Molality, Activity, Activity Coefficients, Ionic Strength and the Debye-Hückel Law

Molality $= m = \text{moles of solute/kg of solvent}$

\[ a = \gamma_m \quad a_+ = \gamma_+ m_+ \quad a_- = \gamma_- m_- \]

For an ionic compound $M_{v_+}X_{v_-}$ that dissociates 100% $M_{v_+}X_{v_-} \rightarrow (v_+) M^{z_+} + (v_-)X^{z_-}$

$v_+$ represents the number of positive ions of charge $z_+$

$v_-$ represents the number of negative ions of charge $z_-$

and $v$ represents the total number of ions: $v = v_+ + v_-$

The symbol ± refers to a mean ionic variable and is defined in terms of the number of ions. Thus, the mean ionic activity coefficient is defined as $\gamma_\pm = (\gamma_+\gamma_-)^{1/v}$ and consequently

mean ionic molality $\Rightarrow m_\pm = (m_+^v m_-^v)^{1/v}$ and mean ionic activity $\Rightarrow a_\pm = (a_+^v a_-^v)^{1/v}$

The ionic strength of a solution ($I$) depends on the molal concentration of the ions and the charges on those ions:

\[ I = \frac{1}{2} \sum_i m_i z_i^2 \]

The Debye-Hückel Law is most often presented in two formats: the Debye-Hückel Limiting Law that is generally good for concentrations smaller than $10^{-2}$ m and the Extended Debye-Hückel Law which is reasonable up to about 0.10 m.

Debye-Hückel Limiting Law

\[ \ln \gamma_\pm = -z_+ z_- \alpha I^{1/2}, \text{where } \alpha = 1.171 \text{ for aqueous solutions at } 25^\circ C \]

Extended Debye-Hückel Law

\[ \ln \gamma_\pm = \frac{-z_+ z_- \alpha I^{1/2}}{I + \alpha \beta I^{1/2}}, \text{ where } \alpha \beta = 1.00 \text{ for aqueous solutions at } 25^\circ C \]

NOTE: THESE ARE NOT THE SAME AS THE EQUATIONS IN YOUR TEXT!