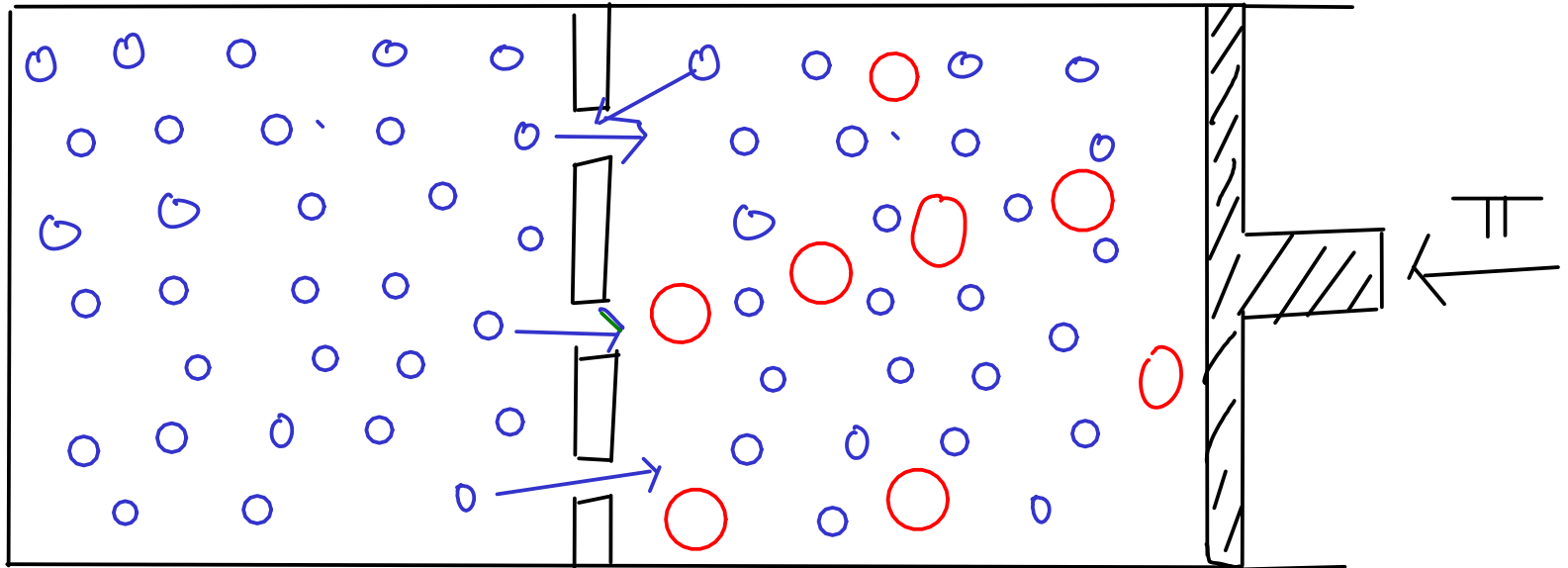


## OSMOTIC PRESSURE

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

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

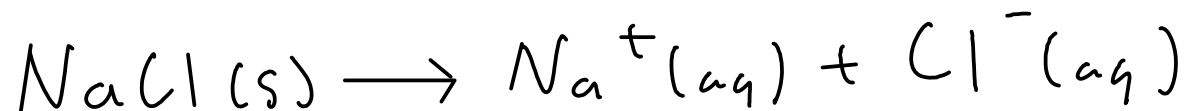
temperature

ideal gas constant

molar concentration of solute

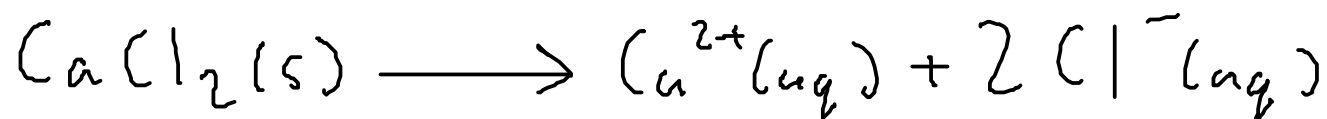
IONIC COMPOUNDS and colligative properties

- 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?

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

$$\frac{\Delta T_b}{0.512 \text{ } ^\circ\text{C}/m} = C_m \quad \left| \quad C_m = \frac{\text{mol ions}}{\text{kg H}_2\text{O}} \right] 1.000 \text{ kg}$$

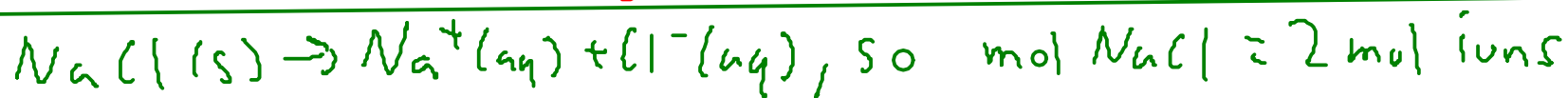
$$\left[ 100.00 \text{ } ^\circ\text{C} - 95.00 \text{ } ^\circ\text{C} = 5.00 \text{ } ^\circ\text{C} \right.$$

Find  $C_m$  (molal concentration of IONS)

$$5.00 \text{ } ^\circ\text{C} = 0.512 \text{ } ^\circ\text{C}/m \times C_m; \quad C_m = 9.765625 \text{ } m \text{ ions}$$

Find moles IONS ...

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



Find moles sodium chloride, then convert to mass for weighing.

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

## 81 EXTERNAL FACTORS AFFECTING SOLUBILITY

- There are a few external factors that affect the solubility. (By external, we mean other than the chemical identity of the solute and solvent).

### ① TEMPERATURE

- For gases dissolved in liquids, the solubility DECREASES as the temperature INCREASES

- This is why THERMAL POLLUTION is bad! Hot water holds less oxygen than cooler water.

- For solids dissolved in liquids, solubility USUALLY increases with temperature. This is not true for ALL solid/liquid solutions.

### ② PRESSURE

- For gases dissolved in liquids, solubility INCREASES when the partial pressure of the solute gas over the solution INCREASES.

- Consider soft drinks. They go flat after opening because the pressure of carbon dioxide over the liquid goes down.

- No significant pressure effects for solid/liquid solutions.

## Some sample colligative properties and concentration problems ...

What is the freezing point of a 41% solution of urea in water?



$$\Delta T_f = K_f \times C_m \quad C_m = \frac{\text{mol urea}}{\text{kg water}}$$

ps09

$$K_{f,w} = 1.858^\circ\text{C/m}$$

$$T_{f,w} = 0.000^\circ\text{C}$$

We need to find  $C_m$  ... and for that we need moles urea and kilograms water.

$$41\% \text{ urea: } \frac{41 \text{ g urea}}{100 \text{ g solution}}$$

We need mass WATER (not mass solution), so subtract out urea!

$$100 \text{ g} - 41 \text{ g} = 59 \text{ g water} = 0.059 \text{ kg H}_2\text{O}$$

Since we've assumed a basis of 100g solution, we can calculate the moles urea and then find  $C_m$  ...

$$41 \text{ g urea} \times \frac{\text{mol urea}}{60.062 \text{ g urea}} = 0.6826279511 \text{ mol urea}$$

Now, find  $C_m$ :

$$C_m = \frac{0.6826279511 \text{ mol urea}}{0.059 \text{ kg H}_2\text{O}} = 11.56996527 \text{ m urea}$$

Now, we can find  $\Delta T_f$

$$\Delta T_f = \frac{k_f \times C_m}{1.858^\circ\text{C/m (ps09)}}$$

$$\begin{aligned} \Delta T_f &= (1.858^\circ\text{C/m})(11.56996527 \text{ m urea}) \\ &= 21^\circ\text{C} \end{aligned}$$

To get the  $T_f$  of the solution, subtract  $T_f$  for the pure solvent and  $\Delta T_f$ :

$$T_{f, \text{H}_2\text{O}} = 0.000^\circ\text{C (ps09)}$$

$$T_{f, 41\% \text{ urea}} = 0.000^\circ\text{C} - 21^\circ\text{C} = \boxed{-21^\circ\text{C}}$$

0.2436 g of an unknown substance is dissolved in 20.0 mL of cyclohexane,  $C_6H_{12}$ . If the freezing point depression of this solution is 2.5 C, what is the molecular weight of the unknown? The density of cyclohexane at the temperature the cyclohexane volume was measured is 0.779 g/mL.

$$\frac{\Delta T_f}{2.5^\circ C} = \frac{K_f \times C_m}{20.0^\circ C/m} \quad \left| \quad C_m = \frac{\text{mol unknown}}{\text{kg } C_6H_{12}} \right.$$

First, calculate  $C_m$ :

$$2.5^\circ C = (20.0^\circ C/m) \times C_m$$

$$C_m = 0.125 \text{ m unknown}$$

We want to find moles unknown (we need it for formula weight). To do that, we'll have to first find out the amount of solvent used ... in kilograms.

$$0.779 \text{ g } C_6H_{12} = \text{ml } C_6H_{12}$$

$$20.0 \text{ ml } C_6H_{12} \times \frac{0.779 \text{ g } C_6H_{12}}{\text{ml } C_6H_{12}} = 15.58 \text{ g } C_6H_{12}$$

$$= 0.01558 \text{ kg } C_6H_{12}$$

Find moles unknown:

$$0.01558 \text{ kg C}_6\text{H}_{12} \times \frac{0.125 \text{ mol unknown}}{\text{kg C}_6\text{H}_{12}} = 0.0019475 \text{ mol unknown}$$

Now we can get molecular weight:

$$\text{MW} = \frac{\text{mass unknown}}{\text{mol unknown}} = \frac{0.2436 \text{ g unknown}}{0.0019475 \text{ mol unknown}} = \boxed{130 \text{ g/mol}}$$



56 grams of a sample contain 0.51 mole fraction propane with the remainder butane.  
What are the masses of propane and butane in the sample?



know  $X_{C_3H_8} = 0.51$

$$X_{C_4H_{10}} = (1 - 0.51) = 0.49$$

want  
g  $C_3H_8$   
g  $C_4H_{10}$  in 56 g

How do we get from MOLE FRACTION to the masses we need?

$$X_{C_3H_8} = \frac{\text{mol } C_3H_8}{\text{total mol}}$$

Let's assume ... for now ... that we have one mole of solution. So, we're ignoring the actual amount of solution for the moment.

$$\text{mol } C_3H_8 = 1.00 \text{ mol} \times 0.51 = 0.51 \text{ mol } C_3H_8$$

Convert  
to mass!

$$\text{mol } C_4H_{10} = 1.00 \text{ mol} \times 0.49 = 0.49 \text{ mol } C_4H_{10}$$

$$g \text{ } C_3H_8 = 0.51 \text{ mol } C_3H_8 \times \frac{44.094 \text{ g } C_3H_8}{\text{mol } C_3H_8} = 22.48794 \text{ g } C_3H_8$$

$$g \text{ } C_4H_{10} = 0.49 \text{ mol } C_4H_{10} \times \frac{58.12 \text{ g } C_4H_{10}}{\text{mol } C_4H_{10}} = 28.4788 \text{ g } C_4H_{10}$$

$$\underline{\underline{50.96674 \text{ g total}}}$$

We'll use the ratio of mass propane / total mass mixture to find the amount of propane in the mixture:

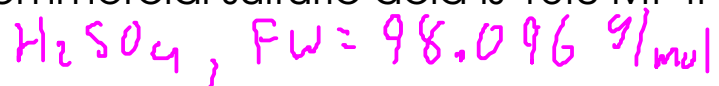
$$56 \text{ g} \times \frac{22.48794 \text{ g } \text{C}_3\text{H}_8}{50.96674 \text{ g total}} = 24.71 \text{ g } \text{C}_3\text{H}_8$$

Do the same for butane

$$56 \text{ g} \times \frac{28.4788 \text{ g } \text{C}_4\text{H}_{10}}{50.96674 \text{ g total}} = 31.29 \text{ g } \text{C}_4\text{H}_{10}$$

So, 25 g  $\text{C}_3\text{H}_8$  and 31 g  $\text{C}_4\text{H}_{10}$  in the 56 g mixture!

Commercial sulfuric acid is 18.0 M. If the density of the acid is 1.802 g/mL, what is the molality?



$$\frac{18.0 \text{ mol H}_2\text{SO}_4}{\text{L solution}} \longrightarrow \frac{\text{mol H}_2\text{SO}_4}{\text{kg solvent}}$$

molarity  molality

ASSUME A BASIS of 1 L solution....

$$1 \text{ L solution} \times \frac{18.0 \text{ mol H}_2\text{SO}_4}{\text{L}} = 18.0 \text{ mol H}_2\text{SO}_4$$

We know the moles sulfuric acid ... all that's left to do is to figure out the mass of the solvent. Start by using the volume and density of the SOLUTION.

$$1000 \text{ mL solution} \times \frac{1.802 \text{ g}}{\text{mL}} = 1802 \text{ g } \underline{\underline{\text{solution}}}$$

To find the mass of SOLVENT ... we need to subtract out the mass of SULFURIC ACID:

$$18.0 \text{ mol H}_2\text{SO}_4 \times \frac{98.096 \text{ g H}_2\text{SO}_4}{\text{mol H}_2\text{SO}_4} = 1765.728 \text{ g H}_2\text{SO}_4$$

So the mass of solvent is ...

$$1802 \text{ g solution} - 1765.728 \text{ g H}_2\text{SO}_4 = 36.272 \text{ g solvent} \\ = 0.036272 \text{ kg solvent}$$

... and the molal concentration is ...

$$m = \frac{\text{mol H}_2\text{SO}_4}{\text{kg solvent}} = \frac{18.0 \text{ mol H}_2\text{SO}_4}{0.036272 \text{ kg solvent}} = \boxed{496 \text{ m H}_2\text{SO}_4}$$