Marks 5

- Consider the reaction $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

  $\Delta H° = -198.4$ kJ mol^{-1} and $\Delta S° = -187.9$ J K^{-1} mol^{-1} at 25 °C.

  Show that this reaction is spontaneous at 25 °C.

For a reaction to be spontaneous, $\Delta G°$ must be negative. As

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

At T = 25 °C,

$$\Delta G° = (-198.4 \times 10^3) - (25 + 273) \times (-187.9) \text{ J mol}^{-1} = -140 \text{ kJ mol}^{-1}$$

As $\Delta G°$ is negative at this temperature, the reaction is spontaneous.

If the volume of the reaction system is increased at 25 °C, in which direction will the reaction move?

The reaction involves 3 moles of gas being converted into 2 moles of gas. If the volume is increased, the pressure will decrease and the reaction will therefore shift to increase the number of moles of gas (Le Chatelier's principle).
It will shift to the left.

Calculate the value of the equilibrium constant, K, at 25 °C.

As $\Delta G° = -RT\ln K$, the equilibrium constant, K, at T = 25° is given by

$$-140 \times 10^3 = -8.314 \times (25 + 273) \times \ln K \quad \text{or } K = e^{57}$$

$$K = 9.2 \times 10^{24}$$

$K = 9.2 \times 10^{24}$ **(K has no units)**

Assuming $\Delta H°$ and $\Delta S°$ are independent of temperature, in which temperature range is the reaction non-spontaneous?

The reaction is non-spontaneous when $\Delta G° > 0$. Assuming $\Delta H°$ and $\Delta S°$ are independent of temperature, this will occur when $\Delta H° - T\Delta S° > 0$:

$$(-198.4 \times 10^3) - T \times (-187.9) > 0$$

$$T > \frac{198.4 \times 10^3}{187.9} \quad \text{or } T > 1056 \text{ K}$$

Answer: **T > 1056 K**