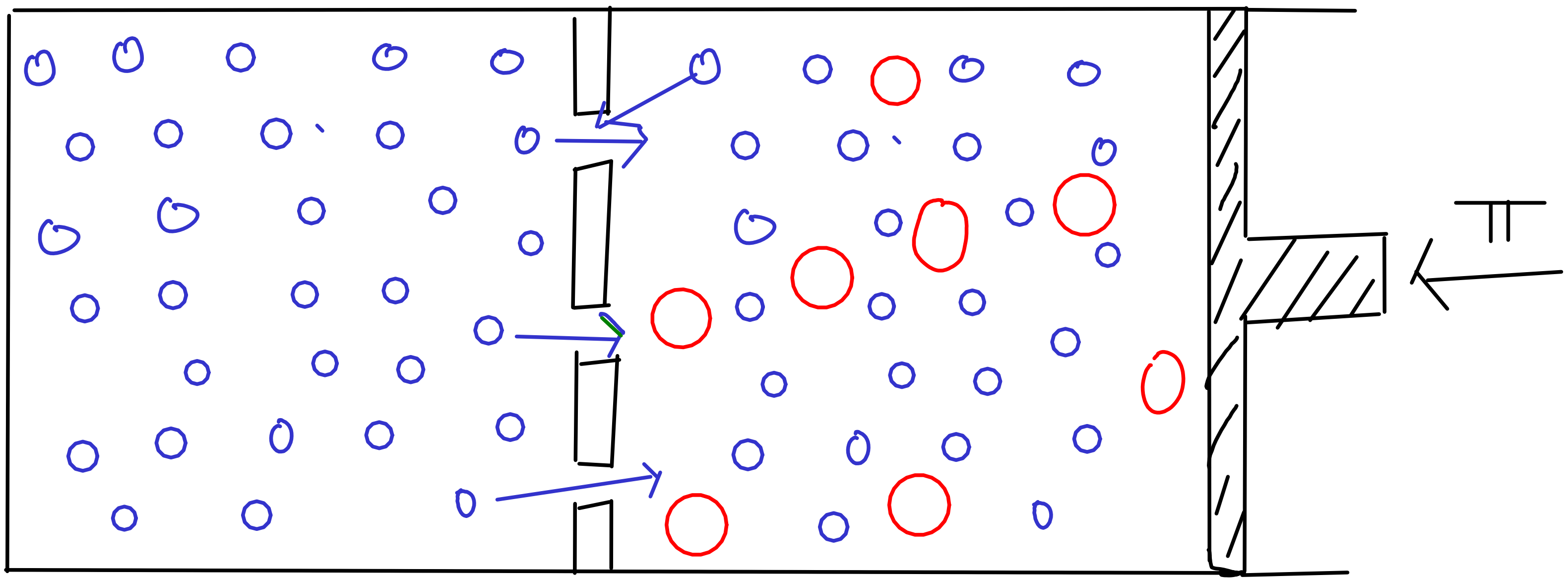
And finally, the new boiling temperature...

$T_{b,solution} = 118.5°C + 0.338°C = \boxed{118.8°C}$

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!

$$NaCl(s) \longrightarrow Na^+(aq) + Cl^-(aq)$$

2 ions!

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

$$CaCl_2(s) \longrightarrow Ca^{2+}(aq) + 2\,Cl^-(aq)$$

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?

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

$$\underbrace{\Delta T_b}_{100.00^{o}C - 95.00^{o}C = 5.00^{o}C} = \underbrace{K_b}_{0.512\ ^{o}C/m} \times C_m$$

Start by finding Cm ... which is the MOLAL concentration of ions in solution (since NaCl is ionic and breaks aoart on dissolving!)

$$5.00^{o}C = (0.512\ ^{o}C/m)(C_m\ ;\quad C_m = 9.765625\ \frac{mol\ ions}{Kg\ H_2O}$$

Now find moles of ions.

$$1.000\ Kg\ H_2O \times \frac{9.765625\ mol\ ions}{Kg\ H_2O} = 9.765625\ mol\ ions$$

How much NaCl? $NaCl \rightarrow Na^{+} + Cl^{-}$ (2 ions per NaCl) (2 mol ions = mol NaCl)

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

↑ convert to mass ...