Free energy and concentration

G represents the amount of energy available in the system that can be used for work.

We need to consider the change in free energy of a substance (A) on changing the concentration from 1M to some other value. At 1M: $G = G^{\circ\prime}$

We know that $\Delta G = \Delta H - T\Delta S$. However, since H does not change with concentration (for an ideal solution; $\Delta H = 0$), we can write the free energy change just in terms of the entropy change: $\Delta G = - T\Delta S$

As concentration increases, entropy decreases, because the multiplicity (W) decreases ($S = k_B \ln W$). The multiplicity of the substance is inversely proportional to the concentration:

$W = 1 / [A]$.

So the entropy is proportional to 1/ the log of the concentration:

$S = 1 / \ln[A]$, $(S = - \ln[A])$

The change in entropy is going to be proportional to the ln of the concentration, so:

$\Delta S = R\ln(1/[A])$

$\Delta S = - R\ln[A]$

So, the ΔG for the concentration change is

$\Delta G = -T\Delta S = RT\ln[A]$

(We use R rather than k_B ($S = k_B \ln W$) because we are considering the value per mole ($R = k_B$ X Na; $R = 8.314$ J mol^{-1} k^{-1}))

So, at the new concentration:

$G_{[A]} = G^{\circ\prime} + \Delta G$

$$\mathbf{G = G^{\circ\prime} + RT\ln[A]}$$

As entropy gets smaller, G increases. G increases as the log of the concentration.