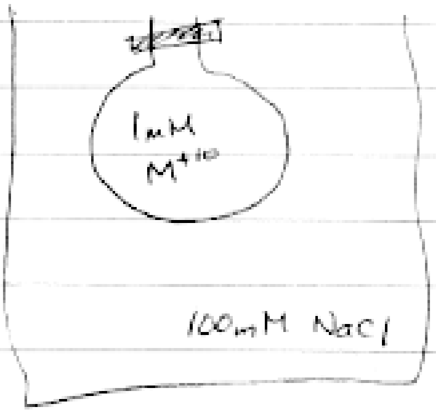
So

$$\frac{C_{Na^+_{IN}}}{C_{Na^+_{OUT}}} \approx 1 - \frac{Z_m C_m}{2C_{Na^+_{OUT}}}$$



Example at right:

Protein is ⊕

$$\left.\begin{array}{l} C_{Na^+_{OUT}} = 100\,mM \\ C_M = 1\,mM \\ Z_m = +10 \end{array}\right\} \Longrightarrow \begin{array}{l} C_{Na^+_{IN}} = 95\,mM \\ C_{Cl^-_{IN}} = 105\,mM \end{array}$$

To balance ⊕ on protein

At equilibrium (all species except M)

At equil for $Na^+$,

$$RT \ln \frac{C^{IN}_{Na^+}}{C^{OUT}_{Na^+}} + ZFV = 0$$

$$V = -\frac{RT}{ZF} \ln \frac{C_{Na^+_{IN}}}{C_{Na^+_{OUT}}} = +1.3\,mV$$

at 298K

Donnan Potential

(should get same number and sign if calculated with $C_{Cl^-_{IN}}$ and $C_{Cl^-_{OUT}}$

Skip pp. 214-230

## Colligative Properties

Normal Boiling Pt: Temperature at which the pure liquid is in equilibrium with it's vapor at 1 atm

Normal Freezing Pt: Temperature at which the pure liquid is in equilibrium with it's solid

But we saw that the vapor pressure of a solvent (impure) with [illegible] dissolved solutes in it is less than that of the pure solvent.

ie. if normally, at the boiling temperature

Boiling Pt Elevation

$P_{H_2O}$ = 1 atm, if we add a solute (any solute) the $P_{H_2O} <$ 1 atm and we will no longer be at a boiling/equilib point. Have to go to higher T.

Freezing Point Depression

Same argument but use "activities"

These are colligative properties.

Colligative ⇒ depend on having a dissolved solute, but it doesn't matter <u>what</u> solute.

<u>Really</u> → depend on the mole fraction of the <u>solvent</u>

<u>Raoult</u>

$P_A = X_A P_A^\bullet$

$$X_{\text{SOLVENT}} = \frac{(\text{moles solvent})}{(\text{moles solvent}) + (\text{moles solute})}$$

⇑ <u>this</u> perturbs $X_{\text{solvent}}$

We saw before this all really derives from

$$\mu_{A_{\text{sol'n}}} = \mu_{A_{\text{solid}}} = \mu_{A_{\text{gas}}}$$

<u>Nothing New</u>

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<u>EMPIRICALLY</u> (p. 233) → Actually - derivation is on p. 235

$$T_0 - T_{\text{freeze}} = K_{\text{freeze}}\, m$$

freezing point of <u>pure</u> solvent

$$T_{\text{boil}} - T_0 = K_{\text{boil}}\, m$$

boiling point of <u>pure</u> solvent

$K_{\text{boil}}, K_{\text{freeze}}$ ≡ Constants that depend only on the solvent

$$m = \text{molality} = \frac{\text{moles solute}}{1000\text{ g solvent}}$$

Can interconvert $X, m, C$

$$X = \frac{\text{moles solute}}{(\text{moles solute}) + (\text{moles solvent})} = \text{mole fraction}$$

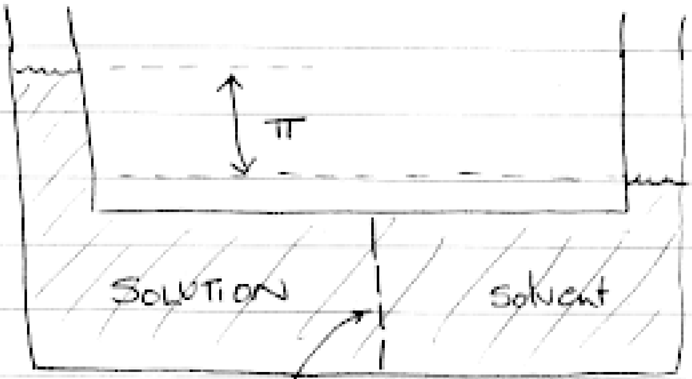
$$C = \frac{\text{moles solute}}{\text{volume solution}} = \text{concentration} = \text{molarity}$$

$$\rho_0 = \underline{\text{density}} \text{ of solvent} = \frac{\text{g solvent}}{\text{volume solvent}}$$

$$m = \frac{\text{moles solute}}{\text{kg solvent}} = \text{molality}$$

$$M_A = \text{molecular weight of solvent} = \frac{\text{g solvent}}{\text{mole solvent}}$$

## Osmotic Pressure



semi-permeable membrane
(not permeable to solute)
Yes permeable to solvent A

$$\mu_A(\text{solution}, \overset{P_1 + \pi}{P_2}) = \mu_A(\text{solvent}, P_1)$$

($A$ = solvent)

So...

$$\mu_A(\text{sol'n}, P_1 + \pi) = \mu_A(\text{solvent}, P_1)$$

IF $P = 1$ atm

$$\text{" "} = \mu_A^\circ(\text{solvent})$$

Ignoring Pressure Change, at $P_1$ (1 atm)

$$\mu_A(\text{sol'n}, 1\text{atm}) = \mu_A^\circ + RT \ln a_A$$

~~$\Delta\mu \approx \mu_A(\text{sol'n}, 1\,\text{atm}) - \mu_A$~~

From pressure dependence of $\mu(\text{sol'n})$

$$\mu_A(\text{sol'n}, 1+\pi) = \mu_A(\text{sol'n}, 1) + \boxed{\Delta\mu}$$

then

$$\mu_A(\text{sol'n}, 1+\pi) = \mu_A^{\circ}(\text{solvent}, 1\,\text{atm})$$

$$\mu_A(\text{sol'n}, 1) + \Delta\mu = \mu_A^{\circ}(\text{solvent}, 1)$$

$$\Delta\mu = \mu_A^{\circ}(\text{solvent}, 1) - \mu_A(\text{sol'n}, 1)$$

$$= \cancel{\mu_A^{\circ}(\text{solvent}, 1)} - \left[\cancel{\mu_A^{\circ}(\text{sol'n}, 1)} + RT \ln a_A\right]$$

$$= -RT \ln a_A$$

$$\Delta\mu = G_{P_2} - G_{P_1} = \int_{P_1}^{P_2} \bar{V}\,\partial P = \bar{V}(P_2 - P_1)$$

$$\Delta\mu = -RT \ln a_A = \bar{V}\left[(1+\pi) - 1\right]$$

$$-RT \ln a_A = \bar{V}\,\pi$$

$$\ln a_A = -\frac{\pi \bar{V}_A}{RT}$$

For dilute sol'ns

$$\ln a_A = \ln X_A = \ln(1 - X_B) \cong -X_B \approx -\frac{n_B}{n_A}$$

$$\Pi = \frac{RT}{n_A \bar{V}_A} n_B$$

In dilute sol'n $n_A \bar{V}_A \approx$ total volume of sol'n

$$\Pi = RT \frac{n_B}{V} = RT c$$

$$\Pi = \text{osmotic pressure} = cRT$$

$$(x \ \cancel{mol} \ \cancel{L}^{-1})(.08206 \ \boxed{atm} \ \cancel{L} \cdot \cancel{K}^{-1} \cdot \cancel{mol}^{-1})(y \ \cancel{K})$$

$\Uparrow$

UNITS
CORRECT!