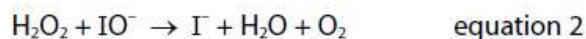
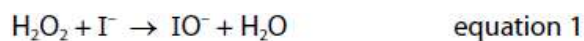


Q1.

### Entropy - Questions by Topic

The mechanism for the rapid decomposition of hydrogen peroxide,  $\text{H}_2\text{O}_2$ , in the presence of iodide ions, is:



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

..... (2)

.....

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

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

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

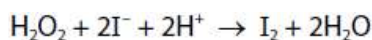
$$\ln k = -\frac{E_a}{R} \times \frac{1}{T} + \text{constant} \quad R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$$

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  $\text{kJ mol}^{-1}$  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:



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)**

**Q2.**

Which substance has the highest standard molar entropy?

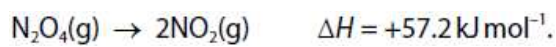
(1)

- A** ethane(g)
- B** water(s)
- C** water(l)
- D** water(g)

**(Total for question = 1 mark)**

Q3.

This question is about the thermodynamics of the reaction:



| Compound               | Standard molar entropy at 298 K, $S^\ominus / \text{J K}^{-1} \text{ mol}^{-1}$ | Standard molar enthalpy of formation at 298 K, $\Delta_f H^\ominus / \text{kJ mol}^{-1}$ | Colour     |
|------------------------|---|--|------------|
| $\text{NO}_2$          | +240.0  | +33.2  | brown      |
| $\text{N}_2\text{O}_4$ | +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  $\text{N}_2\text{O}_4$  (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,  $\Delta S_{\text{surroundings}}$ , at 298 K.

Give your answer to an appropriate number of significant figures.

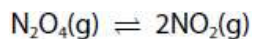
Include a sign and units in your answer.

(3)

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

(1)

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



Calculate the temperature at which  $\Delta S_{\text{total}}$  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  $\text{N}_2\text{O}_4(\text{g})$  was placed in a closed container at  $50\text{ }^\circ\text{C}$ . At equilibrium, 27% of the  $\text{N}_2\text{O}_4(\text{g})$  had dissociated, and the pressure in the container was 4.0 atm.

Calculate the value of  $K_p$  at  $50\text{ }^\circ\text{C}$ .

(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  $\text{N}_2\text{O}_4(\text{g})$  by considering the effect on the partial pressures of  $\text{NO}_2(\text{g})$  and  $\text{N}_2\text{O}_4(\text{g})$ .

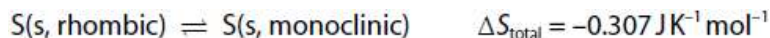
(3)

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**(Total for question = 20 marks)**

Q4.

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



The value of  $\Delta S_{\text{total}}$  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)**