Marks 5

- For the reaction $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ at 25 °C

  $\Delta H° = –198.4$ kJ mol$^{–1}$ and $\Delta S° = –187.9$ J K$^{–1}$ mol$^{–1}$

  Show that this reaction is spontaneous in the forward direction at 25 °C.

As $\Delta G^o = \Delta H^o – T\Delta S^o$,

$$\Delta G^o = ((-198.4 \times 10^3)\ \text{J mol}^{-1}) – ((25 + 273)\ \text{K}) \times (-187.9\ \text{J K}^{-1}\ \text{mol}^{-1})$$
$$= -142400\ \text{J mol}^{-1} = -142.4\ \text{kJ mol}^{-1}$$

As $\Delta G^o < 0$, the reaction is spontaneous.

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

In the reaction, 3 mol of gas → 2 mol of gas. In the volume of the reaction system is increased, the pressure will decrease. The reaction will shift to produce more gas: it will shift to the left (reactants).

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

Using $\Delta G^o = -RT\ln K_p$:

$$(-142.4 \times 10^3)\ \text{J mol}^{-1} = -(8.314\ \text{J K}^{-1}\ \text{mol}^{-1}) \times ((25 + 273)\ \text{K}) \times \ln K_p$$

$$K_p = 9.3 \times 10^{24}$$

K_p = **9.3×10^{24}**

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

The reaction is spontaneous as long as $\Delta H^o – T\Delta S^o < 0$. $\Delta G^o = 0$ when

$$T = \frac{\Delta H°}{\Delta S°} = \frac{(-198.4 \times 10^3\ \text{J mol}^{-1})}{(-187.9\ \text{J K}^{-1}\ \text{mol}^{-1})} = 1056\ \text{K}$$

The reaction is spontaneous below this temperature and non-spontaneous above it.

Answer: **$T > 1056$ K**