HYDROGEN FUEL CELL AT HIGHER TEMPERATURES

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Reference: Daniel V. Schroeder, *An Introduction to Thermal Physics*, (Addison-Wesley, 2000) - Problem 5.11.

We'll revisit the hydrogen fuel cell, which we considered originally operating at room temperature ($25°C = 298$ K) and atmospheric pressure. The reaction is

$$(0.1) \qquad H_2 + \frac{1}{2}O_2 \rightarrow H_2O$$

We can use the relation derived from the Gibbs thermodynamic identity to estimate the behaviour of a hydrogen fuel cell at the higher temperature of $75°C = 348$ K (and still at atmospheric pressure. The relation is

$$(0.2) \qquad S = -\left(\frac{\partial G}{\partial T}\right)_{V,N}$$

If we take the values of ΔG from Schroeder's book, where the values for pure hydrogen and oxygen gas are taken as zero (to set a reference point), then $\Delta G = -237.13$ kJ mol^{-1} and $S = 69.91$ J K^{-1} for water at 298 K. For water, if we assume that S is constant over the temperature range in question (I'm not sure how good an approximation this is, but since the water remains liquid over this range, it's probably not too bad), we can estimate the change in G as we go from 298 K to 348 K:

$$
\begin{aligned}
(0.3) \qquad \Delta G &= -S\,\Delta T \\
(0.4) \qquad &= -69.91 \times 10^{-3} \text{kJ K}^{-1}\text{mol}^{-1} \times 50 \text{ K} \\
(0.5) \qquad &= -3.496 \text{ kJ mol}^{-1}
\end{aligned}
$$

We can do similar calculations for hydrogen and oxygen, using the entropy values given in Schroeder. Here, we're dealing with gases at constant pressure, so the volume *does* change as we increase the temperature, so we'd expect the entropy to increase as the temperature is raised. However, as the problem asks us to use only the data at 298 K to estimate the changes, I suppose we can approximate things by assuming the entropy remains constant. The results are, for 1 mole

	S (J K^{-1})	G_{25} (kJ)	ΔG (kJ)	G_{75} (kJ)
H_2O	69.91	-237.13	-3.496	-240.63
H_2	130.68	0	-6.534	-6.534
O_2	205.14	0	-10.257	-10.257

The net ΔG for the reaction at 75° C for one mole of hydrogen is therefore

$$(0.6) \qquad \Delta G = -240.63 - \left(-\frac{10.257}{2} - 6.534 \right) = -228.97 \text{ kJ}$$

Thus the maximum amount of electrical work we can get from the fuel cell at 75° C is 228.97 kJ, slightly lower than the 237 kJ we got at 25° C.