By the end of today's class you will be able to determine the elevation of boiling point and the depression of freezing point of an electrolyte solution.

Electrolyte Solutions

Solute Dissociation

- Some molecules (like NaCl) dissociate into ions (Na^+ and Cl^-) when dissolved.
- Colligative properties depend on the ratio of solute particles to solvent molecules.
- Include van 't Hoff factor, *i*, to account for the increased number of solute particles.

effective molality

$$\Delta T_b = \underbrace{iK_b b}_{\text{molality}} \qquad \Delta T_f = -iK_f b$$

molality

The van 't Hoff Factor, *i*

- *i* represents the number of particles released into solution per formula unit of solute.
- Minimum value is 1 and applies no dissociation.
- Maximum value is number of ions formed through complete dissociation (ex. 2 for NaCl).
- Because aqueous ions of opposite charges associate into ion-pairs, the value of *i* varies between the min and max value depending on solution concentration.

TABLE 14.3 Variation of the van't Hoff Factor, i, with Solution Molality

Solute	Molality, m: 1.0	0.10	0.010	0.0010	...	Inf dil*
NaCl	1.81	1.87	1.94	1.97	...	2
$MgSO_4$	1.09	1.21	1.53	1.82	...	2
$Pb(NO_3)_2$	1.31	2.13	2.63	2.89	...	3

*The limiting values: i = 2, 2, and 3 are reached when the solution is infinitely dilute. Note that a solute whose ions are singly charged (for example, NaCl) approaches its limiting value more quickly than does a solute whose ions carry higher charges. Interionic attractions are greater in solutes with more highly charged ions.

Example 1

Lanthanum (III) trichloride ($LaCl_3$) dissociates into ions as it dissolves in water:

$$LaCl_3(s) \rightarrow La^{3+}(aq) + 3Cl^-(aq)$$

Suppose 0.2453 g of $LaCl_3$ is dissolved in 100 g of H_2O. If the solution behaves ideally, what is the boiling point at atmospheric pressure, assuming complete dissociation and no association among ions? (K_b = 0.512 K·kg/mol)

$$\Delta T_b = 0.512 \cdot \frac{0.2453/245.264}{0.1} \cdot 4$$
$$= 0.0205K$$
$$= 0.0205\,°C$$

Example 2

The freezing point of a solution formed by dissolving 0.0100 moles of A_2B in 1000 g of H_2O is -0.0241 °C. Determine whether A_2B molecules have been dissociated by water, and if so, what percentage of A_2B exists in dissociated form.

Data: K_f for water is 1.86 °C·kg/mol

$$A_2B \leftrightarrow 2A^+ + B^{2-}$$

$$i = \frac{-\Delta T_f}{K_f b} = \frac{0.0241}{1.86 \times \frac{0.0100}{1kg}}$$
$$= 1.296$$

$$\begin{array}{ccc} A_2B \leftrightarrow & 2A^+ + & B^{2-} \\ 1-x & 2x & x \end{array}$$

$$i = 2x + x + 1 - x$$
$$1.296 = 2x + x + 1 - x$$
$$x = 0.148$$

∴ 14.8% dissociates

Example 3

A 5.0 g mixture consisting of sucrose ($C_{12}H_{22}O_{11}$) and sodium chloride(NaCl) is dissolved in 250.0 g of water. If the resulting solution freezes at –0.682 °C, what is the mass fraction of sucrose in the mixture? Assume that NaCl dissociates completely in water.

Data: K_f for water is 1.86 °C·kg/mol

$5.0g = n_s M_s + n_N M_N$

$\Delta T_f = \Delta T_{f,s} + \Delta T_{f,N}$

$= -K_f b_s i - K_f b_N i$

Suggested Readings

- 13.9 Solutions of Electrolytes