Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

Wednesday 28 May 2025

Morning (Time: 1 hour 45 minutes)

Paper reference **WCH14/01**

Chemistry

International Advanced Level
UNIT 4: Rates, Equilibria and Further Organic Chemistry

You must have:
Scientific calculator, Data Booklet, ruler

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B).
- **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.*
- In the question marked with an **asterisk (*)**, marks will be awarded for your ability to structure your answer logically, showing how the points that you make are related or follow on from each other where appropriate.
- 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 include units where appropriate.
- Try to answer every question.
- 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 This question is about carbonyl compounds.

(a) Propanone reacts with hydrogen cyanide, HCN, in the presence of potassium cyanide, KCN.

How is this reaction classified?

(1)

☒ **A** electrophilic addition

☒ **B** electrophilic substitution

☒ **C** nucleophilic addition

☒ **D** nucleophilic substitution

(b) What is the first step in the mechanism of the reaction between propanone and a mixture of HCN and KCN?

(1)

☒ **A** the lone pair of electrons on the carbon of CN^- attacking the carbonyl $C^{\delta+}$ of propanone

☒ **B** the lone pair of electrons on the nitrogen of CN^- attacking the carbonyl $C^{\delta+}$ of propanone

☒ **C** the lone pair of electrons on the oxygen of propanone attacking the $C^{\delta+}$ of HCN

☒ **D** the lone pair of electrons on the oxygen of propanone attacking the $H^{\delta+}$ of HCN

(c) What is the name of the organic product formed in part (a)?

(1)

☒ **A** 2-hydroxy-2-methylpropylamine

☒ **B** 2-hydroxy-2-methylethylamine

☒ **C** 2-hydroxy-2-methylethanenitrile

☒ **D** 2-hydroxy-2-methylpropanenitrile

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(d) Which of these carbonyl compounds would produce pale yellow crystals when warmed with iodine in the presence of sodium hydroxide?

(1)

- ☒ **A** butanone
- ☒ **B** butanal
- ☒ **C** pentan-3-one
- ☒ **D** 2-methylpropanal

(e) What is the formula of the pale yellow crystals formed in part (d)?

(1)

- ☒ **A** CI_4
- ☒ **B** CHI_3
- ☒ **C** CH_2I_2
- ☒ **D** CH_3I

(Total for Question 1 = 5 marks)

2 Which of these statements about the reaction of ethanoyl chloride with ammonia is **not** correct?

- ☒ **A** an amide is formed
- ☒ **B** the reaction is exothermic
- ☒ **C** misty fumes and white smoke are given off
- ☒ **D** a gas is produced that turns damp red litmus paper blue

(Total for Question 2 = 1 mark)

3 Which of these substances would be expected to have the greatest standard molar entropy?

- ☒ **A** FeO
- ☒ **B** FeS
- ☒ **C** $FeCl_2$
- ☒ **D** $FeCl_3$

(Total for Question 3 = 1 mark)

4 What is the pH of a 1.25 mol dm^{-3} solution of hydrochloric acid?

- ☒ **A** –1.25
- ☒ **B** –0.097
- ☒ **C** 0.097
- ☒ **D** 1.25

(Total for Question 4 = 1 mark)

5 At 25 °C, the pH of pure water is 7.0 and at 75 °C the pH is 6.4 .

Why is the pH of pure water lower at 75 °C than at 25 °C?

- ☒ **A** there are more hydrogen ions than hydroxide ions when the water is at 75 °C
- ☒ **B** the dissociation of water is endothermic so the concentration of hydrogen ions is lower at 75 °C
- ☒ **C** the dissociation of water is endothermic so the concentration of hydrogen ions is higher at 75 °C
- ☒ **D** the dissociation of water is exothermic so the concentration of hydrogen ions is higher at 75 °C

(Total for Question 5 = 1 mark)

6 A sodium hydroxide solution with pH = 12 is diluted by a factor of 100.

What is the pH of the diluted solution?

- ☒ **A** 10
- ☒ **B** 11
- ☒ **C** 13
- ☒ **D** 14

(Total for Question 6 = 1 mark)

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

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7 High resolution mass spectrometers can give peak data accurate to four decimal places.

An organic compound **X** has a molecular ion peak at $m/z = 60.0210$.

The accurate relative atomic masses are shown.

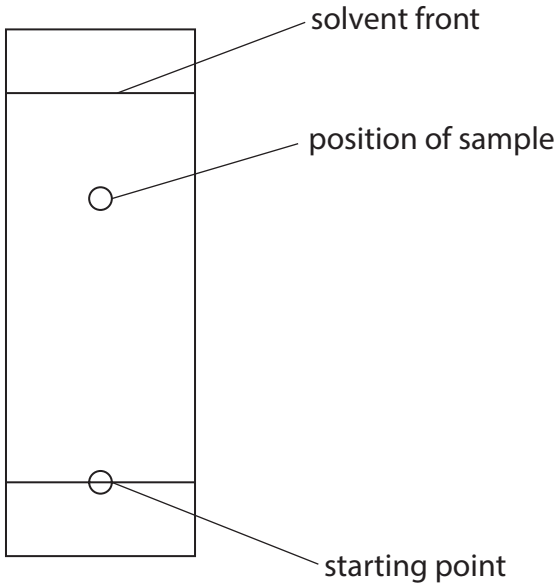
H = 1.0078, C = 12.0000, N = 14.0031, O = 15.9949

Which compound is **X**?

- ☒ **A** $CH_3CH_2CH_2OH$
- ☒ **B** CH_3COOH
- ☒ **C** $CO(NH_2)_2$
- ☒ **D** $(CH_3)_3N$

(Total for Question 7 = 1 mark)

8 A thin layer chromatogram of a substance is shown.



What is the R_f value of the sample?

- ☒ **A** 0.27
- ☒ **B** 0.69
- ☒ **C** 0.73
- ☒ **D** 1.37

(Total for Question 8 = 1 mark)

9 In an experiment to determine the rate of reaction between bromine and methanoic acid, which method would **not** be suitable?

$$Br_2(aq) + HCOOH(aq) \rightarrow 2H^+(aq) + 2Br^-(aq) + CO_2(g)$$

☒ **A** quenching and titrating with an acid

☒ **B** measuring the loss in mass

☒ **C** colorimetry

☒ **D** measuring the volume of gas produced

(Total for Question 9 = 1 mark)

10 The reaction shown is second order with respect to NO and first order with respect to O_2.

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

If the concentration of NO is doubled and the concentration of O_2 is tripled, by what factor will the rate increase?

☒ **A** 6

☒ **B** 12

☒ **C** 18

☒ **D** 27

(Total for Question 10 = 1 mark)

11 A chloroalkane, RCl, undergoes hydrolysis according to the equation shown.

$$RCl + OH^- \rightarrow ROH + Cl^-$$

The rate equation is rate = k[RCl]

Which chloroalkane is most likely to be RCl?

☒ **A** CH_3CH_2Cl

☒ **B** $(CH_3)_3CCl$

☒ **C** $CH_3CHClCH_3$

☒ **D** $(CH_3)_3CCH_2Cl$

(Total for Question 11 = 1 mark)

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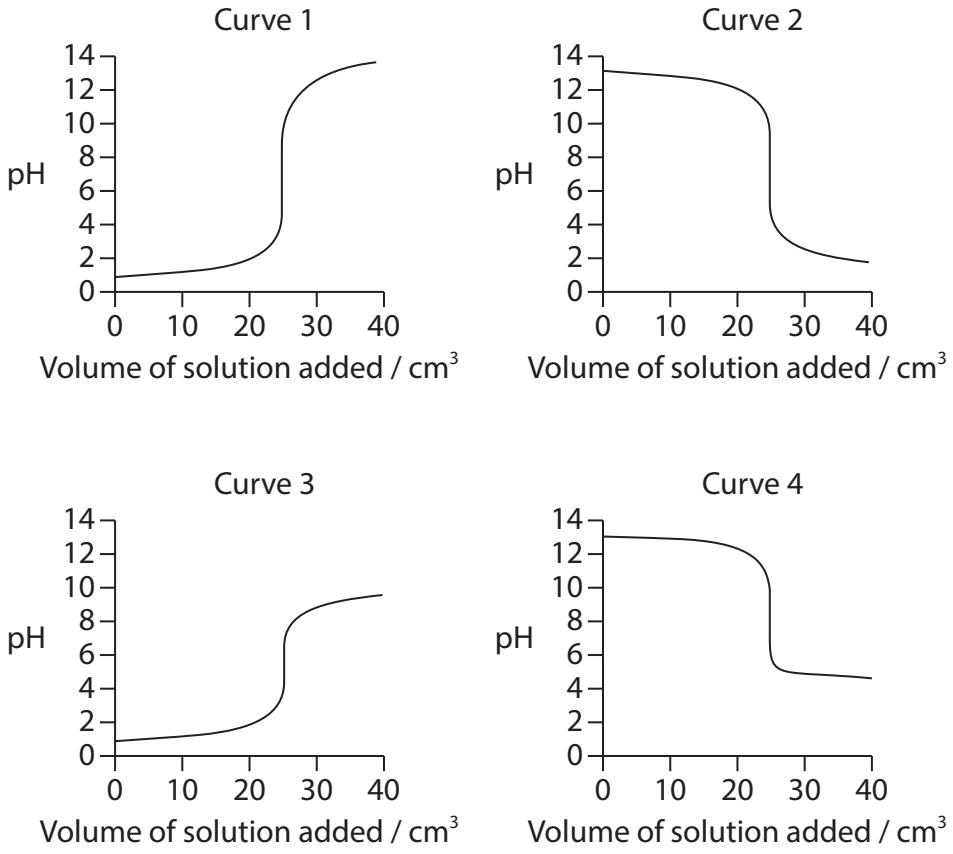
12 This question is about the titration curves obtained by reacting different acids and alkalis of the same concentration.



(a) Which curve is produced by adding ammonia to 25 cm^3 of hydrochloric acid?

(1)

☒ **A** Curve 1

☒ **B** Curve 2

☒ **C** Curve 3

☒ **D** Curve 4

(b) Which of these indicators would be **most** suitable to determine the end-point for the titration that gives Curve 4?

(1)

		Indicator	pH range
☒	**A**	congo red	3.0–5.0
☒	**B**	bromocresol purple	5.2–6.8
☒	**C**	thymol blue (base)	8.0–9.6
☒	**D**	alizarin yellow R	10.1–13.0

(Total for Question 12 = 2 marks)

13 This question is about the equilibrium for the reaction shown.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -196\,kJ\,mol^{-1}$$

(a) Which is the expression for the equilibrium constant, K_p?

(1)

☒ **A** $K_p = \dfrac{2(pSO_3)}{2(pSO_2) \times (pO_2)}$

☒ **B** $K_p = \dfrac{[SO_3]^2}{[SO_2]^2 \times [O_2]}$

☒ **C** $K_p = \dfrac{(pSO_3)^2}{(pSO_2)^2 \times (pO_2)}$

☒ **D** $K_p = \dfrac{(pSO_2)^2 \times (pO_2)}{(pSO_3)^2}$

(b) Which statement about this equilibrium is correct?

(1)

☒ **A** increasing the pressure increases the value of K_p

☒ **B** decreasing the pressure decreases the equilibrium yield of SO_3

☒ **C** adding a catalyst increases the equilibrium yield of SO_3

☒ **D** adding a catalyst increases the value of K_p

(c) What is the relationship between the equilibrium constant, K, and ΔS_{total}?

(1)

☒ **A** $\Delta S_{total} = R \ln K$

☒ **B** $\ln \Delta S_{total} = R K$

☒ **C** $\Delta S_{total} = R \log K$

☒ **D** $\log \Delta S_{total} = R K$

(Total for Question 13 = 3 marks)

TOTAL FOR SECTION A = 20 MARKS

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SECTION B

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

14 This question is about nitrosyl chloride, NOCl, which is a yellow gas.
Nitrosyl chloride decomposes into yellow-green chlorine, Cl_2, and colourless nitric oxide, NO, as shown.

$$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$$

(a) A mixture of nitrosyl chloride, chlorine and nitric oxide was placed in a sealed container and allowed to reach equilibrium.

Explain what you would expect to **see** when the pressure of the equilibrium mixture is increased.

(2)

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(b) 0.250 mol of nitrosyl chloride in a 500 cm^3 sealed container was heated to 200 °C. At equilibrium there was 0.016 mol of chlorine in the mixture.

(i) Write the expression for the equilibrium constant K_c.

(1)

(ii) Complete the table using the equilibrium equation and the data.

(2)

Substance	NOCl	NO	Cl_2
Initial mol	0.250	0	0
Equilibrium mol			0.016
Concentration / mol dm^3			

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(iii) Using your answers from (b)(i) and (b)(ii), calculate the equilibrium constant, K_c.
Give your answer to an appropriate number of significant figures and include units.

(3)

(iv) When the temperature is reduced, the value of the equilibrium constant, K_c, becomes smaller.

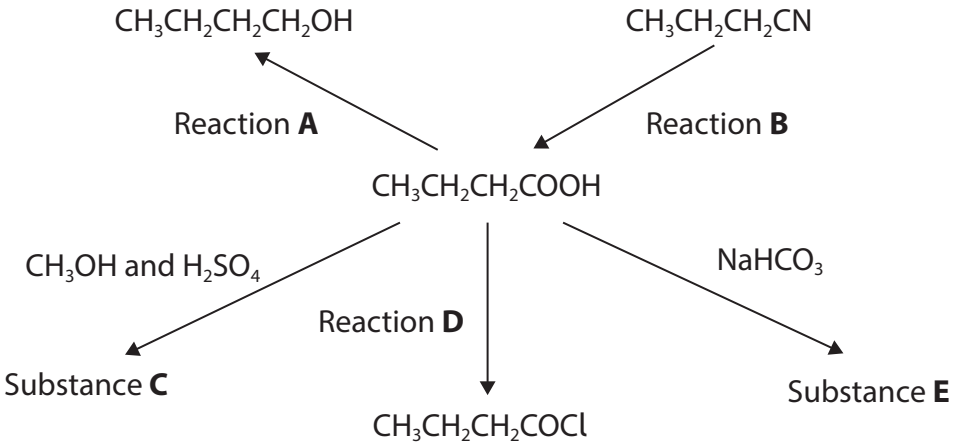
Explain what can be deduced about the nature of the reaction.

(2)

(Total for Question 14 = 10 marks)

15 This question is about butanoic acid.

(a) Some reactions involving butanoic acid are shown.



(i) Identify the reagent, by name or formula, **and** the conditions required to carry out Reaction **A**.

(2)

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(ii) Name the type of reaction taking place in Reaction **B**.

(1)

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(iii) Give the structural formula **and** name of Substance **C**.

(2)

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(iv) Identify, by name or formula, the reagent required to carry out Reaction **D**, giving **one** observation.

(2)

Reagent .....

Observation .....

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(v) Write the full equation for the formation of Substance **E**.

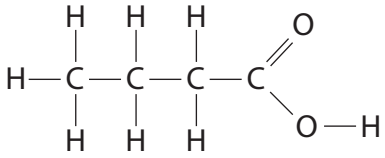
State symbols are not required.

(1)

(b) Butanoic acid is very soluble in water. This is due to strong intermolecular forces between butanoic acid molecules and water molecules.

Complete the diagram by adding **one** water molecule to show this intermolecular force. Include relevant dipoles and lone pairs.
Label the intermolecular force involved.

(3)



(Total for Question 15 = 11 marks)

***16** Proton NMR spectroscopy and mass spectrometry give detailed information about the structure of organic compounds.

Discuss the similarities and differences in these spectra for propanal and propanone.

Include in your answer:

Proton NMR Spectroscopy

- the number of peaks, the relative peak areas and, where relevant, splitting patterns

Mass spectrometry

- any *m* / *z* peaks that show one similarity and one difference between the spectra of the two compounds.

(6)

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(Total for Question 16 = 6 marks)

17 This question is about weak acids.

The values for the acid dissociation constant of ethanoic acid and chloroethanoic acid are shown.

Acid	K_a / mol dm^{-3}
ethanoic acid	1.70×10^{-5}
chloroethanoic acid	1.30×10^{-3}

(a) (i) Write the expression for K_a for ethanoic acid, CH_3COOH.

(1)

(ii) Calculate the pH of a 0.25 mol dm^{-3} solution of ethanoic acid.

(2)

(iii) State **one** assumption you have made when calculating the pH in (a)(ii).

(1)

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(b) (i) Suggest a reason why chloroethanoic acid, $CH_2ClCOOH$, is a stronger acid than ethanoic acid.

(1)

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(ii) When ethanoic acid and chloroethanoic acid are added together an equilibrium is set up containing two acid-base pairs.

Complete the equilibrium equation, labelling the conjugate acid-base pairs as A1, B1 and A2, B2.

(2)

$CH_3COOH + CH_2ClCOOH \rightleftharpoons$

(c) A buffer was made by mixing 8.20 g of sodium ethanoate, CH_3COONa, with 250 cm^3 of 0.700 mol dm^{-3} solution of ethanoic acid, CH_3COOH.

Calculate the pH of the buffer.

(4)

(d) A type of bubble bath contains a weak acid and the indicator bromocresol green. The bubble bath is initially yellow but when diluted with bath water, its colour changes from yellow to green to blue.

Use the information on page 9 of the Data Booklet to deduce why the bubble bath changes colour.

(3)

(Total for Question 17 = 14 marks)

18 This question is about the kinetics of the catalytic decomposition of hydrogen peroxide, H_2O_2, using manganese(IV) oxide as a catalyst.

The equation for the decomposition is shown.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

In an experiment, 10 cm^3 of hydrogen peroxide solution was added to 150 cm^3 of distilled water. A small amount of manganese(IV) oxide granules was added and the clock started.

Every 5 minutes, 10 cm^3 samples of the reaction mixture were withdrawn using a pipette and transferred to a conical flask.

The samples were then acidified with dilute sulfuric acid and titrated with potassium manganate(VII) solution. The equation for the titration is shown.

$$2MnO_4^- + 5H_2O_2 + 6H^+ \rightarrow 2Mn^{2+} + 5O_2 + 8H_2O$$

The results of the experiment are given in the table.

Time / min	0	5	10	15	20	25	30
Volume of manganate(VII) / cm^3	32.5	24.8	18.9	13.9	10.5	8.1	6.5

(a) (i) The reaction in the sample stops immediately on removal from the reaction mixture.

Suggest why this occurs.

(1)

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(ii) State why it is not necessary to calculate the concentration of hydrogen peroxide solution when trying to deduce the order of reaction with respect to hydrogen peroxide.

(1)

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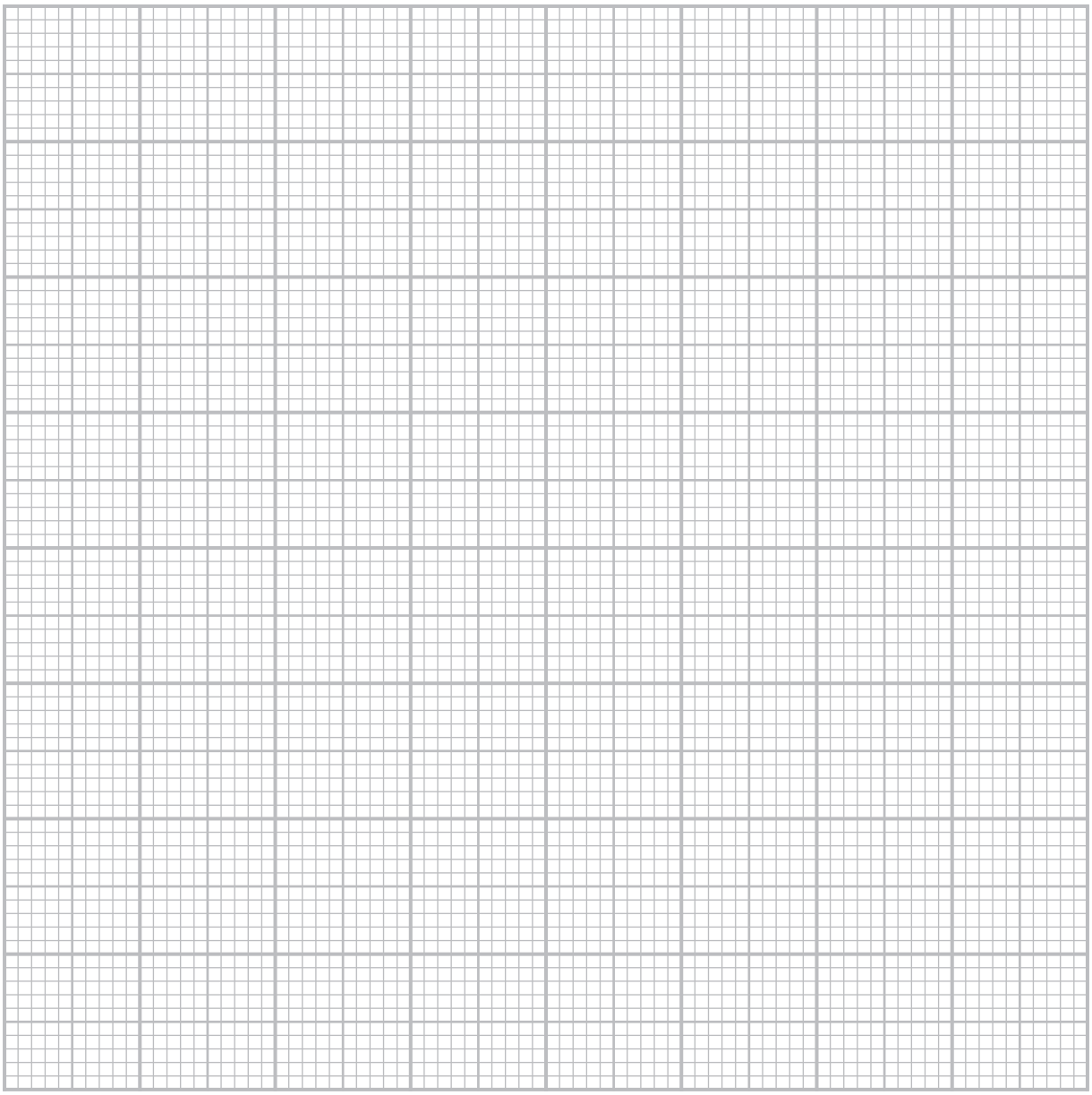
(iii) Plot a graph of the volume of potassium manganate(VII) solution against time.

(3)



(iv) Use your graph to show that the reaction is first order with respect to hydrogen peroxide. You must show your working on the graph.

(3)

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(b) Two possible mechanisms have been suggested by students carrying out this reaction.

Mechanism 1

Step 1 $2H_2O_2(aq) \rightarrow [H_4O_4](aq)$ (transition state) slow

Step 2 $[H_4O_4](aq) \rightarrow 2H_2O(l) + O_2(g)$ fast

Mechanism 2

Step 1 $H_2O_2 \rightarrow 2OH$ slow

Step 2 $H_2O_2 + OH \rightarrow H_2O + HO_2$ fast

Step 3 $HO_2 + OH \rightarrow H_2O + O_2$ fast

Explain whether or not these mechanisms are consistent with the reaction being first order.

(2)

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(Total for Question 18 = 10 marks)

TOTAL FOR SECTION B = 51 MARKS

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SECTION C

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

19 This question is about some copper compounds.

(a) Crystals of hydrated copper(II) sulfate, $CuSO_4 \cdot 5H_2O$, lose water when heated, forming anhydrous copper(II) sulfate, $CuSO_4$.

$$CuSO_4 \cdot 5H_2O(s) \rightarrow CuSO_4(s) + 5H_2O(l)$$

Substance	$CuSO_4 \cdot 5H_2O(s)$	$CuSO_4(s)$	$H_2O(l)$
Standard enthalpy of formation, $\Delta_f H^{\ominus}$ / kJ mol^{-1}	−2279.6	−771.4	−285.8
Standard molar entropy, $S^{\ominus}$ / J K^{-1} mol^{-1}	300.4	109.0	69.9

(i) Using the data in the table, calculate the standard enthalpy change, $\Delta_r H^{\ominus}$, for this reaction.

(2)

(ii) Using the data in the table, calculate the standard molar entropy change, $\Delta S^{\ominus}_{system}$, for this reaction.

(2)

(iii) Using your answers from (a)(i) and (a)(ii), calculate the **lowest** temperature at which hydrated copper(II) sulfate will decompose.

(3)

(b) Hydrated copper(II) sulfate is soluble in water. A student carried out an experiment to determine its enthalpy change of solution.

100 g of distilled water was placed in a polystyrene cup and the temperature recorded.

21.36 g of hydrated copper sulfate was added to the distilled water, the mixture stirred, and the minimum temperature recorded.

Using this data, the student's calculated enthalpy change of solution was $+12.3\ kJ\ mol^{-1}$.

Calculate the temperature change in this experiment.

[specific heat capacity of the solution is $3.7\ J\ g^{-1}\ °C$
total mass of solution = 121.36 g
molar mass of $CuSO_4 \cdot 5H_2O = 249.6\ g\ mol^{-1}$]

(4)

(c) Copper(II) chloride, $CuCl_2$, is another copper compound that is soluble in water. It is possible to calculate the enthalpy change of solution, $\Delta_{sol}H$, using a Hess cycle and the lattice energy and enthalpy changes of hydration, $\Delta_{hyd}H$.

(i) Explain what is meant by the term **enthalpy change of hydration**.

(2)

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(ii) Complete the Hess cycle by filling in the empty boxes.

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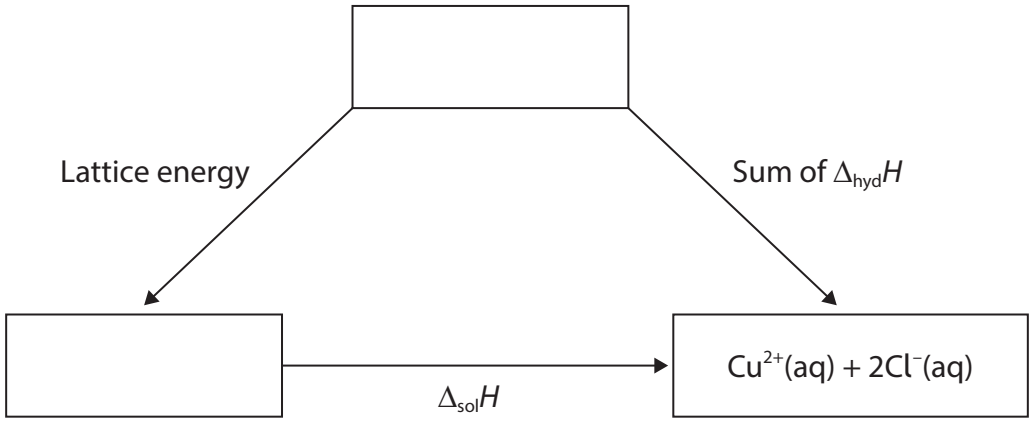

(iii) Complete the expression for the enthalpy change of solution using the enthalpy changes of hydration and lattice energy.

(1)

$\Delta_{sol}H =$

(iv) The lattice energy of copper(II) chloride is $-2811\ kJ\,mol^{-1}$.
Use this value, the data in the table, and your expression in (c)(iii) to calculate the enthalpy change of solution.

(2)

Ion	Enthalpy change of hydration / kJ mol^{-1}
Cu^{2+}	−2100
Cl^{-}	−378

(v) The enthalpy change of hydration of Cu^+ is $-593\,kJ\,mol^{-1}$.
Explain why the hydration enthalpy of Cu^+ is much less exothermic than Cu^{2+}.

(2)

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(Total for Question 19 = 19 marks)

TOTAL FOR SECTION C = 19 MARKS
TOTAL FOR PAPER = 90 MARKS

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The Periodic Table of Elements

1	2											3	4	5	6	7	0 (8)
																	(18)
							1.0 H hydrogen 1										4.0 He helium 2
(1)	(2)		Key									(13)	(14)	(15)	(16)	(17)	
6.9 Li lithium 3	9.0 Be beryllium 4		relative atomic mass atomic symbol name atomic (proton) number									10.8 B boron 5	12.0 C carbon 6	14.0 N nitrogen 7	16.0 O oxygen 8	19.0 F fluorine 9	20.2 Ne neon 10
23.0 Na sodium 11	24.3 Mg magnesium 12	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	27.0 Al aluminium 13	28.1 Si silicon 14	31.0 P phosphorus 15	32.1 S sulfur 16	35.5 Cl chlorine 17	39.9 Ar argon 18
39.1 K potassium 19	40.1 Ca calcium 20	45.0 Sc scandium 21	47.9 Ti titanium 22	50.9 V vanadium 23	52.0 Cr chromium 24	54.9 Mn manganese 25	55.8 Fe iron 26	58.9 Co cobalt 27	58.7 Ni nickel 28	63.5 Cu copper 29	65.4 Zn zinc 30	69.7 Ga gallium 31	72.6 Ge germanium 32	74.9 As arsenic 33	79.0 Se selenium 34	79.9 Br bromine 35	83.8 Kr krypton 36
85.5 Rb rubidium 37	87.6 Sr strontium 38	88.9 Y yttrium 39	91.2 Zr zirconium 40	92.9 Nb niobium 41	95.9 Mo molybdenum 42	[98] Tc technetium 43	101.1 Ru ruthenium 44	102.9 Rh rhodium 45	106.4 Pd palladium 46	107.9 Ag silver 47	112.4 Cd cadmium 48	114.8 In indium 49	118.7 Sn tin 50	121.8 Sb antimony 51	127.6 Te tellurium 52	126.9 I iodine 53	131.3 Xe xenon 54
132.9 Cs caesium 55	137.3 Ba barium 56	138.9 La* lanthanum 57	178.5 Hf hafnium 72	180.9 Ta tantalum 73	183.8 W tungsten 74	186.2 Re rhenium 75	190.2 Os osmium 76	192.2 Ir iridium 77	195.1 Pt platinum 78	197.0 Au gold 79	200.6 Hg mercury 80	204.4 Tl thallium 81	207.2 Pb lead 82	209.0 Bi bismuth 83	[209] Po polonium 84	[210] At astatine 85	[222] Rn radon 86
[223] Fr francium 87	[226] Ra radium 88	[227] Ac* actinium 89	[261] Rf rutherfordium 104	[262] Db dubnium 105	[266] Sg seaborgium 106	[264] Bh bohrium 107	[277] Hs hassium 108	[268] Mt meitnerium 109	[271] Ds darmstadtium 110	[272] Rg roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

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 mendelevium 101	[254] No nobelium 102	[257] Lr lawrencium 103

* Lanthanide series

* Actinide series

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GradeMax