

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

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### Solute Dissociation

- Some molecules (like NaCl) dissociate into ions ( $\text{Na}^+$  and  $\text{Cl}^-$ ) 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.

$$\Delta T_b = iK_b b$$

*effective molality*

$$\Delta T_f = -iK_f b$$

*molality*

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### 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.

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

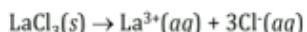
Solute	Molality, $m$					
	1.0	0.10	0.010	0.0010	...	Inf dil <sup>+</sup>
NaCl	1.81	1.87	1.94	1.97	...	2
MgSO <sub>4</sub>	1.09	1.21	1.53	1.82	...	2
Pb(NO <sub>3</sub> ) <sub>2</sub>	1.31	2.13	2.63	2.89	...	3

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.

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### Example 1

Lanthanum (III) trichloride ( $\text{LaCl}_3$ ) dissociates into ions as it dissolves in water:



Suppose 0.2453 g of  $\text{LaCl}_3$  is dissolved in 100 g of  $\text{H}_2\text{O}$ . If the solution behaves ideally, what is the boiling point at atmospheric pressure, assuming complete dissociation and no association among ions? ( $K_b = 0.512 \text{ K}\cdot\text{kg/mol}$ )

$$\begin{aligned} \Delta T_b &= 0.512 \cdot \frac{0.2453/245.264}{0.1} \cdot 4 \\ &\approx 0.0205 \text{ K} \\ &\approx 0.0205^\circ\text{C} \end{aligned}$$

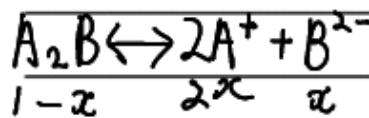
### Example 2

The freezing point of a solution formed by dissolving 0.0100 moles of  $\text{A}_2\text{B}$  in 1000 g of  $\text{H}_2\text{O}$  is  $-0.0241^\circ\text{C}$ . Determine whether  $\text{A}_2\text{B}$  molecules have been dissociated by water, and if so, what percentage of  $\text{A}_2\text{B}$  exists in dissociated form.

Data:  $K_f$  for water is  $1.86^\circ\text{C}\cdot\text{kg/mol}$



$$\begin{aligned} i &= \frac{-\Delta T_f}{K_f b} = \frac{0.0241}{1.86 \times \frac{0.0100}{1\text{kg}}} \\ &\approx 1.296 \end{aligned}$$



$$\begin{aligned} i &= 2x+x+1-x && \therefore 14.9\% \\ 1.296 &= 2x+x+1-x && \text{dissociates} \\ x &= 0.148 \end{aligned}$$

**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  $-0.682\text{ }^{\circ}\text{C}$ , what is the mass fraction of sucrose in the mixture? Assume that NaCl dissociates completely in water.

Data:  $K_f$  for water is  $1.86\text{ }^{\circ}\text{C}\cdot\text{kg/mol}$

$$5 \cdot 0_f = n_s M_s + n_n M_N$$

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

$$= -K_f b_i - K_f b_N$$

**Suggested Readings**

- 13.9 Solutions of Electrolytes