

1. This question is about energy storage using a chemical cycle

- (a) (i) $\Delta_r H^\circ$ (reaction (3)) = $\Delta_f H^\circ$ (I₂(g)) – 2 $\Delta_f H^\circ$ (HI) = (62.4 – 2 × 26.5) kJ mol⁻¹
= +9.4 kJ mol⁻¹ 1
Plus sign not required.
- (ii) ΔS° (reaction (3)) = (131 + 261 – 2 × 207) J K⁻¹ mol⁻¹
= –22 J K⁻¹ mol⁻¹ 1
Minus sign must be present.
- (iii) $\Delta_r G^\circ$ (reaction (3)) = 9.4 kJ mol⁻¹ – (298 K × –0.022 kJ K⁻¹ mol⁻¹)
= +16.0 kJ mol⁻¹ 1
Plus sign not required. Allow error carried forward from (i) and/or (ii)
- (iv) $K_{298} = \exp(-\Delta G/RT) = \exp(15956 / (8.314 \times 298))$
= 1.60 × 10³ 2
Allow error carried forward from (iii). Do not penalise if equilibrium constant has units.
- (v) $\Delta_r G^\circ$ (reaction (3)) = 9.4 kJ mol⁻¹ – (723 K × –0.022 kJ K⁻¹ mol⁻¹)
= 25.3 kJ mol⁻¹
 $K_{723} = \exp(-\Delta G/RT) = \exp(25306 / (8.314 \times 723))$
= 0.0148 2
Allow error carried forward from (i) and/or (ii). Do not penalise if equilibrium constant has units.
- (b) Products of reaction (1) cancel out when they occur in the following proportion:
2 × reaction (1) + reaction (2) + 2 × reaction (3).
This simplifies down to the following reaction: 2
 $2\text{H}_2\text{O}_{(g)} \rightarrow 2\text{H}_{2(g)} + \text{O}_{2(g)}$
State symbols not required. Accept the equation with mole ratio 1:1:½. Award 1 mark if the reactions are combined in the correct ratio but simplifying is done incorrectly.
- (c) $2 \times \Delta_r H^\circ$ (1) + $\Delta_r H^\circ$ (2) + $2 \times \Delta_r H^\circ$ (3) = –2 × $\Delta_f H^\circ$ (H₂O_(g))
[2 × $\Delta_r H^\circ$ (1) + 439 + 2 × 9.4] kJ mol⁻¹ = 484 kJ mol⁻¹
 $\Delta_r H^\circ$ (1) = +13 kJ mol⁻¹ 2
Plus sign not required. Allow error carried forward from (i).
- (d) Energy stored = 242 kJ 1
For the sequence: 2 × reaction (1) + reaction (2) + 2 × reaction (3) there are two moles of sulfur atoms.
This sequence has an overall $\Delta_r H^\circ = 484$ kJ mol⁻¹
All this energy is ‘stored’ as separate hydrogen and oxygen and can be released when these are recombined.
Therefore, per mol of sulfur, the energy stored is 242 kJ.

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