HWA CHONG INSTITUTION
C2 Preliminary Examination
Higher 1

CANDIDATE NAME		**CT GROUP**	23S
CENTRE NUMBER		**INDEX NUMBER**	

CHEMISTRY — 8873/02

Paper 2 Structured Questions

11 September 2024

2 hours

Candidates answer on the Question Paper

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in dark blue or black pen.
You may use a 2B pencil for any diagrams or graphs.
Do not use staples, paper clips, glue, correction fluid or tapes.

Section A
Answer **all** the questions.

Section B
Answer **one** question.

The use of an approved scientific calculator is expected, where appropriate.
The number of marks is given in brackets [ ] at the end of each question or part question.

FOR EXAMINERS' USE ONLY

Number of additional writing paper(s) submitted

Paper 2 Section A	1	/ 14
	2	/ 17
	3	/ 10
	4	/ 19
Paper 2 Section B	5 or 6	/ 20
Paper 2		/ 80
Paper 1		/ 30
Total		/ 100

This document consists of **20** printed pages and **0** blank page.

Section A

Answer **all** the questions in this section in the spaces provided.

1 *Use of Data Booklet is relevant to this question.*

Tellurium is an element with an electronic configuration of [Kr] $4d^{10}$ $5s^2$ $5p^4$. The most common isotope of tellurium is ^{130}Te.

(a) Complete Table 1.1.

Table 1.1

	number of neutrons	number of electrons
^{130}Te		

[1]

(b) Describe how the behaviour of beams of $^{130}Te^{+}$ ion, ^{130}Te atom and the electron, e^{-}, differ in an electric field.

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.... [2]

(c) **(i)** Write an equation to represent the first ionisation energy of Te.

.... [1]

(ii) State and explain the general trend in first ionisation energy across period 3.

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.... [2]

(iii) Suggest why tellurium may not follow the general trend in **(c)(ii)**.

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.... [1]

(d) **(i)** Sketch a graph in Fig. 1.1 to show the trend in the first seven ionisation energies of Te.

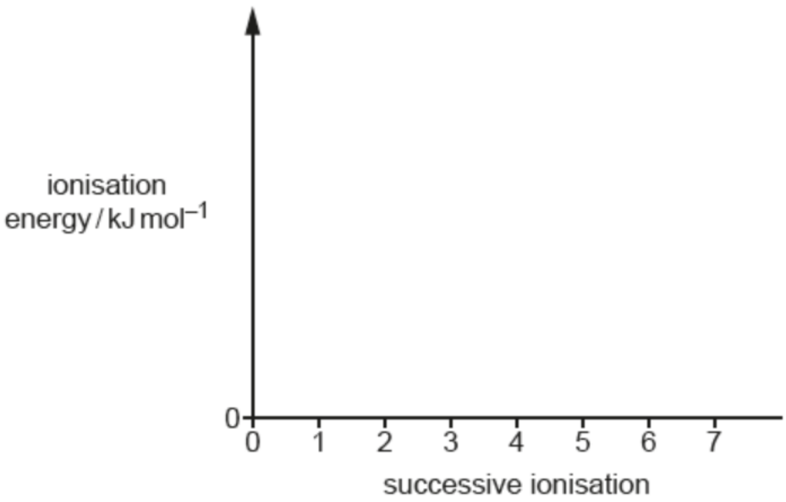

Fig. 1.1

[2]

(ii) Explain why the radius of Te ions decreases after each successive ionisation.

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………………………………………………………………………………………………… [1]

(e) Te reacts with F_2 at 150 °C to form TeF_6. Molecules of TeF_6 are octahedral.

Using the Valence Shell Electron Pair Repulsion theory, explain why TeF_6 is octahedral.

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………………………………………………………………………………………………… [2]

(f) TeF_6 reacts with water to form tellurium hydroxide and HF. The oxidation number of tellurium does **not** change during this reaction.

(i) Construct an equation for the reaction of TeF_6 with water.

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(ii) Name the type of reaction that occurs when TeF_6 reacts with water.

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[Total: 14]

2 Some common chlorides of Period 3 elements are shown in the list.

$NaCl$ $MgCl_2$ $AlCl_3$ $SiCl_4$ PCl_5

(a) From this list, identify **all** the chlorides that:

(i) have giant ionic structures in the solid state.

…………………………………………………………………………………………….… [1]

(ii) cause vigorous effervescence when added to aqueous sodium carbonate.

…………………………………………………………………………………………….… [1]

(b) Sulfur, S_8, reacts with chlorine to form several different chlorides. The most common are S_2Cl_2 and SCl_2. SCl_2 forms when sulfur reacts with excess chlorine.

reaction **1** $S_8(s) + 4Cl_2(g) \rightarrow 4S_2Cl_2(l)$ $\Delta H_r = -58.2$ kJ mol^{-1}

reaction **2** $S_2Cl_2(l) + Cl_2(g) \rightleftharpoons 2SCl_2(l)$ $\Delta H_r = -40.6$ kJ mol^{-1}

(i) Fig. 2.1 shows the structures of S_8 and S_2Cl_2 in reaction **1**.

Fig. 2.1

Using relevant values in the Data Booklet, the enthalpy change of reaction for reaction **1** and the structures in Fig 2.1, calculate the bond energy of S–C*l*.

[3]

(ii) Define the *standard enthalpy change of formation, ΔH_f.*

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…………………………………………………………………………………………….… [1]

(iii) Calculate the standard enthalpy change of formation of $SCl_2(l)$, ΔH_f, using the enthalpy changes of reactions **1** and **2** and the energy cycle in Fig. 2.2.

$$\begin{tikzcd} S_8(s) + 4Cl_2(g) \arrow[rr] \arrow[dr, "+4Cl_2(g)"'] & & 4S_2Cl_2(l) \arrow[dl, "+4Cl_2(g)"] \\ & 8SCl_2(l) & \end{tikzcd}$$

Fig. 2.2

enthalpy change of formation of of $SCl_2(l)$, ΔH_f = ……………………………kJ mol^{-1}

[3]

(c) **(i)** Explain why reaction **2** is a redox reaction. Include oxidation numbers in your answer.

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(ii) When oxidation and reduction occur, there is a movement of electrons.

The unit of charge is the coulomb, C.
The charge on an electron is -1.60×10^{-19} coulombs.

Calculate the charge transferred, in coulombs, when 1.5 moles of chlorine molecules react with S_2Cl_2 in reaction **2**.

charge transferred = …………………………… coulombs

[2]

(iii) State the effect of increasing pressure on the position of equilibrium and the equilibrium constant of reaction **2**. Explain your answer.

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(iv) Deduce whether SCl_2 is a polar molecule. Explain your answer.

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……………………………………………………………………………………………………… [2]

[Total: 17]

3 In industry, different processes are used to manufacture several types of polyethene, each with a different structure. The polymer chains shown in Fig. 3.1 are simplified representations of the actual structures.

low-density polyethene (LDPE)

linear low-density polyethene (LLDPE)

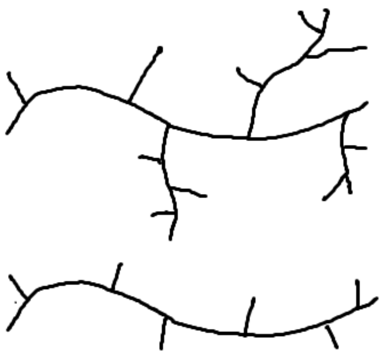

Fig. 3.1

LLDPE is made by mixing other alkenes with ethene before polymerisation. This introduces short side chains into the main polymer chain.

(a) LDPE and LLDPE are used in building materials, packaging and hot drinks containers.

Explain why the tensile strength of LDPE is lower than LLDPE.

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(b) Fig. 3.2 shows the structure of a part of a chain of LLDPE.

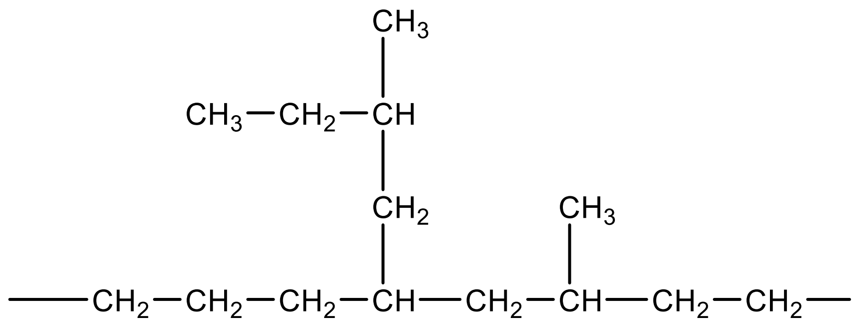


Fig. 3.2

Complete the table below by drawing and naming the **two** alkenes that have been mixed with ethene molecules to make the polymer shown in Fig 3.2.

Two alkenes other than ethene	Alkene 1	Alkene 2
Skeletal formula		
Name		propene

[3]

(c) *Use of the Data Booklet is relevant to this question.*

Suggest how the infrared (IR) spectrum of polyvinyl chloride (PVC) would differ from polyethene.

……. [1]

(d) Polyurethanes are polymers made by the reaction of a diisocyanate with a diol as shown in Fig. 3.3. R_1 and R_2 are alkyl groups.

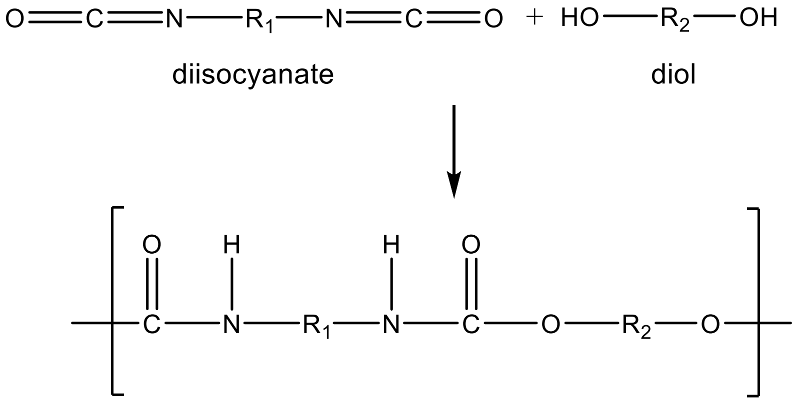
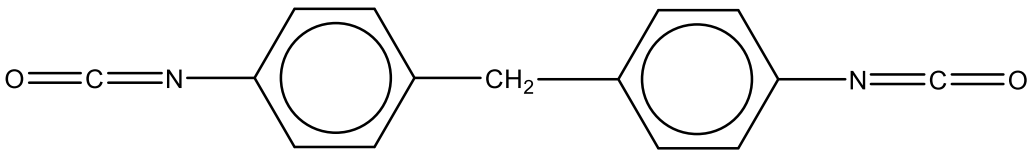


Fig. 3.3

Lycra is a polyurethane formed from diisocyanate **P** and diol, $HOCH_2CH_2OH$.



P

(i) Give the molecular formula for **P**.

…………………………………………………………………………………………..…. [1]

(ii) Draw the repeat unit of Lycra using Fig. 3.3.

[1]

(iii) Similar to Lycra, poly(ethylene terephthalate) (PET) and Nylon 6 are widely used as synthetic fibres in the textile industry.

Explain why Nylon 6 is less crease-resistant than PET.

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…… [3]

[Total: 10]

4 Car manufacturers make cars which use a range of different fuels. Some fuels are renewable, while some are ‘carbon neutral’, which means that the amount of carbon in the atmosphere does not change. The energy output of the fuel and how easy it is to store in the vehicle are also considered.

Ethanol in fuels

Ethanol fuels contain 93–96% ethanol after obtaining from industrial processes like distillation. Ethanol can be produced by either fermentation of sugar from sugarcane or by the catalytic addition of steam to ethene at 300°C and 70 atm pressure. Such fuels are used mainly in countries such as Brazil where sugarcane can be grown in large quantities. The percentage of ethanol in the fuel is indicated by the name of the fuel. For example, E80 contains 80% ethanol by mass. In other parts of the world, standard petrol contains ethanol as an additive because it increases the percentage of oxygen in the fuel.

Comparing fuels

The enthalpy change of combustion, ΔH_c, tells us the energy released per mole of the main compound in each fuel, as shown in Table 4.1.

Table 4.1

type of fuel	main compound in fuel	*ΔH_c of main compound in kJ mol^{-1}*	Mass density of fuel in g cm^{-3}	Energy released in kJ/L of fuel
LPG (liquified petroleum gas)	butane (M_r = 58.0)	–2877	0.55	26 500
petrol	octane (M_r = 114.0)	–5470	0.75	34 200
ethanol fuel	ethanol (M_r = 46.0)	–1366	0.79	25 000

Table 4.1 also shows the mass density and energy released per litre of each type of fuel (1 L = 1000 cm^3).

The GGE index of a fuel compares the energy released from one litre of fuel to that released from one litre of petrol. A fuel with a GGE of 2.0 means two litres of fuel releases the same energy as one litre of petrol. The GGE index is more useful than the enthalpy change of combustion data because it takes into account the volume of the fuel that can be stored in the car.

(a) Explain why some people think that ethanol is a ‘carbon neutral’ fuel and how the above information shows that this is incorrect.

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.... [2]

(b) **(i)** Calculate the percentage by mass of oxygen in E80 fuel, assuming ethanol is the only compound that contains oxygen.

[1]

(ii) Suggest an advantage of increasing the percentage of oxygen in a fuel.

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(c) After the fermentation of sugar from sugarcane to produce ethanol, some ethyl ethanoate is found to be present in the mixture.

Suggest how this ethyl ethanoate may be formed.

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(d) Calculate the GGE of LPG (liquified petroleum gas). Use your value to comment on how this affects the volume of the storage space needed for LPG fuel in vehicles compared to petrol vehicles.

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(e) A value for the energy released per litre of petrol may be estimated from the enthalpy change of combustion of octane, C_8H_{18}, and the mass density of petrol.

Calculate this estimated value and comment on why it differs from the actual value shown in Table 4.1.

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(f) **(i)** State the reagent and condition required to prepare ethene from ethanol.

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(ii) Draw the 'dot-and-cross' diagram for a molecule of ethene, C_2H_4.

[1]

(g) Nearly all petrol vehicles have a catalytic converter fitted to the exhaust to reduce the amount of oxides of nitrogen and carbon monoxide emitted into the atmosphere. Using platinum in the form of nanoparticles increases its efficiency as a heterogeneous catalyst.

(i) Describe how a heterogeneous catalyst speeds up reactions.

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(ii) Explain the difference between a *nanoparticle* and a *nanomaterial.*

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(iii) State a feature of platinum nanoparticles which explains the increase in platinum's efficiency as a catalyst.

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(h) Graphene is a well-known nanomaterial. It is a 2-dimensional layer of carbon atoms which is one atom thick.

Draw a diagram to illustrate the structure of graphene and explain why graphene is a good electrical conductor.

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[Total: 19]

Section B

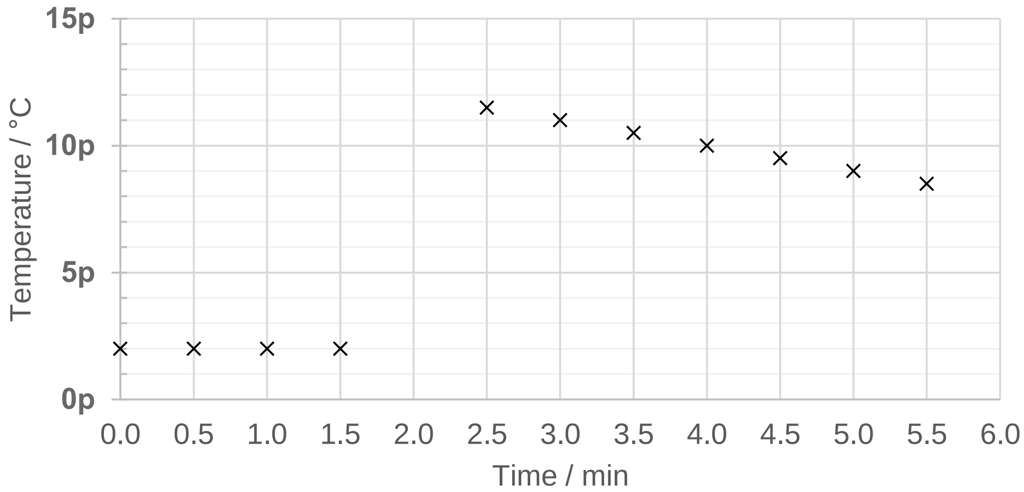
Answer **one** question from this section in the spaces provided.

5 **(a)** The enthalpy change of neutralisation between hydrochloric acid and sodium hydroxide can be determined experimentally.

(i) Calculate the pH of the resulting solution when 60 cm^3 of 1.0 mol dm^{-3} sodium hydroxide was mixed with 50 cm^3 of 2.0 mol dm^{-3} hydrochloric acid at 25 °C.

[3]

(ii) 60 cm^3 of 1.0 mol dm^{-3} sodium hydroxide was mixed with 50 cm^3 of 2.0 mol dm^{-3} hydrochloric acid at time = 2.0 min, and temperature readings were taken subsequently at every 0.5 minute interval. The following graph was obtained:



Using the information from the graph, determine the enthalpy change of neutralisation, ΔH_{neu}, of hydrochloric acid and sodium hydroxide, leaving your answer in terms of **p**.

Assume that the specific heat capacity and density of all solutions are 4.18 J g^{-1} K^{-1} and 1.00 g cm^{-3} respectively.

[3]

(iii) Suggest a value of the enthalpy change of neutralisation, ΔH_{neu}, when the experiment in **(a)(ii)** is repeated with sulfuric acid instead of hydrochloric acid, leaving your answer in terms of **p**. Explain your answer.

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(iv) Explain why the enthalpy change of neutralisation of ethanoic acid and sodium hydroxide should be less exothermic than that in **(a)(ii)**.

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(v) Suggest why the enthalpy change of neutralisation cannot be determined using the addition of dilute sulfuric acid and barium hydroxide.

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………………………………………………………………………………………………… [1]

(b) Describe the thermal decomposition of the hydrogen halides HC*l*, HBr and HI, giving observations where relevant, and state and explain any variation in their thermal stabilities.

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………………………………………………………………………………………………… [3]

(c) *Use of the Data Booklet is relevant for this question.*

When aqueous potassium iodide is added to $CuSO_4$(aq), the blue-coloured solution turns brown and a white precipitate of CuI(s) is seen.

$$2\ Cu^{2+}\ (aq) + 4\ I^{-}\ (aq) \rightarrow 2\ CuI\ (s) + I_2\ (aq)$$

A sample of 4.256g of $CuSO_4.5H_2O$ is dissolved and made up to 500 cm^3 in a volumetric flask. 25.0 cm^3 of the resultant solution is pipetted into excess aqueous potassium iodide. The resultant mixture was filtered and 0.163g of the white precipitate was obtained.

Determine the percentage by mass of copper present in the sample.

[2]

(d) A sample of HI(g) is added to a 5.00 dm^3 sealed vessel at 764 K and allowed to reach equilibrium.

reaction **3** $\quad 2HI(g) \rightleftharpoons H_2(g) + I_2(g) \quad\quad K_c = 0.0217$ at 764 K

At equilibrium, the mixture contains 1.70 mol of HI(g).

(i) Write the K_c expression of reaction **3** and state the units.

……………………………………………………………………………………………… [2]

(ii) Calculate the concentration of I_2 present in the reaction mixture at equilibrium. Show your working clearly.

[2]

(iii) Use Le Chatelier's principle to deduce whether reaction **3** is endothermic or exothermic, given that the value of K_c is 0.00625 at 500 K. Explain your answer.

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[Total: 20]

6 A powder has the following percentage composition by mass:

30.0 % sucrose, $C_{12}H_{22}O_{11}$

45.0 % citric acid, $C_6H_8O_7$

25.0 % sodium hydrogencarbonate, $NaHCO_3$

In the presence of water, the powder effervesces as the citric acid reacts with the sodium hydrogencarbonate to form sodium citrate, $Na_3(C_6H_5O_7)$:

$3NaHCO_3\,(s) + C_6H_8O_7\,(aq) \rightarrow Na_3(C_6H_5O_7)\,(aq) + 3CO_2(g) + 3H_2O\,(l)$

(a) **(i)** Determine the limiting reactant when 1.00 g of this powder reacts.

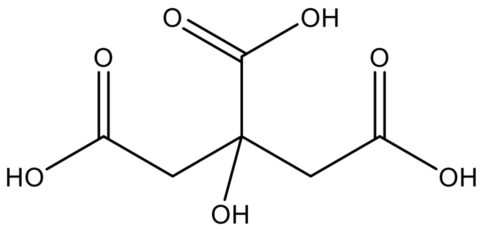
[2]

(ii) In an experiment, 0.043 dm^3 of CO_2 was produced in the above reaction from using 1.00 g of the powder at room temperature and pressure.

Calculate the percentage yield obtained in this experiment.

[2]

(b) **(i)** A molecule of citric acid, $C_6H_8O_7$, is shown.



citric acid

Draw the displayed formula of the organic product when citric acid reacts with excess methylamine in N,N-dicyclohexylcarbodiimide (DCC).

[2]

(ii) State the type of reaction that occurs in **(b)(i).**

.... [1]

(c) Explain why sodium citrate has a melting point of 300 °C but citric acid has a melting point of 150 °C. Include the bonding and structure of each substance in your answer.

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.... [2]

(d) In humans it is important for blood to be maintained at a pH between 7.35 and 7.45. One of the ways it does this is by using a buffer of CO_2(aq) and HCO_3^-(aq).

During vigorous exercise the muscles produce lactic acid. Lactic acid is transported by the blood to the liver to be broken down.

(i) State the effect that exercise will have on the pH of blood if there is no buffer present.

………………………………………………………………………………………….… [1]

(ii) Write equation(s) to explain how the CO_2(aq)/HCO_3^-(aq) buffer system helps to maintain the pH of blood between 7.35 and 7.45 during exercise.

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(e) Aqueous acidified iodate(V) ions, IO_3^-, react with iodide ions, as shown.

$$IO_3^- + 6H^+ + 5I^- \rightarrow 3I_2 + 3H_2O$$

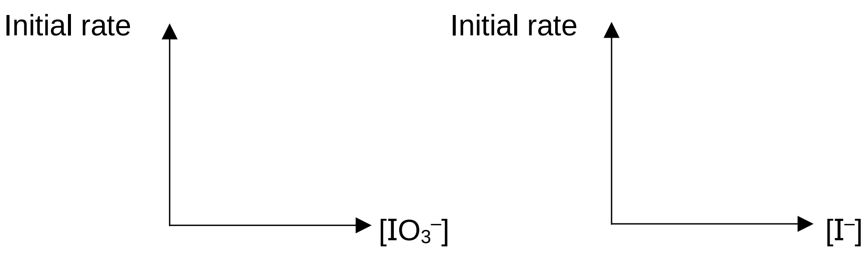
The initial rate of this reaction is investigated. Table 6.1 shows the results obtained.

Table 6.1

experiment	$[IO_3^-]$/mol dm^{-3}	$[H^+]$/mol dm^{-3}	$[I^-]$/mol dm^{-3}	initial rate / mol dm^{-3} min^{-1}
1	0.0400	0.0150	0.0250	0.0420
2	x	0.0225	0.0125	0.0709

The rate equation for this reaction is rate = $k[IO_3^-][H^+]^2[I^-]^2$.

(i) On the axes below, sketch the graphs to show the relationship between initial rates and $[IO_3^-]$ and $[I^-]$ respectively.



[2]

(ii) Use the data from Table 6.1 to calculate the rate constant, *k*, for this reaction. Include the units of *k.*

[2]

(iii) Calculate the concentration of IO_3^-, x, in experiment 2.

[1]

(iv) Two further experiments were carried out at pH 1.0 and at pH 2.0 with constant $[IO_3^-]$, $[I^-]$ and temperature.

Calculate the value of $\frac{\text{rate at pH 1.0}}{\text{rate at pH 2.0}}$.

[2]

(v) When the temperature of a reaction mixture is increased, the reaction rate increases. Explain this in terms of Boltzmann distribution.

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[Total: 20]

Additional answer space

If you use the following page to complete the answer to any question, the question number must be clearly shown.

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