A solution is defined as a homogeneous mixture of two or more components existing in a single phase. In this description, the focus will be on liquid solutions because within the realm of biology and chemistry, liquid solutions play an important role in multiple processes. Without the existence of solutions, a cell would not be able to carry out glycolysis and other signaling cascades necessary for cell growth and development. Chemists, therefore, have studied the processes involved in solution chemistry in order to further the understanding of the solution chemistry in nature.

**Introduction**

The mixing of solutions is driven by entropy, opposed to being driven by enthalpy. While an ideal gas by definition does not have interactions between particles, an ideal solution assumes there are interactions. Without the interactions, the solution would not be in a liquid phase. Rather, ideal solutions are defined as having an enthalpy of mixing or enthalpy of solution equal to zero ($\Delta H_{\text{mixing}}$ or $\Delta H_{\text{solution}} = 0$). This is because the interactions between two liquids, A-B, is the average of the A-A interactions and the B-B interactions. In an ideal solution the average A-A and B-B interactions are identical so there is no difference between the average A-B interactions and the A-A/B-B interactions.

Since in biology and chemistry the average interactions between A and B are not always equivalent to the interactions of A or B alone, the enthalpy of mixing is not zero. Consequently, a new term is used to describe the concentration of molecules in solution. Activity, $a_1$, is the effective concentration that takes into account the deviation from ideal behavior, with the activity of an ideal solution equal to one.

An activity coefficient, $\gamma_1$, is utilized to convert from the solute's mole fraction, $x_1$, (as a unit of concentration, mole fraction can be calculated from other concentration units like molarity, molality, or percent by weight) to activity, $a_1$.

$$a_1 = \gamma_1 x_1 \tag{1}$$

**Debye-Hückel Formula**

The Debye-Hückel formula is used to calculate the activity coefficient.

$$\log \gamma_\pm = - \frac{1.824 \times 10^6}{(\epsilon T)^{3/2}} |z_+ z_-| \sqrt{I} \tag{2}$$

This form of the Debye-Hückel equation is used if the solvent is water at 298 K.

$$\log \gamma_\pm = - 0.509 |z_+ z_-| \sqrt{I} \tag{3}$$

<table>
<thead>
<tr>
<th>$(\gamma_\pm)$</th>
<th>mean ionic activity coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>$(z_+)$</td>
<td>catonic charge of the electrolyte for $(\gamma_\pm)$</td>
</tr>
<tr>
<td>$(z_-)$</td>
<td>anionic charge of the electrolyte for $(\gamma_\pm)$</td>
</tr>
<tr>
<td>$(I)$</td>
<td>ionic strength</td>
</tr>
</tbody>
</table>
\( \gamma_\pm \) \hspace{1cm} \text{mean ionic activity coefficient} \\
\( \epsilon \) \hspace{1cm} \text{relative dielectric constant for the solution} \\
\( T \) \hspace{1cm} \text{temperature of the electrolyte solution} \\

\textbf{Example 1}

Consider a solution of 0.01 M MgCl\(_2\) (aq) with an ionic strength of 0.030 M. What is the mean activity coefficient?

\textbf{SOLUTION}

\[
\log \gamma_\pm = - \left( \frac{1.824 \times 10^6}{(\epsilon T)^{3/2}} \right) | z_+ z_- | \sqrt{I}
\]

\[
\log \gamma_\pm = - 0.509 | z_+ z_- | \sqrt{I}
\]

\[
\log \gamma_\pm = - \left( \frac{1.824 \times 10^6}{(78.54 \cdot 298 \text{ K})^{3/2}} \right) | 2 \cdot 1 | \sqrt{0.0030} \; \text{m}
\]

\[
\log \gamma_\pm = - 0.509 | 2 \cdot 1 | \sqrt{0.0030} \; \text{m}
\]

\[
\gamma_\pm = 0.67
\]

\[
\gamma_\pm = 0.67
\]

\textbf{References}


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