Osmotic Pressure

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WHAT (ELSE) HAPPENS WHEN I ADD SOLUTE TO A SOLVENT?

We've already seen the effect of adding solute to a solvent in terms of vapor pressure (decreases with increasing solute) via Raoult's Law.

All of these properties are dependent only on the concentration of solute, and *not* their identity, and are called colligative properties.

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We've also seen the effect of adding solute to a solvent in terms of phase changes; e.g. freezing point depression and boiling point elevation.

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BOILING POINT ELEVATION

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Lastly, we will consider the effect of adding solute to a solvent in terms of water flow through a semipermeable membrane (osmosis) through the concept of osmotic pressure.

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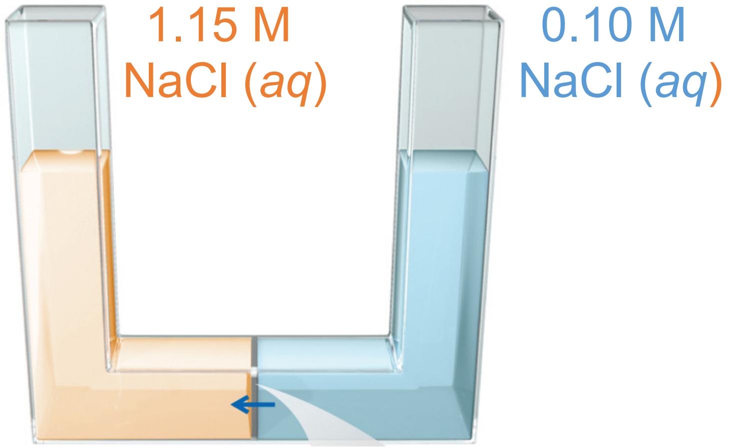
WHAT IS OSMOTIC PRESSURE?

Consider the following contraption where the left side is an aqueous solution of 1.15 M NaCl and the right side is an aqueous solution of 0.10 M NaCl.



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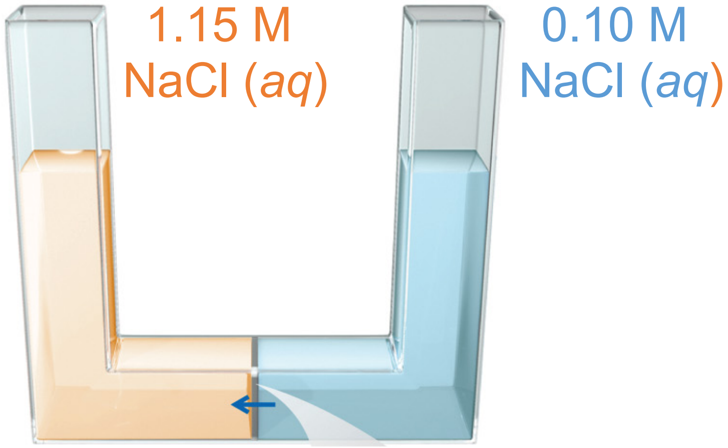
Separating these two solutions is a semi-permeable membrane, which allows water to flow between the two sides but not the ions Na^+ and Cl^-.



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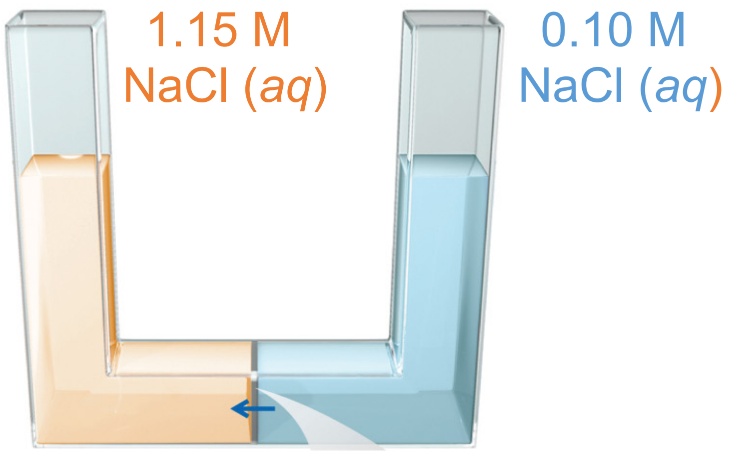

The two solutions each exert a pressure against this membrane, and this pressure depends on the molarity of the solution via:

$$\Pi = i\mathrm{MRT}$$

Π = pressure (atm)
i = number of dissociated particles per mole of solute
M = molarity (mol/L or M)
R = 0.08206 L·atm/mol·K
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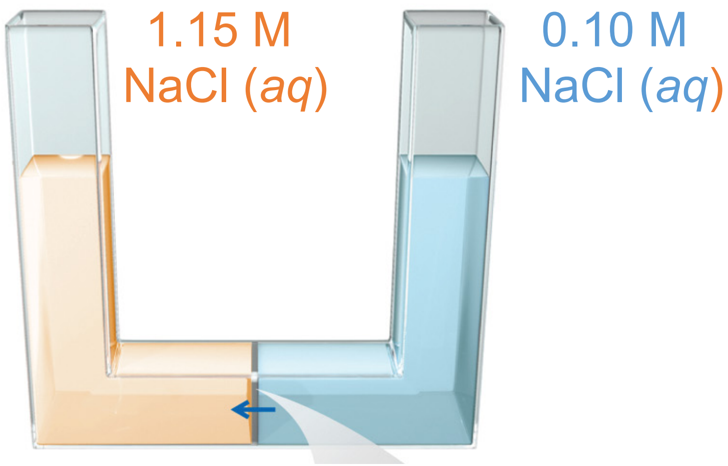

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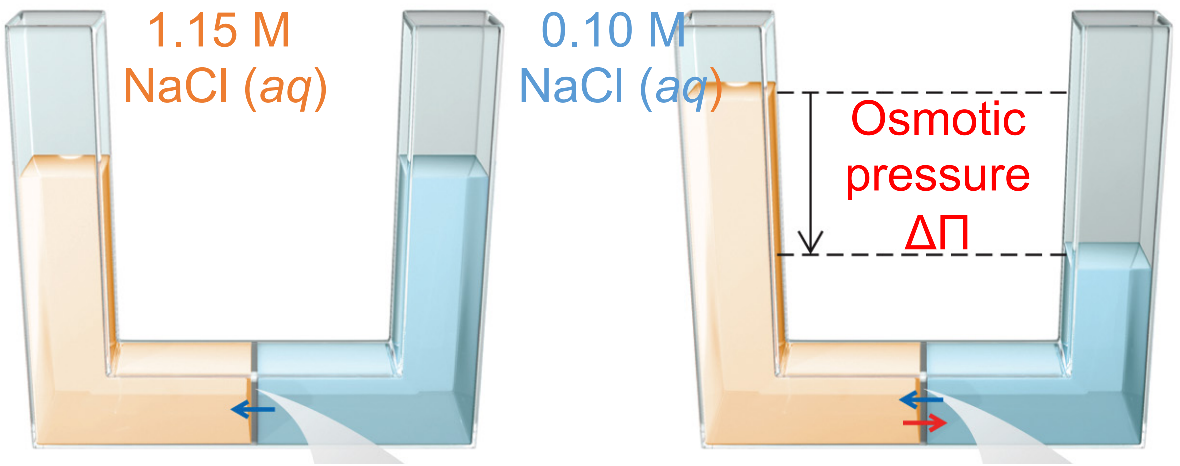

Osmotic pressure (ΔΠ) is the pressure required to achieve equilibrium (stop water flow), which is equal to the difference in the two pressures.

Water always flows to balance the concentrations, so water flows *from* the solution of low concentration (low Π) to the solution of high concentration (low Π).

Solution A: 100. mL of 0.982 M $CaCl_2$ (strong electrolyte)

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Your first actual step in these types of problem is to determine what kind of compound you have! Because:

- Molecular compounds that dissolve have an $i = 1$ since they do not dissociate.
- Insoluble ionic compounds do **not** dissociate in water, so **no changes** are observed!
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$$i\mathrm{M_B} = (2)\times \frac{16\ \mathrm{g\ NaCl} \times \dfrac{1\ \mathrm{mol\ NaCl}}{58.44\ \mathrm{g}}}{100.\ \mathrm{mL} \times \dfrac{1\ \mathrm{L}}{1000\ \mathrm{mL}}} = 5.5\ \mathrm{M}$$

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Solution B has a greater concentration of ions, so water will flow from side A to side B.

A 27.40-mg sample of a nonelectrolye is dissolved in 100.0 mL of water at 23.6 °C. If the measured osmotic pressure (Π) is 9.94 Torr, what is its molar mass?

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$$9.94\ \mathrm{Torr} \times \frac{1\ \mathrm{atm}}{760\ \mathrm{Torr}} = (1)(\mathrm{M})\left(0.08206\,\frac{\mathrm{L}\cdot\mathrm{atm}}{\mathrm{mol}\cdot\mathrm{K}}\right)(23.6 + 273.1_5\ \mathrm{K})$$

$$\mathrm{M} = 5.37 \times 10^{-4}\,\frac{\mathrm{mol}}{\mathrm{L}}$$

Finally, we can back-calculate the molar mass from the molarity:

$$\mathrm{M} = \frac{\mathrm{n_{solute}}}{\mathrm{V_{solution}}} = \frac{\mathrm{m_{solute}} \times \frac{1}{\mathrm{MM_{solute}}}}{\mathrm{V_{solution}}}$$

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$$\mathrm{MM_{solute}} = \frac{\mathrm{m_{solute}}}{\mathrm{M \times V_{solution}}} = \frac{0.02740\ \mathrm{g}}{\left(5.37 \times 10^{-4}\,\frac{\mathrm{mol}}{\mathrm{L}}\right)(0.1000\ \mathrm{L})} = 510.\,\frac{\mathrm{g}}{\mathrm{mol}}$$