Q1.

Entropy - Questions by Topic

The mechanism for the rapid decomposition of hydrogen peroxide, H_2O_2, in the presence of iodide ions, is:

$$H_2O_2 + I^- \rightarrow IO^- + H_2O \qquad \text{equation 1}$$

$$H_2O_2 + IO^- \rightarrow I^- + H_2O + O_2 \qquad \text{equation 2}$$

(a) Write the overall equation for the reaction and hence state the role of the iodide ions.

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(2)

(b) In further experiments, a student calculated the rate constant for the decomposition of hydrogen peroxide at two different temperatures.

Temperature/°C	Rate constant (k) / $dm^3\ mol^{-1}\ s^{-1}$
22.0	4.90×10^{-4}
47.0	2.92×10^{-3}

The rate constant (k) is related to the temperature, T, (in Kelvin) by the following equation:

$$\ln k = -\frac{E_a}{R} \times \frac{1}{T} + \text{constant} \qquad R = 8.31\,J\,K^{-1}\,mol^{-1}$$

Use the data in the table to calculate the activation energy, E_a, for the reaction by a non-graphical method.
Give your answer in kJ mol^{-1} and to an appropriate number of significant figures.
Include a sign in your answer.

(4)

(c) If acid conditions are used, the decomposition of hydrogen peroxide proceeds by a different mechanism. The equation for this reaction is:

$$H_2O_2 + 2I^- + 2H^+ \rightarrow I_2 + 2H_2O$$

This reaction is first order with respect to both iodide ions and hydrogen peroxide.

The progress of this reaction is usually followed by adding a fixed quantity of sodium thiosulfate solution and a little starch solution to the reaction mixture, then timing the appearance of a blue-black colour. This is known as a clock reaction.

(i) Explain the formation of the blue-black colour and why its appearance is delayed.

(3)

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(ii) Although the oxidation of thiosulfate ions ($S_2O_3^{2-}$) by hydrogen peroxide is thermodynamically favourable, it does not take place in this clock reaction.
Suggest a reason for this.

(1)

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(Total for question = 10 marks)

Q**2.**

Which substance has the highest standard molar entropy?

(1)

☒ **A** ethane(g)

☒ **B** water(s)

☒ **C** water(l)

☒ **D** water(g)

(Total for question = 1 mark)

Q**3.**

This question is about the thermodynamics of the reaction:

$$N_2O_4(g) \rightarrow 2NO_2(g) \qquad \Delta H = +57.2\,kJ\,mol^{-1}.$$

Compound	Standard molar entropy at 298 K, $S^{\ominus}$ / J K^{-1} mol^{-1}	Standard molar enthalpy of formation at 298 K, $\Delta_f H^{\ominus}$ / kJ mol^{-1}	Colour
NO_2	+240.0	+33.2	brown
N_2O_4	+304.2		colourless

(a) Calculate the entropy change for the reaction, using the information in the table.

Include a sign and units in your answer.

(2)

(b) Calculate the enthalpy change of formation, $\Delta_f H$, of N_2O_4 (g) at 298 K, using the information in the table and the enthalpy change of the reaction.

Include a sign and units in your answer.

(2)

(c) Calculate the entropy change of the surroundings, $\Delta S_{surroundings}$, at 298 K.

Give your answer to an appropriate number of significant figures.
Include a sign and units in your answer.

(3)

(d) (i) Use your answers to parts (a) and (c) to calculate the total entropy change, ΔS_{total}, for this reaction at 298 K.

(1)

(ii) This reaction can also be written as an equilibrium:

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

Calculate the temperature at which ΔS_{total} is zero for this equilibrium.

(2)

(e) (i) Write the expression for the equilibrium constant, K_p, for this reaction, including the units, if any.

(2)

(ii) In an experiment, 10 mol of $N_2O_4(g)$ was placed in a closed container at 50 °C. At equilibrium, 27% of the $N_2O_4(g)$ had dissociated, and the pressure in the container was 4.0 atm.

Calculate the value of K_p at 50 °C.

(4)

(iii) The total pressure is doubled to 8.0 atm.

State the effect on K_p.

(1)

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(iv) The total pressure is doubled to 8.0 atm at constant temperature.

Explain the change in the percentage dissociation of $N_2O_4(g)$ by considering the effect on the partial pressures of $NO_2(g)$ and $N_2O_4(g)$.

(3)

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(Total for question = 20 marks)

Q**4.**

The element sulfur can exist in two solid, interchangeable, structural forms known as rhombic sulfur and monoclinic sulfur.

$$S(s, \text{rhombic}) \rightleftharpoons S(s, \text{monoclinic}) \qquad \Delta S_{total} = -0.307\,JK^{-1}mol^{-1}$$

The value of ΔS_{total} is for the forward reaction. What can be concluded from this information?

(1)

☒ **A** monoclinic sulfur will change quickly into rhombic sulfur

☒ **B** rhombic sulfur could change into monoclinic sulfur but nothing can be deduced about the rate

☒ **C** there can be no change of structural form as they are both solids

☒ **D** monoclinic sulfur could change into rhombic sulfur but nothing can be deduced about the rate

(Total for question = 1 mark)