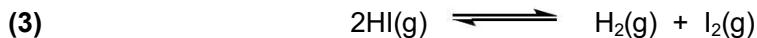
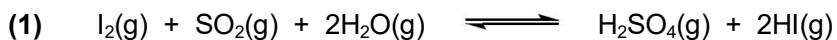


1. This question is about energy storage using a chemical cycle

Daily fluctuations in energy usage and in energy generation from renewables lead to a need for energy storage methods. Energy may be stored chemically using the sulfur-iodine cycle. The cycle has also been proposed as a means of producing hydrogen fuel more efficiently than by electrolysis.



At high temperature the sulfur-iodine cycle involves the three gas-phase equilibria:



- (a) Use the data and the equations at the end of the question to answer the following questions for **reaction (3)**.
 - (i) Calculate the standard enthalpy change at 298 K, Δ_rH° (298 K).
 - (ii) Calculate the standard entropy change at 298 K, Δ_rS° (298 K).
 - (iii) Calculate the standard Gibbs energy change at 298 K, Δ_rG° (298 K).
 - (iv) Calculate the equilibrium constant, K_{298} , at 298 K.
 - (v) Calculate the equilibrium constant, K_{723} , at 723 K. Assume Δ_rH° and Δ_rS° are independent of temperature.
- (b) Conditions are chosen so that the three equilibrium reactions above all proceed from left to right. Assuming that the products of **reaction (1)** are all consumed in **reactions (2)** and **(3)**, write an overall equation for the sulfur-iodine cycle.
- (c) The standard enthalpy change of reaction at 298 K for **reaction (2)** is +439 kJ mol⁻¹. Use the value of Δ_fH° (298 K) for $H_2O(g)$ in the table below to calculate the standard enthalpy change of reaction at 298 K for **reaction (1)**.
- (d) How much energy, per mol of sulfur atoms at 298 K, is stored with one revolution around the sulfur-iodine cycle?

Data:

	HI(g)	$H_2(g)$	$I_2(g)$	$H_2O(g)$
Δ_fH° (298 K) / kJ mol ⁻¹	26.5		62.4	-242
S° (298 K) / J K ⁻¹ mol ⁻¹	207	131	261	189

Useful equations: $\Delta S^\circ = \sum S^\circ(\text{products}) - \sum S^\circ(\text{reactants})$

$$\Delta G = \Delta H - T\Delta S$$

$$\Delta G^\circ = -RT \ln K$$

Useful constant: $R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$