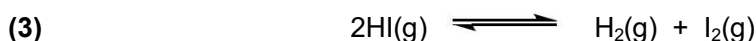
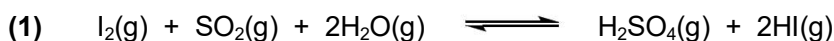


# 1. This question is about energy storage using a chemical cycle

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,  $\Delta_r H^\circ$  (298 K).
  - (ii) Calculate the standard entropy change at 298 K,  $\Delta_r S^\circ$  (298 K).
  - (iii) Calculate the standard Gibbs energy change at 298 K,  $\Delta_r G^\circ$  (298 K).
  - (iv) Calculate the equilibrium constant,  $K_{298}$ , at 298 K.
  - (v) Calculate the equilibrium constant,  $K_{723}$ , at 723 K. Assume  $\Delta_r H^\circ$  and  $\Delta_r S^\circ$  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  $+439 \text{ kJ mol}^{-1}$ . Use the value of  $\Delta_f H^\circ$  (298 K) for  $\text{H}_2\text{O}(\text{g})$  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:

	$\text{HI}(\text{g})$	$\text{H}_2(\text{g})$	$\text{I}_2(\text{g})$	$\text{H}_2\text{O}(\text{g})$
$\Delta_f H^\circ$ (298 K) / $\text{kJ mol}^{-1}$	26.5		62.4	-242
$S^\circ$ (298 K) / $\text{J K}^{-1} \text{mol}^{-1}$	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:  $R = 8.314 \text{ J K}^{-1} \text{mol}^{-1}$