Chemistry 2720 Fall 2003 Quiz 3 Solutions

1. The first of the two reactions shown is the formation reaction for Na_2S_5 so the standard free energy of formation of this compound is $-401\,\text{kJ/mol}$.

2. For the first reaction, as written, we need two moles of sodium and five moles of sulfur to produce 401 kJ of electrical work. Two moles of sodium weigh

$$m_{\text{Na}} = (2\,\text{mol})(22.989\,770\,\text{g/mol}) = 45.979\,540\,\text{g}.$$

Similarly, five moles of sulfur weigh

$$m_{\text{S}} = (5\,\text{mol})(32.066\,\text{g/mol}) = 160.330\,\text{g}.$$

The total mass of reactants required to produce 401 kJ of work is therefore

$$m_1 = 45.979\,540 + 160.330\,\text{g} = 206.310\,\text{g}.$$

The energy stored per unit mass is therefore

$$|\tilde{w}_1| = \frac{401 \times 10^3\,\text{J}}{206.310\,\text{g}} = 1944\,\text{J/g}.$$

We proceed similarly for the second battery:

$$\begin{aligned}
m_{\text{VH}} &= (1\,\text{mol})(51.9494\,\text{g/mol}) = 51.9494\,\text{g}. \\
m_{\text{NiOOH}} &= (1\,\text{mol})(91.7001\,\text{g/mol}) = 91.7001\,\text{g}. \\
\therefore m_2 &= 51.9494 + 91.7001\,\text{g} = 143.6495\,\text{g}. \\
\therefore |\tilde{w}_2| &= \frac{130 \times 10^3\,\text{kJ}}{143.6495\,\text{g}} = 905\,\text{J/g}.
\end{aligned}$$

The sodium/sulfur battery therefore has the larger energy storage capacity, by a factor of more than two.

3. Solids have unit activity, except under very unusual circumstances. Accordingly, $\Delta\bar{G} = \Delta\bar{G}^\circ$ as long as we have any reactants left. If any of the reactants or products were, for instance, solutes, then the work produced per mole consumed would change as the battery discharges. We would somehow have to integrate the work over these changing conditions.