

2.	This question is about hydrogen as a fuel	Mark
(a)	$\Delta H_r^\ominus = \sum \Delta H_f^\ominus (\text{Products}) - \sum \Delta H_f^\ominus (\text{Reactants})$ $\Delta H_r^\ominus = -393.5 \text{ kJ mol}^{-1} - (-74.8 \text{ kJ mol}^{-1} + 2 \times -285.8 \text{ kJ mol}^{-1})$ $= +253 \text{ kJ mol}^{-1}$	<input checked="" type="checkbox"/>
(b)	<p><b>Reaction 2:</b> <math>2\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g})</math></p> <p><i>(Reduction occurs at the cathode). Either "Reaction 2" or the reaction equation gets the mark.</i></p>	<input checked="" type="checkbox"/>
(c)	$\Delta H^\ominus = 2 \times 285.8 \text{ kJ mol}^{-1} = +571.6 \text{ kJ mol}^{-1}$ <p><i>Sign must be correct for mark. A negative value scores zero marks.</i></p>	<input checked="" type="checkbox"/>
(d)	$\Delta S^\ominus = 2 \times 163.0 \text{ J K}^{-1} \text{ mol}^{-1} = +326.0 \text{ J K}^{-1} \text{ mol}^{-1}$ $\Delta G^\ominus = 571.6 \text{ kJ mol}^{-1} - 298 \text{ K} \times 0.326 \text{ kJ K}^{-1} \text{ mol}^{-1} = +474.5 \text{ kJ mol}^{-1} \text{ (one mark)}$ $E^\ominus = 474.5 \times 10^3 \text{ J mol}^{-1} / (4 \times 96485 \text{ C mol}^{-1}) = -1.23 \text{ V (one mark)}$ <p><i>Correct final answer scores both marks. One mark for calculation of <math>\Delta G^\ominus</math> and one mark for calculation of <math>E^\ominus</math>.</i></p> <p><i>ECF: Allow ECF from part (c).</i></p>	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/>
(e)	$E^\ominus = -1.23 \text{ V}$ <p><i>(the same answer as in part (d) – the other half reaction is the standard hydrogen electrode with <math>E^\ominus = 0.00 \text{ V}</math>)</i></p> <p><i>ECF: Accept if answer is same as part (d) or answer is <math>-1.13 \text{ V}</math> if no answer achieved for part (d).</i></p>	<input checked="" type="checkbox"/>
(f)	$\text{CH}_4(\text{g}) + 2\text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l})$ $\Delta H_r^\ominus = \sum \Delta H_f^\ominus (\text{Products}) - \sum \Delta H_f^\ominus (\text{Reactants})$ $\Delta H_r^\ominus = 2 \times -285.8 \text{ kJ mol}^{-1} - 393.5 \text{ kJ mol}^{-1} + 74.8 \text{ kJ mol}^{-1} = -890 \text{ kJ mol}^{-1}$	<input checked="" type="checkbox"/>
(g)	$\Delta H_r^\ominus = -285.8 \text{ kJ mol}^{-1}$ <p><i>The same reaction as the standard enthalpy change of formation of water, which is given.</i></p> <p><i>This is the only correct answer – no ECF for this part.</i></p>	<input checked="" type="checkbox"/>

(h) relative  $M_r(\text{H}_2) = 2$       relative  $M_r(\text{CH}_4) = 16$

Ratio = heat released with  $\text{H}_2$  / heat released with  $\text{CH}_4$

$$= (-285.8 \text{ kJ mol}^{-1} / 2^{1/2}) / (-890.3 \text{ kJ mol}^{-1} / 16^{1/2})$$

$$= 0.908 \text{ or } 0.908 \text{ to } 1 \text{ or } 1 \text{ to } 1.101.$$

*ECF: Answer = (answer to part (g)  $\times 16^{1/2}$ ) / ( $2^{1/2} \times$  answer to part (f))*

$$\text{Answer with given values} = (-352.8 \text{ kJ mol}^{-1} / 2^{1/2}) / (-943.2 \text{ kJ mol}^{-1} / 16^{1/2})$$

$$= 1.058$$

*Correct final answer scores two marks. This must be the correct way around, i.e. value lower than 1. One mark is given for the inverse ratio of 1.101 or 1.101 to 1. All other values score no marks.*



Total out of 10

**10**