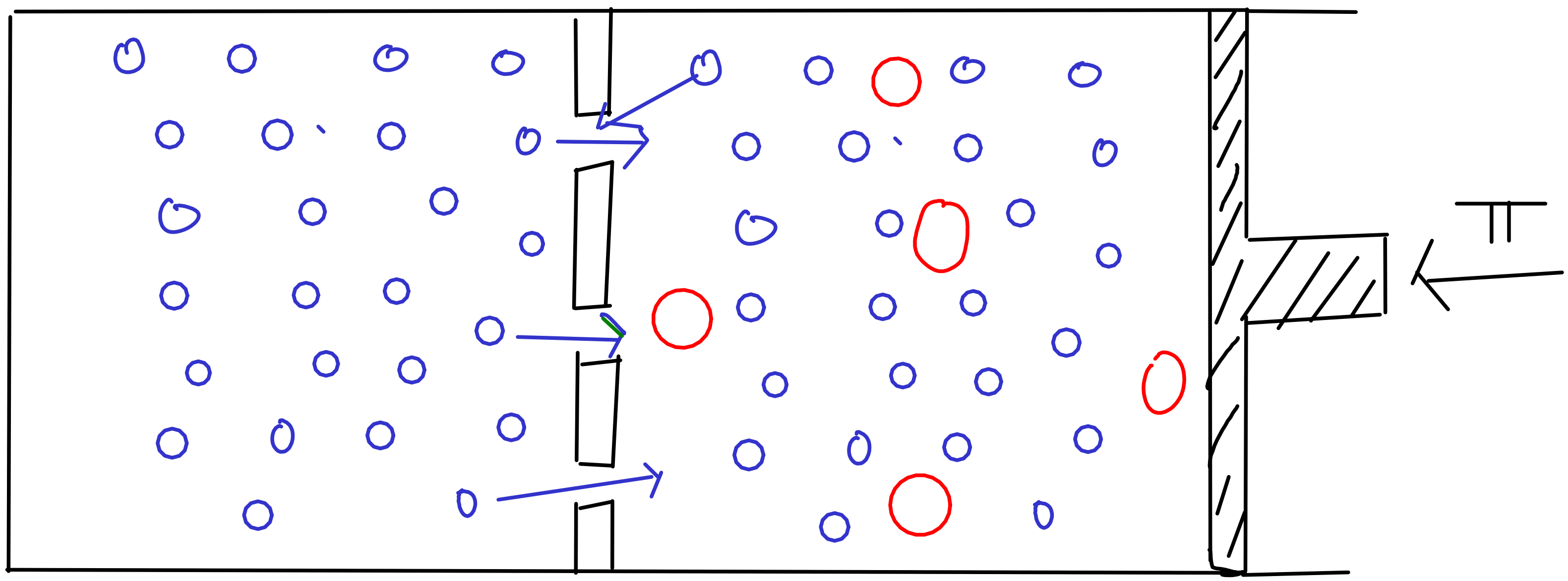
OSMOTIC PRESSURE

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?

$K_b = 0.512\ °C/m$ 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

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

kg H_2O: 1.00 kg

Find molal concentration of IONS:

$5.00\ °C = (0.512\ °C/m) \times C_m$, $C_m = 9.765625\ m$ ions

Find moles:

$1.00\ \text{kg} \times \frac{9.765625 \text{ mol ions}}{\text{kg}} = 9.765625 \text{ mol ions}$

Each mole of NaCl dissociates into TWO moles of ions!

$NaCl(s) \rightarrow Na^+(aq) + Cl^-(aq)$; mol NaCl = 2 mol ions

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

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 propoerties problems from the book...

12.97
p 521

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

$(NH_2)_2CO$: urea

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

K_f: $1.858\ °C/m = K_{f,H_2O}$

$T_{f,\text{pure } H_2O} = 0.000\ °C$

$$C_m = \frac{\text{mol urea}}{\text{kg water}}$$

We need to find mol urea and kg water. We know MASS PERCENTAGE, so we will start there....

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

... but we need to find the MASS WATER for molality!

mass water = 100 g − 41 g = 59 g

We also need moles urea. Use the FORMULA WEIGHT... $(NH_2)_2CO$:

N : 2 × 14.01
H : 4 × 1.008
C : 1 × 12.01
O : 1 × 16.00

60.062 g/mol

$$41\text{ g urea} \times \frac{\text{mol urea}}{60.062\text{ g urea}} = 0.682627951\text{ mol urea}$$

Find Cm:

$$C_m = \frac{\text{mol urea}}{\text{kg water}} = \frac{0.682627951\text{ mol urea}}{0.059\text{ kg water}} = 11.56996527\ m\text{ urea}$$

$$C_m = \frac{\text{mol urea}}{\text{kg water}} = \frac{0.6826279511 \text{ mol urea}}{0.059 \text{ kg water}} = 11.56996527 \ \underline{m} \text{ urea}$$

Now, we can find delta Tf:

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

$1.858\ ^\circ C/m = K_{f,\,H_2O}$

$$\Delta T_f = (1.858\ ^\circ C/m) \times (11.56996527 \ \underline{m} \text{ urea})$$

$$= 21.49699548\ ^\circ C$$

So, $T_f = 0.000\ ^\circ C - 21.49699548\ ^\circ C$

$$= \boxed{-21\ ^\circ C}$$

12.105, p 521

A compound (containing Mn, C, O) is 28.17% Mn, 30.80% C. A solution of the compound containing 0.125 g in 5.38 g cyclohexane freezes at 5.28 C. What is the molecular formula?

$\Delta T_f = K_f \times C_m$

$T_{f, cyc} = 6.55°C$

$K_{f, cyc} = 20.0°C$

$C_m = \frac{\text{mol unknown}}{\text{kg cyc}}$

$5.38 g = 0.00538 \text{ kg cyc}$

Find Cm, then find mol unknown:

$(6.55°C - 5.28°C) = (20.0°C) \times C_m$

$C_m = 0.0625 \text{ m unknown}$

Find mol unknown:

$0.0625 \text{ m} = \frac{\text{mol unknown}}{0.00538 \text{ kg cyc}}$; $\text{mol unknown} = 3.4163 \times 10^{-4} \text{ mol}$

Molecular weight:

$MW = \frac{\text{mass unknown}}{\text{mol unknown}} = \frac{0.125 g}{3.4163 \times 10^{-4} \text{ mol}} = 366 \text{ g/mol}$

Molecular weight of unknown!