# Chemistry 2720 Fall 2005 Quiz 4 Solution

There are two different solutions to this problem, but they both start the same way:

$$\begin{aligned}
\Delta\bar{G}^\circ &= \Delta\bar{G}^\circ_{f(\mathrm{HSO_4^-})} - \left(\Delta\bar{G}^\circ_{f(\mathrm{SO_3})} + \Delta\bar{G}^\circ_{f(\mathrm{H_2O})}\right) \\
&= -677 - [-371.1 + (-237.140)]\ \mathrm{kJ/mol} = -69\,\mathrm{kJ/mol}. \\
\Delta\bar{H}^\circ &= \Delta\bar{H}^\circ_{f(\mathrm{HSO_4^-})} - \left(\Delta\bar{H}^\circ_{f(\mathrm{SO_3})} + \Delta\bar{H}^\circ_{f(\mathrm{H_2O})}\right) \\
&= -887 - [-395.7 + (-285.830)]\ \mathrm{kJ/mol} = -205\,\mathrm{kJ/mol}.
\end{aligned}$$

From here, they diverge:

1.

$$\begin{aligned}
\Delta\bar{S}^\circ &= \frac{\Delta\bar{H}^\circ - \Delta\bar{G}^\circ}{T} \\
&= \frac{-205 - (-69)\,\mathrm{kJ/mol}}{298.15\,\mathrm{K}} = -0.459\,\mathrm{kJ\,K^{-1}mol^{-1}}. \\
\therefore \Delta\bar{G}^\circ_{323} &= \Delta\bar{H}^\circ - T\Delta\bar{S}^\circ \\
&= -205\,\mathrm{kJ/mol} - (323.15\,\mathrm{K})(-0.459\,\mathrm{kJ\,K^{-1}mol^{-1}}) = -57\,\mathrm{kJ/mol} \\
\therefore K_{323} &= e^{-\Delta\bar{G}^\circ_{323}/(RT)} \\
&= \exp\left(\frac{57\times10^3\,\mathrm{J/mol}}{(8.314\,472\,\mathrm{J\,K^{-1}mol^{-1}})(323.15\,\mathrm{K})}\right) \\
&= 1.8\times10^9.
\end{aligned}$$

2.

$$\begin{aligned}
K_{298} &= e^{-\Delta\bar{G}^\circ/(RT)} \\
&= \exp\left(\frac{69\times10^3\,\mathrm{J/mol}}{(8.314\,472\,\mathrm{J\,K^{-1}mol^{-1}})(298.15\,\mathrm{K})}\right) \\
&= 1.1\times10^{12}. \\
\ln\left(\frac{K_{323}}{K_{298}}\right) &= \frac{-205\times10^3\,\mathrm{J/mol}}{8.314\,472\,\mathrm{J\,K^{-1}mol^{-1}}}\left(\frac{1}{298.15\,\mathrm{K}} - \frac{1}{323.15\,\mathrm{K}}\right) \\
&= -6.41 \\
\therefore K_{323} &= (1.1\times10^{12})e^{-6.41} = 1.8\times10^9.
\end{aligned}$$

The equilibrium constant is very large, which suggests that $SO_3$ is extremely soluble in water.