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?

$$K_{f,\text{benzene}} = 5.065\ {}^{\circ}C/m \quad , \quad T_{f,\text{benzene}} = 5.455^{\circ}C$$

(see p500 9th p509, 10th)

$$\Delta T_f = K_f \times C_m \qquad C_m = \frac{\text{mol unknown}}{\text{kg benzene}}$$

$K_f = 5.065\ {}^{\circ}C/m$

$\Delta T_f = 5.455^{\circ}C - 4.880^{\circ}C = 0.575^{\circ}C$

To find molecular weight, we need to divide grams unknown / moles unknown. We already know the grams ...

First, we calculate Cm ... (molal concentration)

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

$$C_m = 0.1135241856\ m$$

Calculate the moles of unknown using the concentration and the 100 grams benzene solvent:

$$0.1000\ \text{kg benzene} \times \frac{0.1135241856\ \text{mol unk}}{\text{kg benzene}} = 0.01135241856\ \text{mol unk}$$

Now we can find molecular weight:

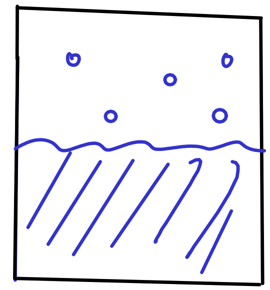
$$MW = \frac{\text{g unk}}{\text{mol unk}} = \frac{2.500\text{g}}{0.01135241856\ \text{mol}} = \boxed{220.\ \text{g/mol}}$$

VAPOR PRESSURE LOWERING

- Described by RAOULT'S LAW

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

- X_A — mole fraction of component A
- P_A^* — vapor pressure of pure component A (depends on temperature)
- P_A — partial pressure of component A in a solution



P_A = partial pressure of the VAPOR of solvent molecules.

... 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...

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

- X_B — mole fraction of component B (the SOLUTE in a two-component mixture)
- ΔP — 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.

$$\Delta T_b = K_b \times c_m$$

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

$\Delta T_b = K_b \times C_m$
└ 3.08 °C/m

$C_m = \frac{\text{mol } S_8}{\text{kg AA}}$

Find Cm using the information given about the solution.

S_8: $\frac{8 \times 32.07}{256.56 \text{ g } S_8} = \text{mol } S_8$

$2.817 \text{ g } S_8 \times \frac{\text{mol } S_8}{256.56 \text{ g } S_8} = 0.01097988077 \text{ mol } S_8$

$\frac{.01097988077 \text{ mol } S_8}{0.1000 \text{ kg AA}} = 0.1097988775 \text{ m} = C_m$

(100.0 g AA)

Find DELTA Tb ...

$\Delta T_b = (3.08 °C/m)(0.1097988775 \text{ m})$

$\Delta T_b = 0.338 °C$

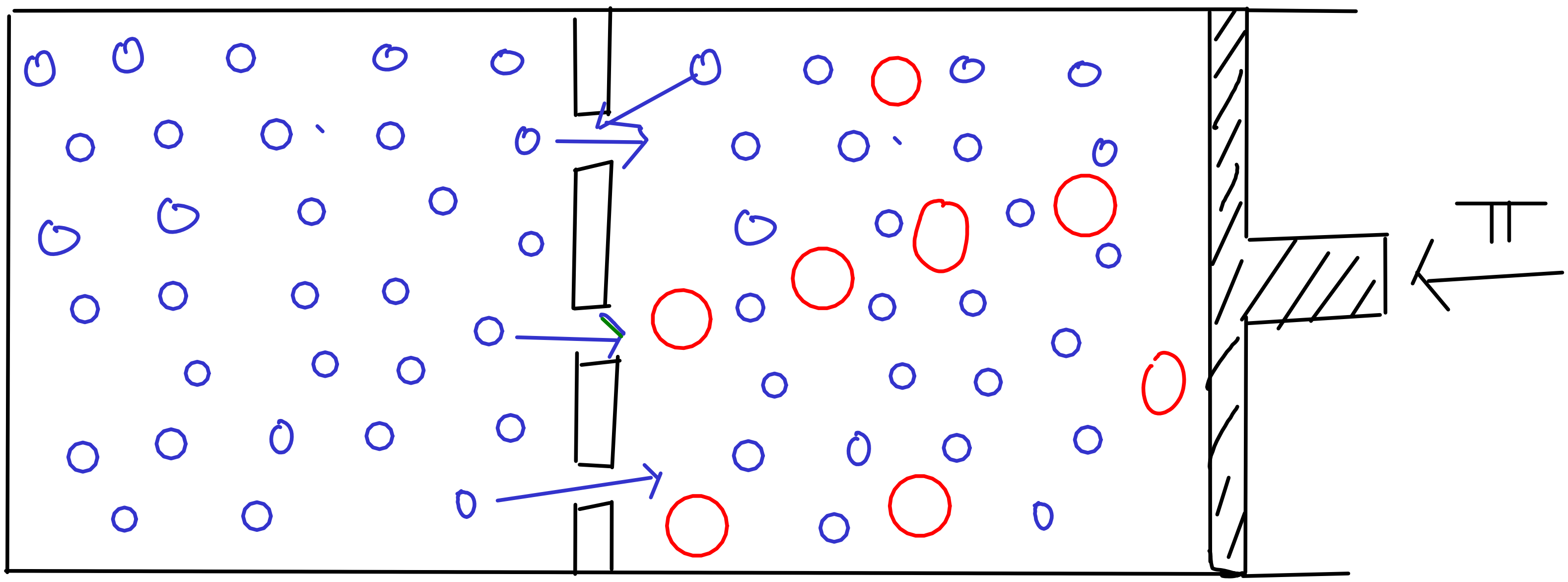
So the new boiling point is ...

$118.5°C + 0.338°C = \boxed{118.8 °C}$

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

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

- T: temperature
- R: ideal gas constant
- M: 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?

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

$\Delta T_b = K_b \times C_m$

K_b = 0.512 °C/m

ΔT_b = 100.00 °C − 95.00 °C = 5.00 °C

$C_m = \frac{\text{mol ions}}{\text{kg } H_2O}$ ← 1.000 kg H_2O

Find Cm ... (molal concentration of IONS)

5.00 °C = (0.512 °C/m) × Cm

Cm = 9.765625 m ions

Find moles ions:

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

$NaCl \rightarrow Na^+ + Cl^-$; so mol NaCl = 2 mol ions

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

Now find mass NaCl:

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