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| Please check the examination details below before entering your candidate information                                                                                                                                                        |  |                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                     |
| Candidate surname                                                                                                                                                                                                                            |  | Other names                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                     |
| <b>Pearson Edexcel</b><br><b>International</b><br><b>Advanced Level</b>                                                                                                                                                                      |  | Centre Number                                                                                                                                                                                                                                                                                                                                                                                                        | Candidate Number                                                                                                                                                                                                                                                                                                                    |
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| <h2 style="margin: 0;">Tuesday 2 June 2020</h2>                                                                                                                                                                                              |  |                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                     |
| Afternoon (Time: 1 hour 40 minutes)                                                                                                                                                                                                          |  | Paper Reference <b>WCH04/01</b>                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                     |
| <h2 style="margin: 0;">Chemistry</h2> <p style="margin: 0;"><b>Advanced</b></p> <p style="margin: 0;"><b>Unit 4: General Principles of Chemistry I – Rates, Equilibria and Further Organic Chemistry (including synoptic assessment)</b></p> |  |                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                     |
| <b>Candidates must have: Scientific calculator</b><br><b>Data Booklet</b><br><b>Ruler</b>                                                                                                                                                    |  |                                                                                                                                                                                                                                                                                                                                                                                                                      | Total Marks<br><div style="border: 1px solid black; height: 40px; width: 100%;"></div>                                                                                                                                                                                                                                              |

### Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided  
– *there may be more space than you need.*

### Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets  
– *use this as a guide as to how much time to spend on each question.*
- Questions labelled with an **asterisk** (\*) are ones where the quality of your written communication will be assessed  
– *you should take particular care with your spelling, punctuation and grammar, as well as the clarity of expression, on these questions.*
- A Periodic Table is printed on the back cover of this paper.

### Advice

- Read each question carefully before you start to answer it.
- Show all your working in calculations and give units where appropriate.
- Check your answers if you have time at the end.

Turn over ►

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## SECTION A

Answer ALL the questions in this section. You should aim to spend no more than 20 minutes on this section. For each question, select one answer from A to D and put a cross in the box ☐. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☐.

- 1 Butanone is warmed with iodine in the presence of sodium hydroxide. What is the formula of the crystalline solid that is formed?

- ☐ A  $\text{CH}_3\text{I}$   
☐ B  $\text{CHI}_3$   
☐ C  $\text{CH}_2\text{ICOC}_2\text{H}_5$   
☐ D  $\text{C}_2\text{H}_5\text{COOH}$

(Total for Question 1 = 1 mark)

- 2 Dinitrogen tetroxide,  $\text{N}_2\text{O}_4$ , forms an equilibrium mixture with nitrogen dioxide,  $\text{NO}_2$ . Dinitrogen tetroxide is colourless and nitrogen dioxide is brown.



- (a) A mixture of dinitrogen tetroxide and nitrogen dioxide was placed in a gas syringe. The end of the syringe was sealed and the plunger pushed to increase the pressure. What would you see?

(1)

- ☐ A No change in colour.  
☐ B The contents of the syringe initially turn darker and then go lighter in colour.  
☐ C The contents of the syringe initially turn lighter and then go darker in colour.  
☐ D The contents of the syringe just go lighter in colour.

- (b) What happens to the mixture when the temperature of the equilibrium is raised by  $50^\circ\text{C}$ ?

(1)

- ☐ A The equilibrium moves to the right and the mixture darkens.  
☐ B The equilibrium moves to the right and the mixture lightens.  
☐ C The equilibrium moves to the left and the mixture darkens.  
☐ D The equilibrium moves to the left and the mixture lightens.

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(c) What is the expression for the partial pressure of nitrogen dioxide gas?

(1)

- ☐ A Total pressure  $\times$  moles of nitrogen dioxide gas
- ☐ B Total pressure  $\times$  moles of nitrogen dioxide gas  $\times 2$
- ☐ C Total pressure  $\times$  (moles of nitrogen dioxide gas  $\div$  total number of moles of gas)
- ☐ D Total pressure  $\div$  (moles of nitrogen dioxide gas  $\div$  total number of moles of gas)

(d) The equilibrium partial pressures of dinitrogen tetroxide and nitrogen dioxide are 0.67 atm and 0.33 atm respectively at 27 °C.

What is the value of  $K_p$  at 27 °C?

(1)

- ☐ A 2.030
- ☐ B 1.360
- ☐ C 0.493
- ☐ D 0.163

(Total for Question 2 = 4 marks)

3 When heated at 500 °C, magnesium carbonate decomposes in an endothermic reaction.



What are the signs of the entropy changes at 500 °C?

- ☐ A
- ☐ B
- ☐ C
- ☐ D

|   | $\Delta S_{\text{system}}$ | $\Delta S_{\text{surroundings}}$ |
|---|----------------------------|----------------------------------|
| A | negative                   | negative                         |
| B | negative                   | positive                         |
| C | positive                   | negative                         |
| D | positive                   | positive                         |

(Total for Question 3 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.



4 Different types of radiation are used in organic chemistry.

(a) Which of these types of radiation is used for initiating reactions?

(1)

- ☐ A Infrared  
☐ B Microwave  
☐ C Radio wave  
☐ D Ultraviolet

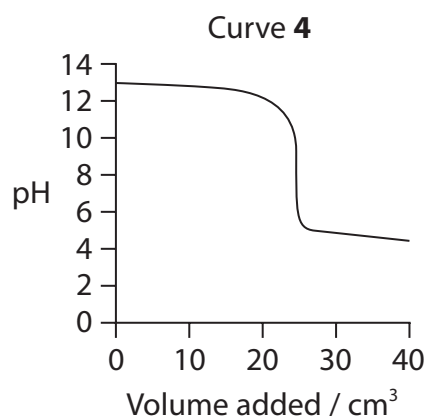
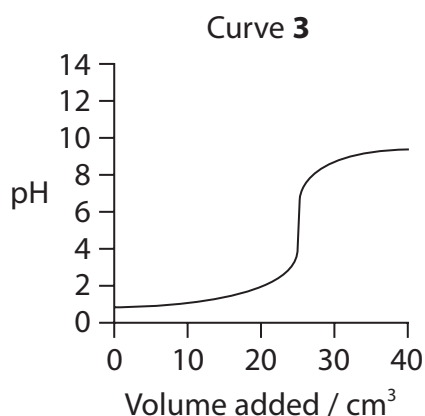
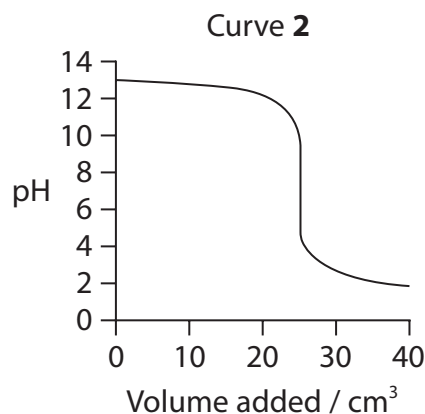
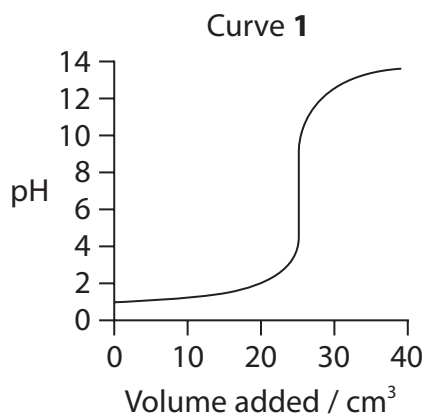
(b) Which of these types of radiation is used in nuclear magnetic resonance, nmr?

(1)

- ☐ A Infrared  
☐ B Microwave  
☐ C Radio wave  
☐ D Ultraviolet

(Total for Question 4 = 2 marks)

5 The titration curves shown were obtained using different acids and bases, each with a concentration of  $0.1 \text{ mol dm}^{-3}$ .



(a) Which curve shows the pH change when nitric acid is added to  $25\text{ cm}^3$  of sodium hydroxide?

(1)

- ☐ A Curve 1
- ☐ B Curve 2
- ☐ C Curve 3
- ☐ D Curve 4

(b) Which curve shows the pH change when ammonia is added to  $25\text{ cm}^3$  of hydrochloric acid?

(1)

- ☐ A Curve 1
- ☐ B Curve 2
- ☐ C Curve 3
- ☐ D Curve 4

(c) Which of these indicators would be **most** suitable for the titration shown by Curve 3?

(1)

- ☐ A
- ☐ B
- ☐ C
- ☐ D

| Indicator         | $pK_{in}$ |
|-------------------|-----------|
| methyl violet     | 0.8       |
| methyl yellow     | 3.5       |
| bromocresol green | 4.7       |
| phenol red        | 7.9       |

(Total for Question 5 = 3 marks)

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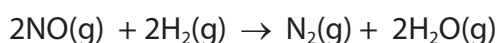


6 The expression for the ionic product of water is

- ☐ A  $K_w = [\text{H}^+] \times [\text{OH}^-]$
- ☐ B  $K_w = \frac{[\text{H}^+]}{[\text{OH}^-]}$
- ☐ C  $K_w = \frac{[\text{H}^+] \times [\text{OH}^-]}{[\text{H}_2\text{O}]}$
- ☐ D  $K_w = \frac{[\text{H}_2\text{O}]}{[\text{H}^+] \times [\text{OH}^-]}$

(Total for Question 6 = 1 mark)

7 This question concerns the kinetics of the reaction between nitrogen(II) oxide and hydrogen.



This reaction is second order with respect to nitrogen(II) oxide and first order with respect to hydrogen and therefore third order overall.

(a) By what factor will the initial rate increase if the concentration of nitrogen(II) oxide is doubled and the concentration of hydrogen is tripled?

(1)

- ☐ A 3
- ☐ B 9
- ☐ C 12
- ☐ D 18

(b) The units of the rate constant  $k$  of this third order reaction are

(1)

- ☐ A  $\text{mol}^3 \text{dm}^{-9} \text{s}^{-1}$
- ☐ B  $\text{dm}^9 \text{mol}^{-3} \text{s}^{-1}$
- ☐ C  $\text{mol}^2 \text{dm}^{-6} \text{s}^{-1}$
- ☐ D  $\text{dm}^6 \text{mol}^{-2} \text{s}^{-1}$

(Total for Question 7 = 2 marks)

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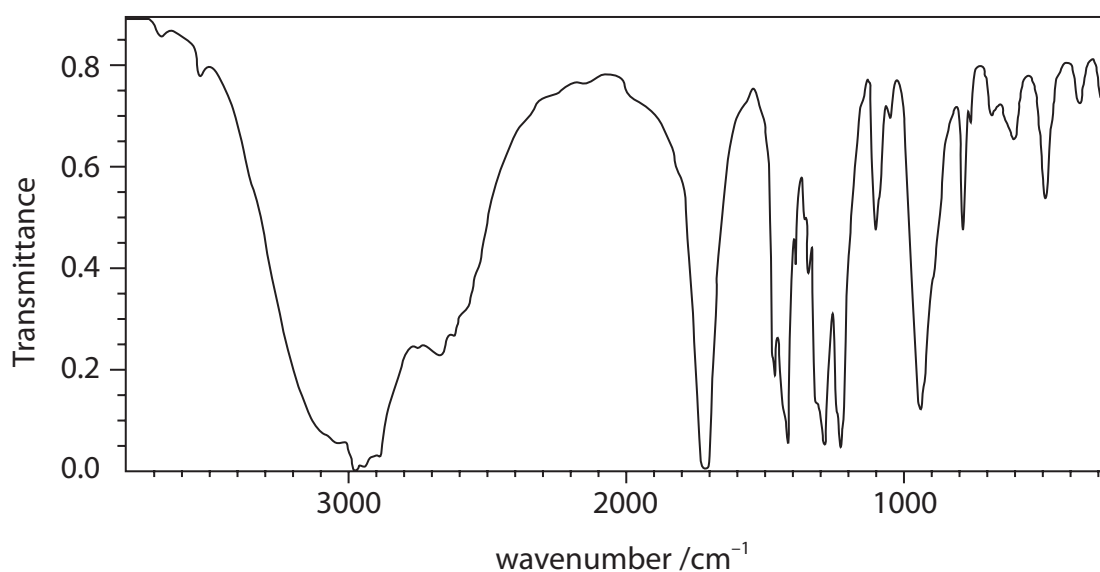


8 Which interaction between propanone and water molecules contributes **most** to the solubility of propanone in water?

- ☐ A London forces
- ☐ B Dipole-dipole forces
- ☐ C Hydrogen bonds
- ☐ D Ion-dipole forces

(Total for Question 8 = 1 mark)

9 Which compound gives this infrared spectrum?



- ☐ A Propan-1-ol
- ☐ B Propanoic acid
- ☐ C Propanal
- ☐ D Propanone

(Total for Question 9 = 1 mark)

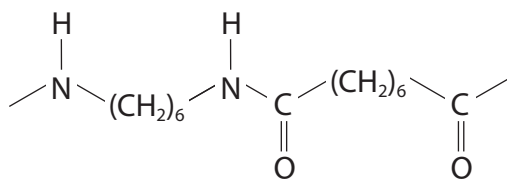
10 Ethanoyl chloride,  $\text{CH}_3\text{COCl}$ , reacts with

- ☐ A ammonia to form an amine.
- ☐ B water to form a halogenoalkane.
- ☐ C a halogenoalkane to form a ketone.
- ☐ D an alcohol to form an ester.

(Total for Question 10 = 1 mark)



11 A section of a polymer is shown.



Which of these monomers would form this polymer?

- ☐ A  $\text{H}_2\text{N}(\text{CH}_2)_6\text{NH}_2$  and  $\text{HO}(\text{CH}_2)_6\text{OH}$
- ☐ B  $\text{H}_2\text{N}(\text{CH}_2)_6\text{NH}_2$  and  $\text{ClOC}(\text{CH}_2)_6\text{COCl}$
- ☐ C  $\text{HO}(\text{CH}_2)_6\text{NH}_2$  and  $\text{HOOC}(\text{CH}_2)_6\text{COOH}$
- ☐ D  $\text{H}_2\text{N}(\text{CH}_2)_6\text{COOH}$  alone

(Total for Question 11 = 1 mark)

12 What is the enthalpy change of hydration for the ammonium ion?

Data

$$\Delta H_{\text{solution}}(\text{NH}_4\text{Cl}) = +20 \text{ kJ mol}^{-1}$$

$$\Delta H_{\text{hydration}}(\text{Cl}^-) = -378 \text{ kJ mol}^{-1}$$

$$\text{Lattice Energy}(\text{NH}_4\text{Cl}) = -705 \text{ kJ mol}^{-1}$$

- ☐ A  $-307 \text{ kJ mol}^{-1}$
- ☐ B  $+307 \text{ kJ mol}^{-1}$
- ☐ C  $-347 \text{ kJ mol}^{-1}$
- ☐ D  $+347 \text{ kJ mol}^{-1}$

(Total for Question 12 = 1 mark)

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**13** Data for some ions are shown in the table.

| Ion | Ionic radius/nm | Ionic charge |
|-----|-----------------|--------------|
| W   | 0.072           | +2           |
| X   | 0.102           | +1           |
| Y   | 0.100           | +2           |
| Z   | 0.138           | +1           |

Which of these ions has the hydration enthalpy of the greatest magnitude?

- ☐ **A** W
- ☐ **B** X
- ☐ **C** Y
- ☐ **D** Z

(Total for Question 13 = 1 mark)

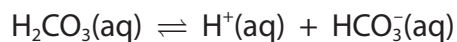
**TOTAL FOR SECTION A = 20 MARKS**



## SECTION B

Answer ALL the questions. Write your answers in the spaces provided.

**14** This question is about carbonic acid. It is a weak acid that dissociates as shown.



- (a) (i) Calculate the pH of a solution of carbonic acid with a concentration of  $0.00125 \text{ mol dm}^{-3}$ . Assume there is no dissociation of the  $\text{HCO}_3^-$  ion.

[ $pK_a$  for carbonic acid = 6.35]

(3)

- (ii) State **two** further assumptions you have made when calculating the pH in (a)(i).

(2)

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(b) Blood is buffered by a mixture of carbonic acid ( $\text{H}_2\text{CO}_3$ ) and hydrogencarbonate ions ( $\text{HCO}_3^-$ ).

- (i) The pH of blood is maintained at 7.4. Calculate the hydrogen ion concentration in the blood and hence the ratio of carbonic acid to hydrogencarbonate ions.

(3)

- \*(ii) Explain how this buffer solution resists a change in pH when extra hydrogen ions enter the blood.

(3)

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(Total for Question 14 = 11 marks)



15 An organic compound **A** contains only carbon, hydrogen and oxygen.

- (a) (i) On analysis, **A** was found to contain 54.55% carbon and 9.09% hydrogen by mass. Show by calculation that the empirical formula of **A** is  $\text{C}_2\text{H}_4\text{O}$ . (3)

- (ii) The molar mass of **A** is  $88 \text{ g mol}^{-1}$ . Deduce the molecular formula of **A**. (1)

\*(b) The results of tests carried out on separate samples of **A** are shown.

| Test |                                               | Results                                       |
|------|-----------------------------------------------|-----------------------------------------------|
| 1    | Addition of sodium                            | Effervescence<br>Gas burns with a squeaky pop |
| 2    | Addition of sodium hydrogencarbonate solution | No visible reaction                           |
| 3    | Addition of 2,4-dinitrophenylhydrazine        | Red precipitate formed                        |
| 4    | Addition of Tollens' reagent and warm         | No visible reaction                           |

Explain what can be deduced about the functional groups present in **A** from each of these test results. (4)

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(c) The high resolution proton nmr spectrum of **A** gives four peaks, **P**, **Q**, **R** and **S**.

| Peak                     | <b>P</b> | <b>Q</b> | <b>R</b> | <b>S</b> |
|--------------------------|----------|----------|----------|----------|
| Number of hydrogen atoms | 2        | 1        | 2        | 3        |
| Splitting pattern        | triplet  | singlet  | triplet  | singlet  |

- (i) Draw a structure for **A** which is consistent with these data and **all** the information from (a) and (b), labelling the hydrogen environments responsible for peaks **Q** and **S**.

(3)

- (ii) State the further information that you need to assign the hydrogen environments responsible for peaks **P** and **R**.

(1)

- (iii) Explain the splitting pattern for **one** of the triplets.

(1)

(Total for Question 15 = 13 marks)



**16** This question is about the production of ammonia by the Haber process.



- (a) (i) Using your Data Booklet, calculate the standard entropy change of the system,  $\Delta S_{\text{system}}^\ominus$ , for this reaction.  
Include a sign and units in your answer.

(3)

[note that Data Booklet values for the standard molar entropy,  $S^\ominus$ , of elements are per atom]

- (ii) State whether the sign for the standard entropy change of the system,  $\Delta S_{\text{system}}^\ominus$ , is as you would expect. Justify your answer.

(1)

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- (b) (i) Calculate the standard entropy change of the surroundings,  $\Delta S_{\text{surroundings}}^{\ominus}$ , at 400 K. Include a sign and units in your answer.

(2)

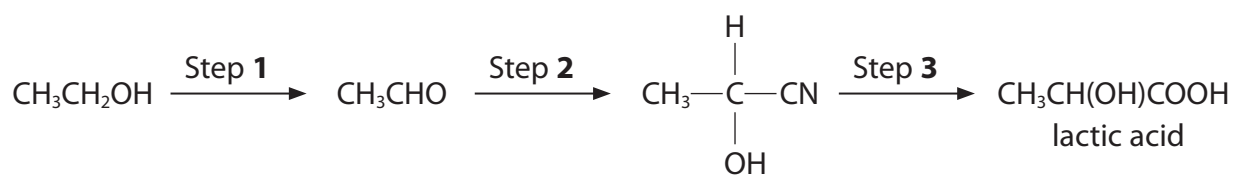
- (ii) Using your answers from (a)(i) and (b)(i), calculate the total standard entropy change,  $\Delta S_{\text{total}}^{\ominus}$ , at 400 K and explain whether or not the reaction is feasible at this temperature.

(2)

(Total for Question 16 = 8 marks)



- 17 This question is about carboxylic acids. A sequence of reactions for the formation of lactic acid is shown.



- (a) A mixture of hydrogen cyanide and cyanide ions is required for Step 2.

Draw the mechanism for Step 2. Include curly arrows, and any relevant dipoles and lone pairs of electrons.

(4)



(b) (i) The reaction in (a) is carried out at a carefully controlled pH.

Given that hydrogen cyanide is a weak acid, suggest why this reaction occurs more slowly at both high and low concentrations of hydrogen ions.

(2)

High concentration .....

.....

Low concentration .....

.....

(ii) The product formed in Step 2 exists as two optical isomers.

Draw a diagram of these two isomers to illustrate their optical isomerism.

(1)

\*(iii) By referring to your mechanism, explain whether or not the product formed in Step 2 would show optical activity.

(2)

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(c) (i) Name the type of reaction in Step 3.

(1)

(ii) Give the systematic name of lactic acid.

(1)

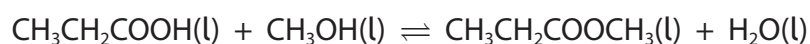
(d) Lactic acid is a weak acid. Explain what is meant by the terms 'weak' and 'acid'.

(2)

Weak .....

Acid .....

(e) Propanoic acid, another carboxylic acid, reacts with methanol in the presence of an acid catalyst to produce an ester.



Name the ester formed and draw its **skeletal** formula.

(2)

| Name | Skeletal formula |
|------|------------------|
|      |                  |



- (f) In an experiment to determine the equilibrium constant,  $K_c$ , for this reaction, 1.0 mol of propanoic acid was mixed with 1.0 mol of methanol and 2.0 mol of water.

A small quantity of hydrochloric acid was also added to catalyse the reaction. The mixture was left for a week to reach equilibrium.

After this time, 0.52 mol of propanoic acid was present. The total volume of the equilibrium mixture was  $134\text{ cm}^3$ .

- (i) Write the expression for the equilibrium constant,  $K_c$ , for the reaction in (e). (1)

- (ii) Using the expression in (f)(i), calculate the value of  $K_c$  for this reaction. Give your answer to two significant figures and include units if appropriate. (4)

(Total for Question 17 = 20 marks)

TOTAL FOR SECTION B = 52 MARKS



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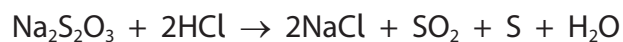
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## SECTION C

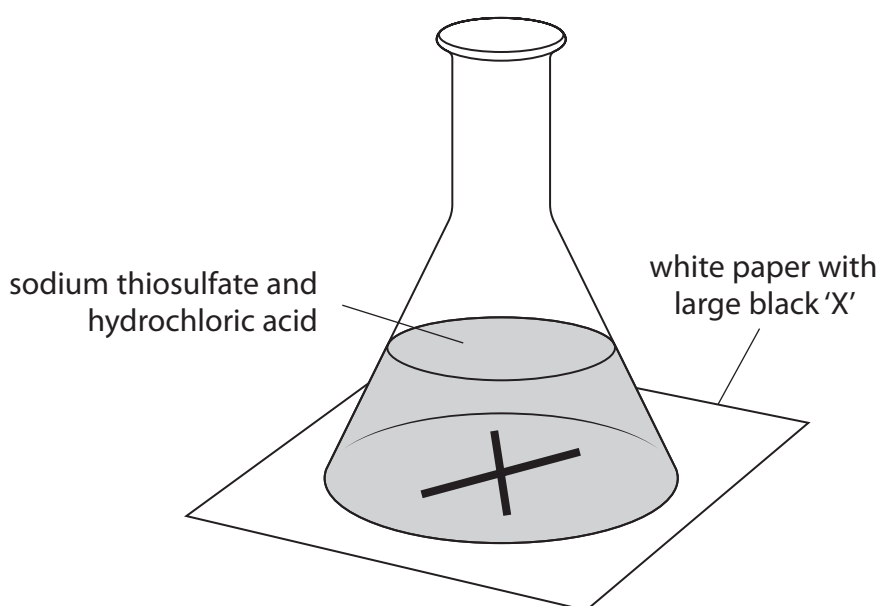
Answer ALL the questions. Write your answers in the spaces provided.

- 18 This question is about the reaction between sodium thiosulfate solution and hydrochloric acid.



- (a) A series of experiments was carried out at different temperatures to determine the activation energy of the reaction, using the apparatus shown. The time taken ( $t$ ) for the solution to become cloudy and obscure the cross was recorded.

The reciprocal of time ( $1/t$ ) was used as a measure of the rate of the reaction.



- (i) State why the solution becomes cloudy.

(1)

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(ii) Explain why  $1/t$  can be used as a measure of the rate.

(2)

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(b) The results obtained in this experiment are shown.

| Temperature ( $T$ )<br>/ K | $1/T$<br>/ K <sup>-1</sup> | Time ( $t$ )<br>/ s | $1/t$<br>/ s <sup>-1</sup> | $\ln(1/t)$ |
|----------------------------|----------------------------|---------------------|----------------------------|------------|
| 298                        | $3.36 \times 10^{-3}$      | 58                  | 0.0172                     | -4.06      |
| 308                        | $3.25 \times 10^{-3}$      | 36                  | 0.0278                     | -3.58      |
| 317                        | $3.15 \times 10^{-3}$      | 23                  | 0.0435                     | -3.14      |
| 328                        | $3.05 \times 10^{-3}$      | 14                  | 0.0714                     | -2.64      |
| 338                        |                            | 9                   |                            |            |

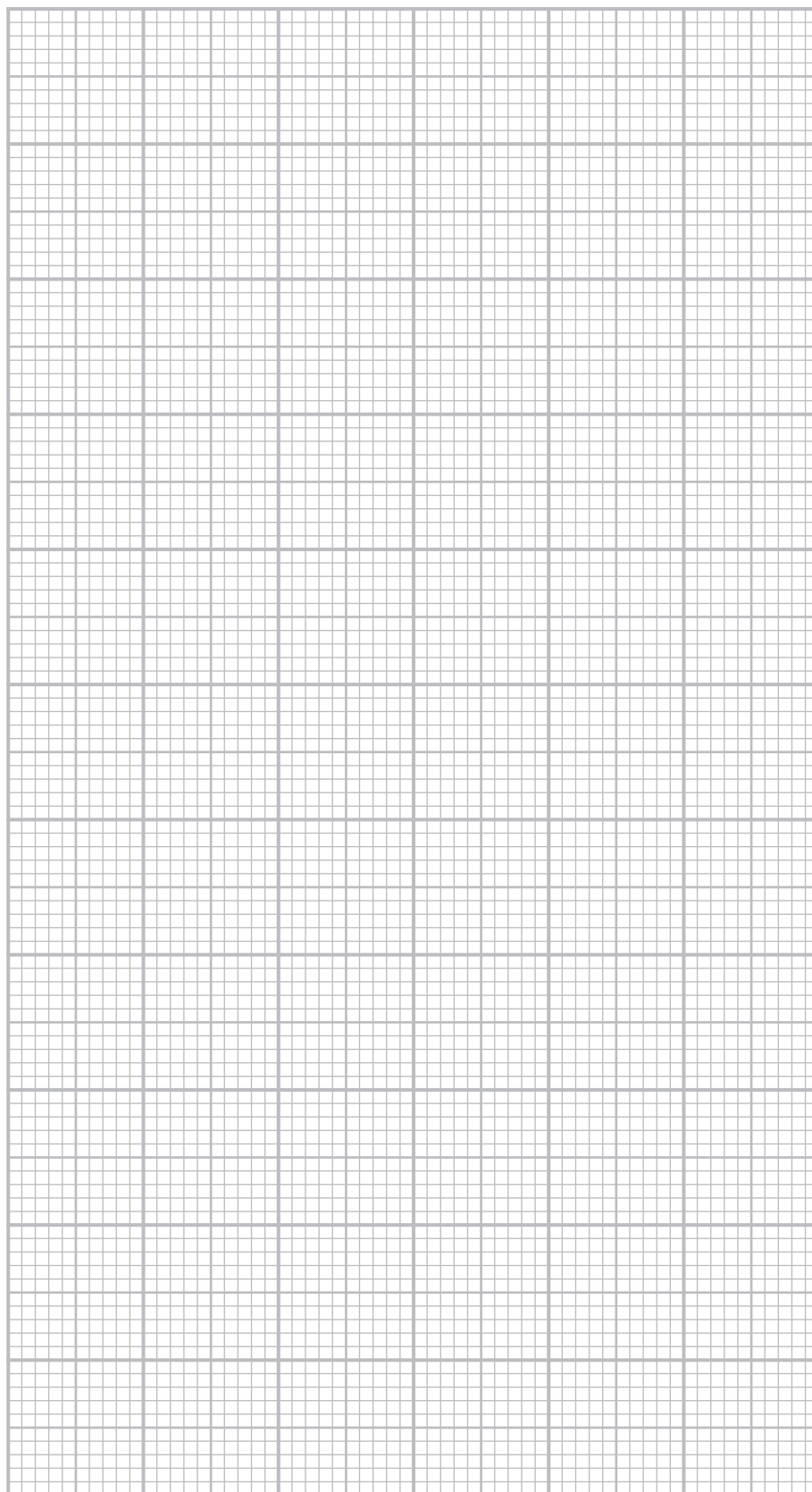
(i) Complete the table.

(2)



(ii) On the grid, plot  $\ln(1/t)$  against  $1/T$ .

(3)



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(iii) State the meaning of the term 'activation energy'.

(1)

(iv) From the graph, determine the gradient of the line.  
Include a sign and units in your answer.

(2)

(v) Calculate the activation energy for this reaction.  
Include a sign and units in your answer.

The Arrhenius equation for this experiment can be expressed as

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

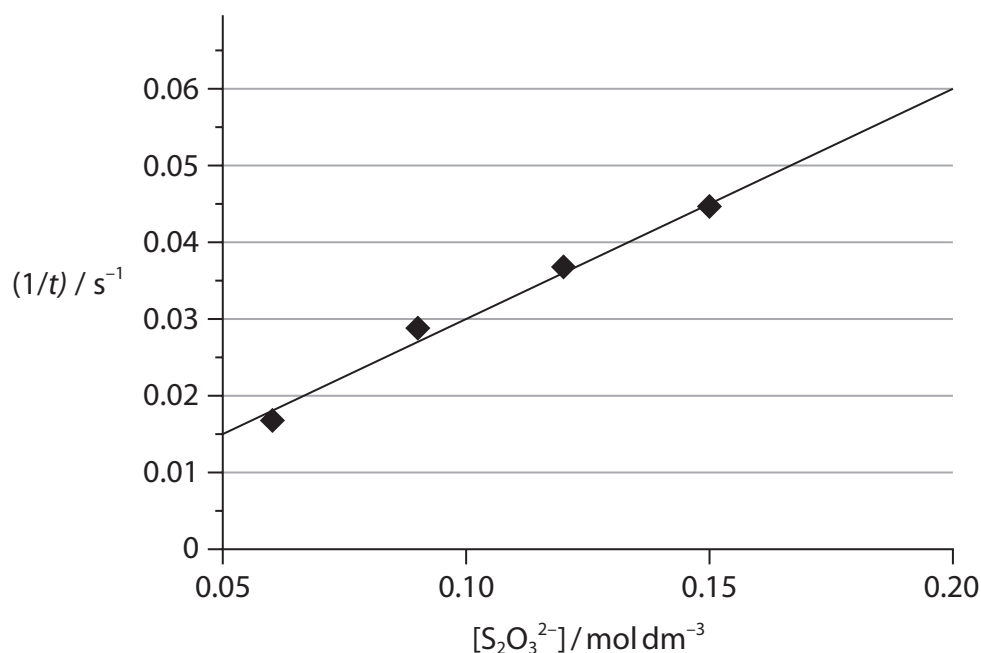
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- (c) Another series of experiments was carried out at constant temperature to determine the order of reaction with respect to thiosulfate ions,  $\text{S}_2\text{O}_3^{2-}$ .

The time taken ( $t$ ) for the solution to become cloudy and obscure the cross was recorded.

A graph was drawn from the data, using reciprocal time ( $1/t$ ) as a measure of rate.



- (i) In these experiments, suggest why the acid was in considerable excess.

(1)

- (ii) State the order of reaction with respect to sodium thiosulfate and justify your answer by referring to the graph in (c).

(2)



(d) Further experiments were carried out to determine the order of reaction with respect to  $\text{H}^+$  ions and hence to identify the species involved in the rate-determining step.

(i) State what is meant by the term 'rate-determining step'.

(1)

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(ii) The reaction is first order with respect to  $\text{H}^+$  ions. Using this fact and your answer to (c)(ii), suggest the **formula** of the intermediate formed during the rate-determining step.

(1)

(Total for Question 18 = 18 marks)

TOTAL FOR SECTION C = 18 MARKS  
TOTAL FOR PAPER = 90 MARKS



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## 28

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\* Lanthanide series

\* Actinide series

|     |    |         |    |     |    |              |    |     |    |           |    |       |    |            |    |     |    |           |    |     |    |           |    |     |    |            |    |     |    |           |    |     |    |             |    |     |    |             |    |     |    |         |     |     |    |           |     |     |    |           |     |     |    |            |     |
|-----|----|---------|----|-----|----|--------------|----|-----|----|-----------|----|-------|----|------------|----|-----|----|-----------|----|-----|----|-----------|----|-----|----|------------|----|-----|----|-----------|----|-----|----|-------------|----|-----|----|-------------|----|-----|----|---------|-----|-----|----|-----------|-----|-----|----|-----------|-----|-----|----|------------|-----|
| 140 | Ce | cerium  | 58 | 141 | Pr | praseodymium | 59 | 144 | Nd | neodymium | 60 | [147] | Pm | promethium | 61 | 150 | Sm | samarium  | 62 | 152 | Eu | europium  | 63 | 157 | Gd | gadolinium | 64 | 159 | Tb | terbium   | 65 | 163 | Dy | dysprosium  | 66 | 165 | Ho | holmium     | 67 | 167 | Er | erbium  | 68  | 169 | Tm | thulium   | 69  | 173 | Yb | ytterbium | 70  | 175 | Lu | lutetium   | 71  |
| 232 | Th | thorium | 90 | 231 | Pa | protactinium | 91 | 238 | U  | uranium   | 92 | 237   | Np | neptunium  | 93 | 242 | Pu | plutonium | 94 | 243 | Am | americium | 95 | 247 | Cm | curium     | 96 | 245 | Bk | berkelium | 97 | 251 | Cf | californium | 98 | 254 | Es | einsteinium | 99 | 253 | Fm | fermium | 100 | 256 | Md | mercurium | 101 | 254 | No | nobelium  | 102 | 257 | Lr | lawrencium | 103 |

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