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Colligative Properties

Chapter 12.5

Colligative properties are properties which depend solely on the number of solute particles within the solution and do not depend on the nature of the particles. The word "colligative" means "bond together in a collection" because the solute particles are responsible for the observed effects. Colligative Properties are observed when compared to the properties of the pure solvent, they include:

- Vapor pressure lowering
- Boiling point elevation
- Melting/freezing point lowering
- Osmotic pressure

Chapter 12.6

Vapor pressure is the amount of pressure exerted by the vapor of a liquid in a container at equilibrium.

When the vapor pressure of a pure solvent (at the same temperature) is compared to a solution with a solute that does not readily evaporate into gas, it is considered nonvolatile. This occurs between a solid and liquid, and the vapor pressure will be lower than that of the pure solvent. If the solute easily evaporates (is volatile), which occurs in mixtures of two liquids, then the vapor pressure of the mixture will be somewhere between the vapor pressure of the two liquids when pure.

Raoult's Law states the vapor pressure of a solution (P_{soln}) containing a nonvolatile solute is equal to the vapor pressure of the pure solvent (P_{solv}) times the mole fraction of the solvent (X_{solv})

$$P_{soln} = P_{solv} * X_{solv}$$

If an ionic substance is the solute, the mole fraction must be calculated based on the total concentration of ions (solute particles). For example, 0.5 mol of NaCl contains 1.0 mol of particles. As the solute concentration increases, the behavior of the solution deviates from the ideal.

Because ionic substances rarely dissociate completely, the van't Hoff factor is used to show the actual extent of dissociation:

$$i = (\text{Moles of particles in solution})/(\text{Moles of solute dissolved})$$

*For non-ionic compounds, assume i is 1.

For volatile mixtures, Dalton's Law of partial pressures says the total pressure of the mixture is the sum of each individual component. The individual pressures must be calculated using Raoult's Law.

$$P_{total} = (P_A * X_A) + (P_B * X_B)$$

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Changes in colligative properties depend only on the number of solute particles present and do not depend on the identity of the solute particles.

Properties:

1. Boiling Point Elevation.

$$\Delta T = T_{solution} - T_{solvent} = = iK_bM$$

ΔT = Boiling point of the mixture (added to the normal boiling point of the solvent).
$T_{solution}$ = Boiling point of the dissolved solution.
$T_{solvent}$ = Boiling point of the solvent.
i = Van't Hoff factor
K_b = Molal boiling point elevation constant.
M = Molality of the solution.

2. Freezing Point Depression.

$$\Delta T = T_{solution} - T_{solvent} = = -iK_fM$$

ΔT = Freezing point of the mixture (subtracted from the normal freezing point of the solvent).
$T_{solution}$ = Freezing point of the dissolved solution.
$T_{solvent}$ = Freezing point of the solvent.
i = Van't Hoff factor
K_f = Molal freezing point depletion constant.
M = Molality of the solution.

3. Osmotic Pressure (van't Hoff's Law).

$$\Pi = i\left(\frac{n}{V}\right)RT = iMRT$$

Π = Osmotic pressure.
n = Moles of solute.
V = Volume of the solution.
R = Ideal gas constant = 8.314 (J/mol)
T = Temperature
M = Morarity of the solution.
i = Van't Hoff factor.

4. Vapor Pressure Lowering (Raoult's Law).

$$P_A = X_A \bullet P_A^*$$

P_A = Partial pressure exerted by compound A.
X_A = Mole fraction of A in the solution.
P_A^* = Vapor pressure of pure compound A.