

## Lecture 29: More Colligative

---

Van't Hoff Factor, Raoult's Law, Osmotic Pressure

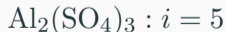
# Molecular vs Ionic Solutes

## Molecular solutes (e.g., polymers, gas)

- Dissolve but stays as one molecule
- $i = 1$

## Ionic solutes (salts)

- Dissociate into multiple ions when dissolving
- $i$ : number of ions formed (van't Hoff factor)



## Example: Freezing Point Depression

What is the freezing point of 0.544 m NaCl in benzene?

$k_f = 5.12 \frac{\text{K} \cdot \text{kg}}{\text{mol}}$  in benzene,  $T_f = 5.53^\circ\text{C}$

$$\begin{aligned}\Delta T_f &= i \cdot k_f \cdot m \\ &= 2 \cdot 5.12 \frac{\text{K} \cdot \text{kg}}{\text{mol}} \cdot 0.544 \frac{\text{mol}}{\text{kg}} \\ &= 5.57 \text{ K} = 5.57^\circ\text{C} \\ T_f &= 5.53^\circ\text{C} - 5.57^\circ\text{C} \\ &= -0.04^\circ\text{C}\end{aligned}$$

# Vapor Pressure Lowering

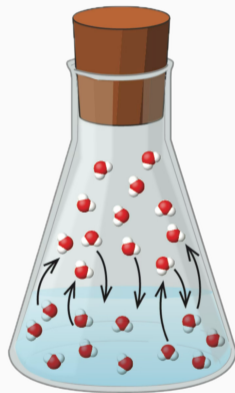
## Raoult's Law

Finds vapor pressure of a solution

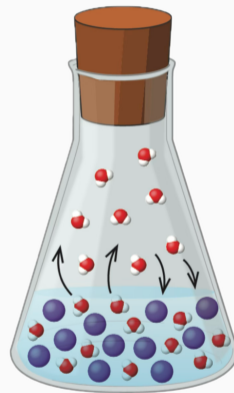
$$P_{\text{vap}} = \chi_{\text{solvent}} \cdot P_{\text{vap}}^{\text{pure}}$$

$$\chi_{\text{solvent}} = \frac{n_{\text{solvent}}}{n_{\text{solvent}} + n_{\text{solute particles}}}$$

Solvent in numerator, not solute!



Pure Solvent



Solution

## Example: Raoult's Law

What is  $\chi_{\text{H}_2\text{O}}$  and  $P_{\text{vap}}$  for a 0.5 m solution of  $\text{Ca}(\text{NO}_3)_2$ ?  $P_{\text{vap}}^{\text{pure}} = 1 \text{ atm}$  at  $100^\circ\text{C}$

$$\chi_{\text{solvent}} = \frac{n_{\text{solvent}}}{n_{\text{solvent}} + n_{\text{solute particles}}}$$

Assume 1 kg of solvent:

$$0.5 \frac{\text{mol solute}}{\text{kg solvent}} \cdot 1 \text{ kg} = 0.5 \text{ mol Ca}(\text{NO}_3)_2$$



$$n_{\text{solute particles}} = 0.5 \text{ mol} \times 3 = 1.5 \text{ mol}$$

$$1000 \text{ g H}_2\text{O} \times \frac{1 \text{ mol}}{18.02 \text{ g}} = 55.5 \text{ mol H}_2\text{O}$$

$$\chi_{\text{H}_2\text{O}} = \frac{55.5 \text{ mol}}{55.5 \text{ mol} + 1.5 \text{ mol}} = \boxed{0.975}$$

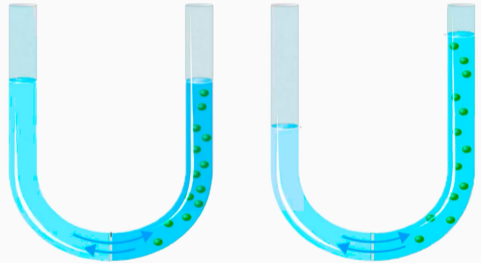
$$\boxed{P_{\text{vap}} = \chi_{\text{solvent}} \cdot P_{\text{vap}}^{\text{pure}} = 0.975 \text{ atm}}$$

# Osmotic Pressure

## Osmotic Pressure ( $\Pi$ )

Minimum pressure required to prevent the flow of solvent across a semipermeable membrane from low to high solute concentration

$$\Pi = iRTc$$



Initial

Equilibrium

## Example: Osmotic Pressure

Yeast cells are placed in a 4.0 % by mass NaCl solution ( $\rho = 1.02 \frac{\text{g}}{\text{mL}}$ ,  $T = 25 \text{ }^\circ\text{C}$ ). Find the osmotic pressure of the salt solution.

Assume 100 g of solution:

$$\begin{aligned}M_{\text{NaCl}} &= \frac{4 \text{ g NaCl}}{100 \text{ g solution}} \times \frac{1.02 \text{ g}}{1 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} \times \frac{1 \text{ mol}}{58.44 \text{ g}} \\ &= 0.70 \frac{\text{mol}}{\text{L}}\end{aligned}$$

$$\Pi = iRTc = 2 \cdot 0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \cdot 298 \text{ K} \cdot 0.7 \frac{\text{mol}}{\text{L}}$$

$$\boxed{\Pi = 34 \text{ atm}}$$