FREEZING POINT DEPRESSION

$$\Delta T_f = K_f \times C_m$$

- C_m: concentration of solute (molality)
- K_f: Freezing point depression constant (for SOLVENT)
- ΔT_f: Freezing point depression: The amount the freezing temperature is LOWERED by the solute.

- Applications: In chemistry, this effect is often used to determine the molecular weight of an unknown molecule.

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?

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

$\Delta T_f = K_f \times C_m$, where $C_m = \dfrac{\text{mol unknown}}{\text{Kg benzene}}$

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

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

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

First, calculate molal concentration, Cm ...

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

$0.1135241856\ m = C_m = \dfrac{\text{mol unk}}{\text{Kg benzene}}$ ← 0.1000 Kg benzene (from 100.0 g)

Find moles unknown...

$0.1135241856\ m = \dfrac{\text{mol unk}}{0.1000\ \text{kg}}$, mol unk = 0.01135241 86 mol

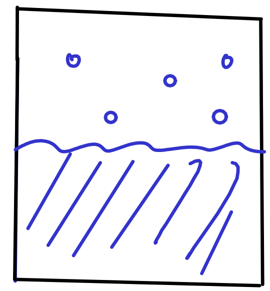
Finally, calculate molecular weight

$MW = \dfrac{\text{mass unk}}{\text{mol unk}} = \dfrac{2.500\ g}{0.0113524186\ mol} = 22\bar{0}\ g/mol$

VAPOR PRESSURE LOWERING

- Described by RAOULT'S LAW

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



P_A = partial pressure of the VAPOR of solvent molecules.

- 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

... 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

$\Delta T_b = K_b \times C_m$ (K_b = 3.08 °C/m); $C_m = \frac{mol\ S_8}{Kg\ acetic}$ ← 0.1000 Kg (from 100.0 g acetic)

First, let's calculate the moles of molecular sulfur. Use FORMULA WEIGHT S_8: S − 8 x 32.07 = 256.56 g S_8 = mol S_8

$$2.817\,g\,S_8 \times \frac{mol\ S_8}{256.56\,g\,S_8} = 0.010979888 77\ mol\ S_8$$

Now find molality, Cm ...

$$C_m = \frac{0.01097988 77\ mol\ S_8}{0.1000\ Kg\ acetic} = 0.1097988775\ m\ S_8$$

Find delta Tb (boiling point ELEVATION)

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

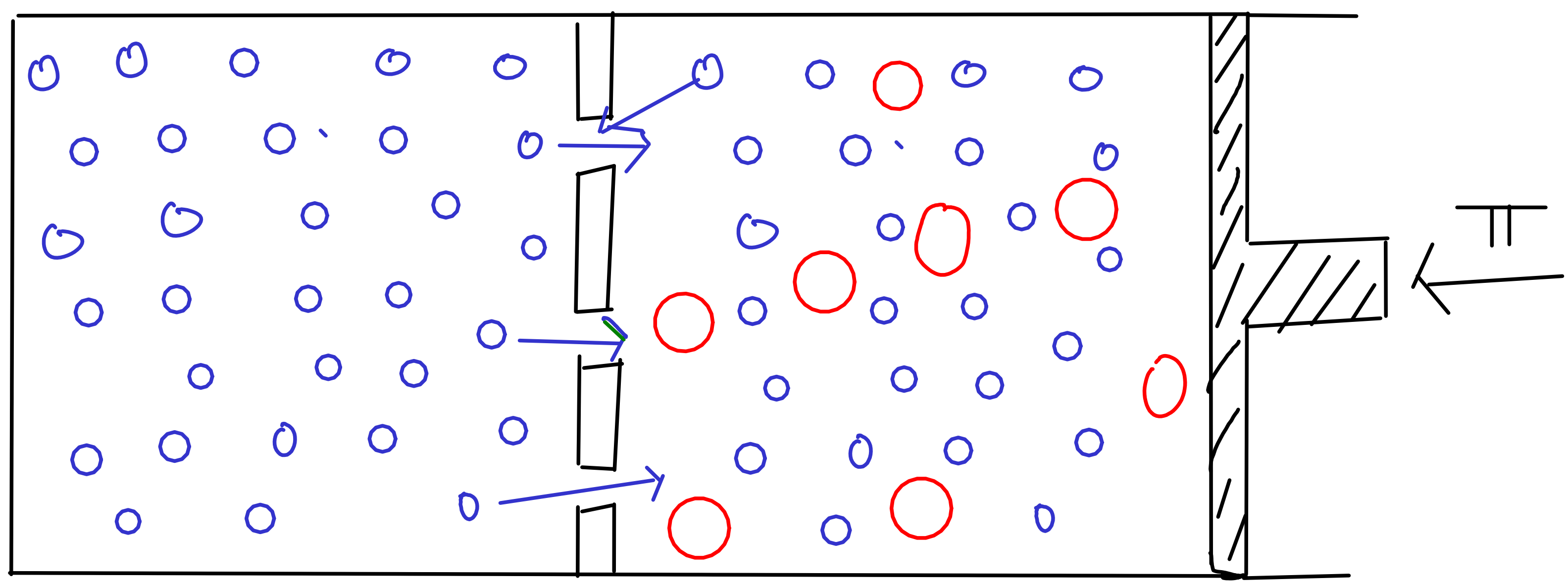
Now, find the new boiling point by adding the delta Tb to the original Tb ...

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

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!