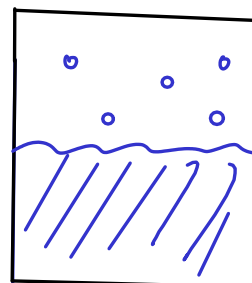


## VAPOR PRESSURE LOWERING

- Described by RAOULT'S LAW



$P_A$  = partial pressure of the VAPOR of solvent molecules.

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

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...

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

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.

$$\Delta T_b = K_b \times C_m$$

$\Delta T_b$  — Boiling point elevation: The amount the boiling temperature is RAISED by the solute.

$K_b$  — Boiling point elevation constant (for SOLVENT)

$C_m$  — concentration of solute (molality)

(Find constant values on p619 OpenStax Table 11.2)

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?

$$T_b = 118.1^\circ\text{C}$$

$$K_b = 3.07^\circ\text{C}/m$$

(Values from p619 OpenStax Table 11.2)

$$\Delta T_b = \underbrace{K_b}_{3.07^\circ\text{C}/m} \times C_m \quad C_m = \frac{\text{mol } S_8}{\text{kg } \text{HC}_2\text{H}_3\text{O}_2}$$

Start by finding  $C_m$  ... We can calculate the moles of sulfur by doing a mass/mole conversion.

$$S_8: \frac{4 \times 32.07}{256.56 \text{ g } S_8} = \text{mol } S_8$$

$$2.817 \text{ g } S_8 \times \frac{\text{mol } S_8}{256.56 \text{ g } S_8} = 0.0109798877 \text{ mol } S_8 \quad \text{Now, find } C_m!$$

$$C_m = \frac{\text{mol } S_8}{\text{kg } \text{HC}_2\text{H}_3\text{O}_2} = \frac{0.0109798877 \text{ mol } S_8}{0.1000 \text{ kg } \text{HC}_2\text{H}_3\text{O}_2} = 0.1097988775 \text{ m } S_8$$

$\uparrow$  from 100.0 g  $\text{HC}_2\text{H}_3\text{O}_2$

Find DELTA  $T_b$ ...

$$\Delta T_b = (3.07^\circ\text{C}/m)(0.1097988775 \text{ m } S_8) = 0.337^\circ\text{C}$$

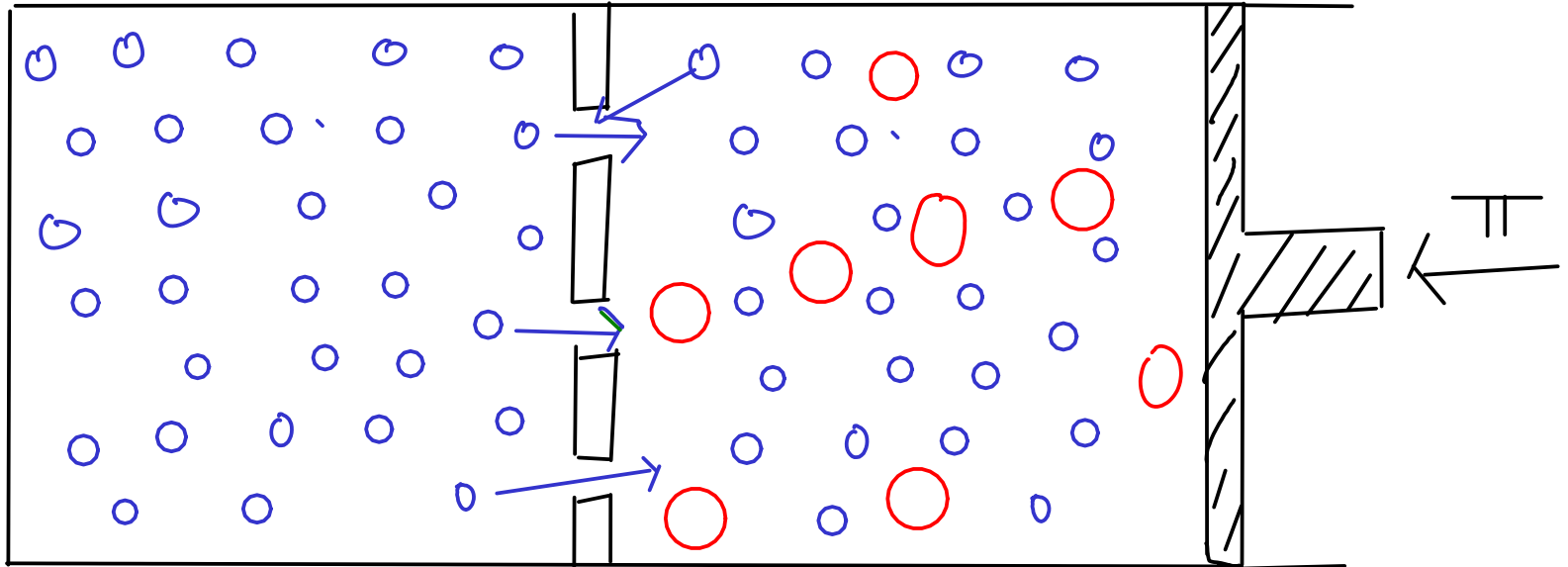
Add to get the boiling point of the solution:

$$T_{b, \text{solution}} = 118.1^\circ\text{C} + 0.337^\circ\text{C} = \boxed{118.4^\circ\text{C}}$$

## 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

$$\Pi = M \times R \times T$$

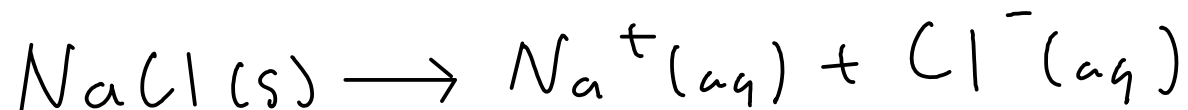
temperature

ideal gas constant

molar concentration of solute

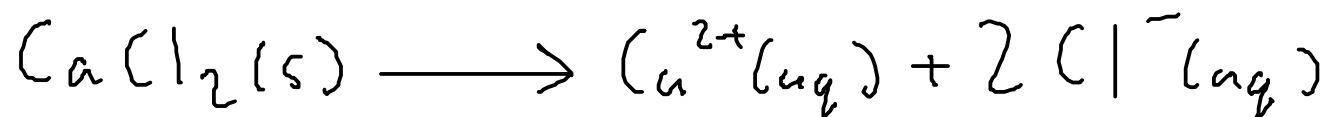
## IONIC COMPOUNDS and colligative properties

- Ionic compounds DISSOCIATE in water into their component ions. Each ion formed can act as a solute and influence the colligative properties!



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?

$$K_b = 0.512 \text{ } ^\circ\text{C}/m$$

$$\text{NaCl}: 58.443 \text{ g/mol}$$

$$\Delta T_b = K_b \times C_m \quad C_m = \frac{\text{mol ions}}{\text{kg H}_2\text{O}}$$

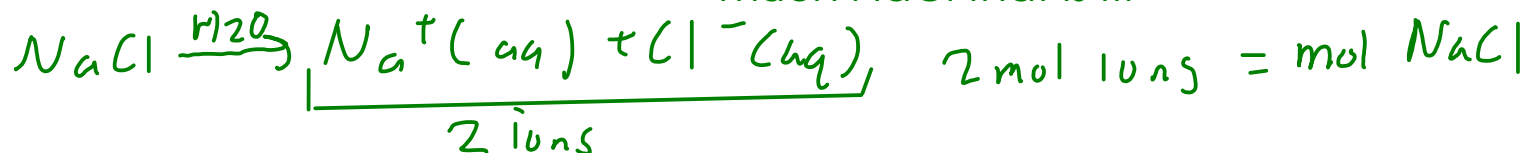
$$\underbrace{\Delta T_b}_{100.00^\circ\text{C} - 95.00^\circ\text{C} = 5.00^\circ\text{C}} = \underbrace{K_b}_{0.512^\circ\text{C}/m} \times C_m$$

Start off by finding  $C_m$  ...

$$5.00^\circ\text{C} = 0.512^\circ\text{C}/m \times C_m$$

$$C_m = 9.765625 \text{ m ions}$$

We have the concentration of IONS here in molality units. We now need to figure out how much NaCl that is ...



$$\frac{9.765625 \text{ mol ions}}{\text{kg H}_2\text{O}} \times \frac{\text{mol NaCl}}{2 \text{ mol ions}} = \frac{4.8828125 \text{ mol NaCl}}{\text{kg H}_2\text{O}}$$

Since we have 1.000 kg of water, we can easily find out how many moles NaCl are required!

$$1.000 \text{ kg H}_2\text{O} \times \frac{4.8828125 \text{ mol NaCl}}{\text{kg H}_2\text{O}} = 4.8828125 \text{ mol NaCl}$$

Find mass of NaCl:

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

## KINETICS

- the study of the RATE of chemical reactions. Or, the study of the factors affecting how fast chemical reactions proceed.

### DEFINING RATE

- RATE is defined as the change in the molar (M) concentration of a reactant or product over time. Usually, rate is defined in terms of one of the REACTANTS



...Let's look at a simple combination

$$\text{Rate} = \frac{-\Delta[A]}{\Delta t}$$

$[A]$  = "molar concentration of substance "A".

Square brackets ( ) are used to denote MOLAR concentration

change in time

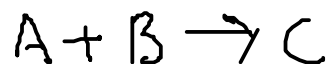
$$\text{Rate} = \frac{\Delta[C]}{\Delta t}$$

You could ALSO define the rate in terms of the disappearance of B or the appearance of C over time! Our choice of A was arbitrary,

Negative sign because we define the rate as a POSITIVE number, and (A) will decrease over time!

## THE RATE LAW

- We express the rate of reaction using an equation called the RATE LAW.



$$\text{Rate} = - \frac{\Delta[A]}{\Delta t} = k \times [A]^p \times [B]^q$$

This is the RATE CONSTANT. It depends on TEMPERATURE, but does not depend on the CONCENTRATION of any reactant or product.

"p" and "q" are called REACTION ORDERS. They indicate the effect a particular reactant or catalyst has on the rate of a reaction. Reaction orders may be positive, zero (in which case the substance has NO effect on rate) and negative (in which case the substance actually slows the reaction down).

- Rate laws depend on CONCENTRATION of reactants. Since the concentrations of reactants CHANGE throughout the course of the reaction, so does the rate!
- RATE CONSTANTS and REACTION ORDERS are determined experimentally. If you do experiment 13 (the iodine clock reaction), you will see how this can be done in the lab via the INITIAL RATES METHOD.