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 22 October 2025

Afternoon (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

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 ▶

Pearson

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 Nitrogen dioxide, NO_2, is produced in the reaction shown.

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

The table shows the results of a series of experiments to measure the initial rate of this reaction at 298 K.

Experiment number	Initial concentration / mol dm^{-3}		Initial rate / mol dm^{-3} s^{-1}
	[NO]	[O_2]	
1	0.0125	0.0050	5.10×10^{-4}
2	0.0125	0.0100	10.2×10^{-4}
3	0.0250	0.0200	81.6×10^{-4}

What are the orders of reaction with respect to NO and O_2?

		NO	O_2
☒	**A**	first order	first order
☒	**B**	second order	first order
☒	**C**	first order	second order
☒	**D**	second order	second order

(Total for Question 1 = 1 mark)

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

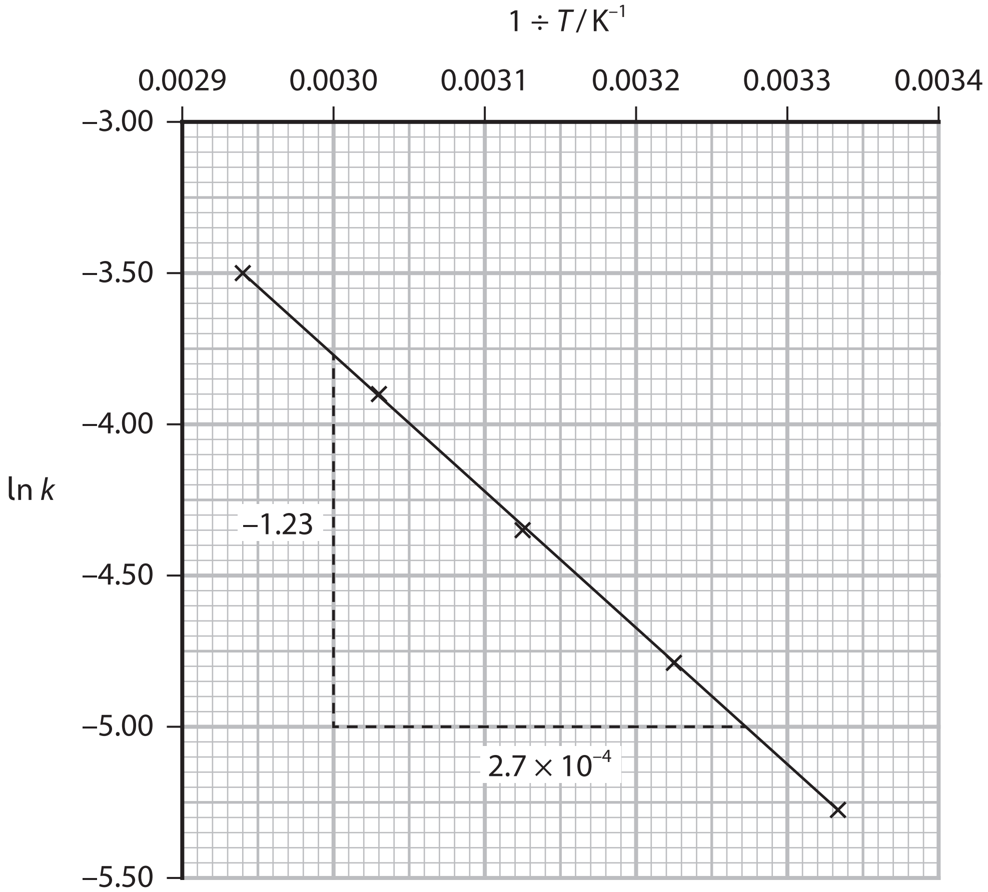
2 A series of experiments was carried out to determine the effect of temperature on the rate of the reaction between peroxodisulfate ions and iodide ions.

$$S_2O_8^{2-} + 2I^- \rightarrow 2SO_4^{2-} + I_2$$

A student plotted a graph of ln *k* against 1 ÷ *T* and used the gradient of the line of best fit to determine the activation energy, E_a, using the Arrhenius equation.

$$\ln k = -\frac{E_a}{RT} + \text{a constant}$$

The graph is shown.



Which is the expression for the activation energy for this reaction?

☒ **A** $-(-1.23 \div 2.7 \times 10^{-4}) \times 8.31$

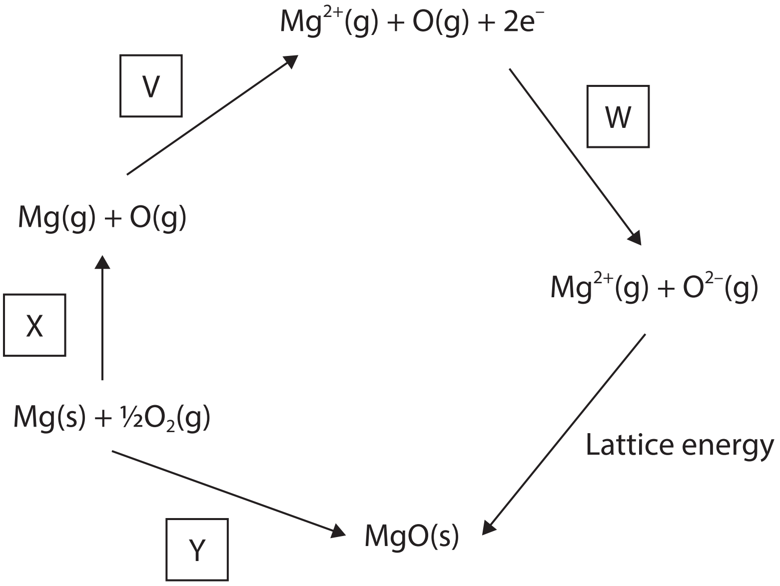
☒ **B** $-\dfrac{(-1.23 \div 2.7 \times 10^{-4})}{8.31}$

☒ **C** $-(2.7 \times 10^{-4} \div -1.23) \times 8.31$

☒ **D** $-\dfrac{(2.7 \times 10^{-4} \div -1.23)}{8.31}$

(Total for Question 2 = 1 mark)

3 The diagram shows how the lattice energy of magnesium oxide, MgO, can be calculated using a Born-Haber cycle. The diagram is not drawn to scale.



(a) Which arrow represents the energy change for a single chemical process rather than the sum of the energy changes for two processes?

(1)

☒ **A** arrow V

☒ **B** arrow W

☒ **C** arrow X

☒ **D** arrow Y

(b) Which arrow represents two energy changes, one exothermic and the other endothermic?

(1)

☒ **A** arrow V

☒ **B** arrow W

☒ **C** arrow X

☒ **D** arrow Y

(c) The theoretical value for the lattice energy of MgO is $-3795\,kJ\,mol^{-1}$, while the value obtained from the Born-Haber cycle is $-3791\,kJ\,mol^{-1}$.

The difference in these two values is small because

(1)

☒ **A** the magnesium ion is not very polarising

☒ **B** magnesium oxide contains significant covalent character

☒ **C** the oxide ion is not very polarisable

☒ **D** the ions are highly distorted in shape

(Total for Question 3 = 3 marks)

4 This question is about sodium chloride.

(a) Sodium chloride dissolves in water.

$$\text{NaCl(s)} + \text{(aq)} \rightarrow \text{Na}^+\text{(aq)} + \text{Cl}^-\text{(aq)} \qquad \Delta_{sol}H(\text{NaCl}) = +1.0\,\text{kJ mol}^{-1}$$

Which expression gives the enthalpy change of hydration for Cl^-, $\Delta_{hyd}H(Cl^-)$?

[Data: Lattice energy of NaCl = $\Delta_{LE}H(\text{NaCl})$
Enthalpy change of hydration for Na^+ = $\Delta_{hyd}H(Na^+)$]

(1)

☒ **A** $\Delta_{hyd}H(Cl^-) = \Delta_{sol}H(\text{NaCl}) - \Delta_{hyd}H(Na^+) + \Delta_{LE}H(\text{NaCl})$

☒ **B** $\Delta_{hyd}H(Cl^-) = \Delta_{sol}H(\text{NaCl}) + \Delta_{hyd}H(Na^+) + \Delta_{LE}H(\text{NaCl})$

☒ **C** $\Delta_{hyd}H(Cl^-) = -\Delta_{sol}H(\text{NaCl}) - \Delta_{hyd}H(Na^+) - \Delta_{LE}H(\text{NaCl})$

☒ **D** $\Delta_{hyd}H(Cl^-) = -\Delta_{sol}H(\text{NaCl}) - \Delta_{hyd}H(Na^+) + \Delta_{LE}H(\text{NaCl})$

(b) The dissolving of sodium chloride in water is thermodynamically feasible.

What may be deduced from this statement and the data in part (a)?

(1)

☒ **A** the activation energy for the reaction is small

☒ **B** the enthalpy change for $\Delta_{hyd}H(Na^+)$ is positive

☒ **C** the reaction has a positive entropy change of the surroundings

☒ **D** the reaction has a positive entropy change of the system

(Total for Question 4 = 2 marks)

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5 What are the pH values of these solutions?

(a) 2.0 mol dm^{-3} nitric acid.

(1)

☒ **A** +2.0

☒ **B** +0.3

☒ **C** –0.3

☒ **D** –2.0

(b) 0.2 mol dm^{-3} barium hydroxide solution.

[Data: K_w = 1.0 × 10^{-14} mol^2 dm^{-6} at 25 °C]

(1)

☒ **A** 0.4

☒ **B** 13.0

☒ **C** 13.3

☒ **D** 13.6

(c) The solution formed when 20 cm^3 of 0.50 mol dm^{-3} sodium hydroxide is mixed with 20 cm^3 of 1.00 mol dm^{-3} hydrochloric acid.

(1)

☒ **A** 0.0

☒ **B** 0.3

☒ **C** 0.6

☒ **D** 7.0

(d) The solution formed when 20 cm^3 of 1.00 mol dm^{-3} sodium hydroxide is mixed with 40 cm^3 of 1.00 mol dm^{-3} ethanoic acid.

[Data: K_a ethanoic acid = 1.75 × 10^{-5} mol dm^{-3} at 25 °C]

(1)

☒ **A** 2.4

☒ **B** 2.5

☒ **C** 4.8

☒ **D** 5.2

(Total for Question 5 = 4 marks)

6 The mechanism for the reaction between bromoalkanes and hydroxide ions to form alcohols is either S_N1 or S_N2. The reaction mechanism depends on the stability of the intermediate carbocation formed, and the steric hindrance of the halogenoalkane.

Steric hindrance is where large groups bonded to the carbon of the C—Br bond block the attack by the hydroxide ion.

(a) Which statement is correct for the reactions of **primary** halogenoalkanes?

(1)

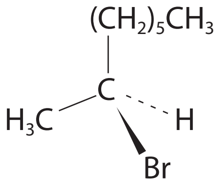
☒ **A** S_N1 because they readily form a carbocation

☒ **B** S_N1 because they have little steric hindrance

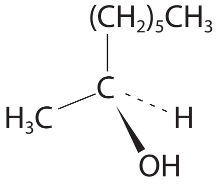
☒ **C** S_N2 because they readily form a carbocation

☒ **D** S_N2 because they have little steric hindrance

(b) 2-Bromooctane is chiral. One isomer is shown.

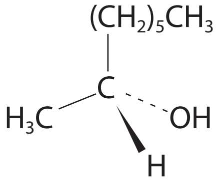


The possible products of nucleophilic substitution of this isomer are



enantiomer 1

and



enantiomer 2

Nucleophilic substitution for 2-bromooctane occurs by both S_N1 and S_N2 at the same time.

Which best describes the organic product of this reaction?

(1)

☒ **A** a racemic mixture of the two alcohol enantiomers

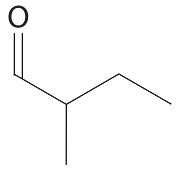
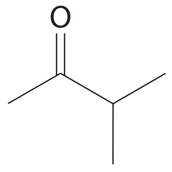
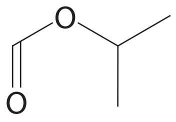
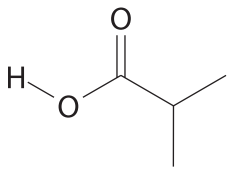
☒ **B** enantiomer 2 only

☒ **C** a mixture containing more of enantiomer 1 than enantiomer 2

☒ **D** a mixture containing more of enantiomer 2 than enantiomer 1

(Total for Question 6 = 2 marks)

7 The four compounds shown all contain a $C=O$ group.

			
P	**Q**	**R**	**S**

(a) Which will react with 2,4-dinitrophenylhydrazine?

(1)

☒ **A** compound **P** only

☒ **B** compounds **P** and **Q** only

☒ **C** compounds **R** and **S** only

☒ **D** all four compounds

(b) Which contain a chiral carbon atom?

(1)

☒ **A** compound **P** only

☒ **B** compounds **P** and **R** only

☒ **C** compounds **Q**, **R** and **S** only

☒ **D** all four compounds

(c) Which will react with lithium tetrahydridoaluminate(III) in dry ether to produce a secondary alcohol?

(1)

☒ **A** compound **Q** only

☒ **B** compounds **P** and **Q** only

☒ **C** compounds **P** and **S** only

☒ **D** compounds **Q** and **S** only

(Total for Question 7 = 3 marks)

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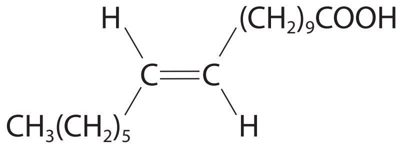
8 Vaccenic acid is a long-chain fatty acid found in dairy products such as yoghurt.



(a) The IUPAC name for vaccenic acid is

(1)

☒ **A** *E*-octadec-7-enoic acid

☒ **B** *Z*-octadec-7-enoic acid

☒ **C** *E*-octadec-11-enoic acid

☒ **D** *Z*-octadec-11-enoic acid

(b) Which ion is most likely to cause a peak at $m/z = 45$ in the mass spectrum of vaccenic acid?

(1)

☒ **A** $[CH_3CH_2CH_2]^+$

☒ **B** $[COOH]^+$

☒ **C** $[CH_2CH{=}CH]^+$

☒ **D** $[CH_2CH_2OH]^+$

(c) What would you expect to see if samples of vaccenic acid are tested separately with bromine water and phosphorus(V) chloride?

(1)

		Bromine water	Phosphorus(V) chloride
☒	**A**	decolorises	misty fumes
☒	**B**	no colour change	misty fumes
☒	**C**	decolorises	no visible change
☒	**D**	no colour change	no visible change

(d) Which intermolecular forces are present between vaccenic acid molecules?

(1)

☒ **A** hydrogen bonds only

☒ **B** hydrogen bonds and London forces only

☒ **C** hydrogen bonds and permanent dipole-dipole forces only

☒ **D** hydrogen bonds, permanent dipole-dipole forces and London forces

(Total for Question 8 = 4 marks)

TOTAL FOR SECTION A = 20 MARKS

SECTION B

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

9 Crystals of hydrated cobalt(II) chloride, $CoCl_2{\bullet}6H_2O$, lose water when they are heated, forming anhydrous cobalt(II) chloride, $CoCl_2$.

$$CoCl_2{\bullet}6H_2O(s) \rightarrow CoCl_2(s) + 6H_2O(l)$$

(a) (i) Calculate the entropy change of the system, $\Delta S^{\ominus}_{system}$, at 298 K.
Include a sign and units in your answer.

[Data: $S^{\ominus}$ values ($J\,K^{-1}\,mol^{-1}$) $CoCl_2{\bullet}6H_2O = +343$ $CoCl_2 = +109.2$ $H_2O = +69.9$]

(2)

(ii) State whether the sign of your answer in (a)(i) is as expected from the equation for the reaction.
Justify your answer.

(1)

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(b) The standard enthalpy change of the reaction, $\Delta_r H^{\ominus}$, is $+88.1\,kJ\,mol^{-1}$.

Calculate the entropy change of the surroundings, $\Delta S^{\ominus}_{surroundings}$, at 298 K for this reaction.
Include a sign and units in your answer.

(2)

(c) State whether or not the decomposition is feasible at 298 K.
Justify your answer.

(1)

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(d) Calculate the lowest temperature, in **K**, at which the thermal decomposition of hydrated cobalt(II) chloride becomes feasible.

(2)

(Total for Question 9 = 8 marks)

10 Brønsted and Lowry defined acids and bases in terms of the transfer of a proton between two species.

(a) (i) Write the equation which shows how a compound HA can act as a Brønsted-Lowry acid when dissolved in water.
State symbols are not required.

(1)

(ii) When HA dissolves in water, the acidity of the resulting solution is measured using the pH scale. This depends on the number of moles of protons transferred.

Give the mathematical expression used to determine the value of pH.

(1)

(iii) Ethanoic acid, CH_3COOH, is a weak acid.

Write an expression for the acid dissociation constant of **ethanoic acid**.

(1)

(iv) Give the mathematical expression used to calculate the concentration of hydrogen ions in a solution containing **ethanoic acid**.

(1)

(v) Calculate the pH of an aqueous solution of 0.25 mol dm^{-3} ethanoic acid.

[Data: K_a ethanoic acid = 1.75×10^{-5} mol dm^{-3} at 25 °C]

(2)

(b) The pH values of aqueous solutions of hydrochloric acid and ethanoic acid at three different concentrations are shown in the table.

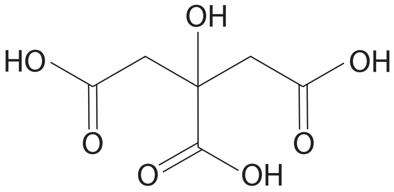
Concentration / mol dm^{-3}	0.100	0.010	0.001
pH of hydrochloric acid	1.00	2.00	3.00
pH of ethanoic acid	2.88	3.38	3.88

The effect on pH of changing the concentrations of the two acids is different.

Explain this difference.
No further calculations are required.

(4)

(c) Marmalades are foodstuffs made from citrus fruit which contain the weak acid, citric acid.



citric acid

Sodium citrate, the sodium salt of citric acid, is usually added to marmalades.

Suggest the benefit of adding sodium citrate to the marmalade.

(3)

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(Total for Question 10 = 13 marks)

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11 Iodine reacts with propanone very slowly in neutral solutions, but much more rapidly in acidic or alkaline solutions.

The reaction in acidic solution is

$$CH_3COCH_3(aq) + I_2(aq) \rightarrow CH_3COCH_2I(aq) + H^+(aq) + I^-(aq)$$

The reaction rate was studied using the procedure shown.

Procedure

Step **1** 0.1 mol of propanone and 0.01 mol of hydrochloric acid, in a total volume of 90 cm^3 of water, were placed in a flask at a constant temperature.

Step **2** 0.0004 mol of iodine in 10 cm^3 of water was added and a timer started. Simultaneously, a 10 cm^3 sample of solution was withdrawn.

Step **3** The sample was neutralised using excess sodium hydrogencarbonate solution.

Step **4** At 10-minute intervals, further 10 cm^3 samples of the mixture were withdrawn and neutralised by adding excess sodium hydrogencarbonate solution.

Step **5** All the samples were titrated with 0.01 mol dm^{-3} sodium thiosulfate solution.

The rate equation for this reaction is shown.

$$\text{Rate} = k[CH_3COCH_3][HCl]$$

(a) State the overall order of this reaction.

(1)

....

(b) The procedure demonstrates the effect of changing the concentration of iodine on the reaction rate.

(i) State why propanone and hydrochloric acid are in a large excess compared to iodine.

(1)

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(ii) Explain how the results could be used to demonstrate that the order with respect to iodine is zero.

(2)

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(iii) Sodium hydrogencarbonate is used to neutralise the acid.

Write an **ionic** equation for the reaction, including state symbols.

(2)

(iv) Give a reason why sodium hydroxide cannot be used to neutralise the acid in this experiment.

(1)

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(c) The rate of reaction is first order with respect to hydrochloric acid.

Describe, without giving experimental detail, how you would show that this was due to the hydrogen ion rather than the chloride ion.

(2)

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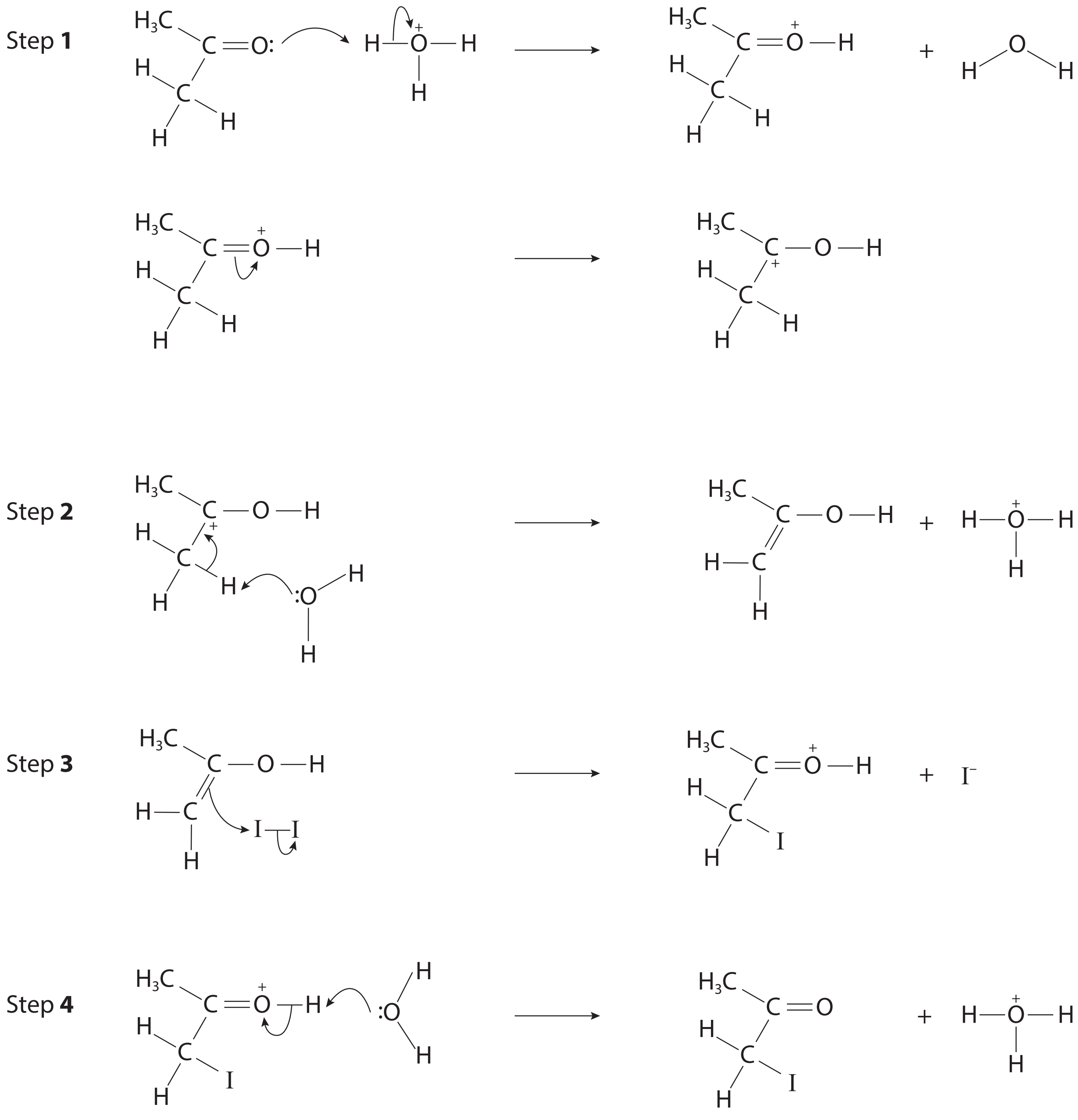
(d) The steps shown have been suggested as the mechanism for this reaction.
The rate of reaction is determined by the rate of the slowest step, the rate-determining step.
The acid H^+ ion is shown in the mechanism as H_3O^+.



(i) Explain why the rate-determining step must be Step **1** or Step **2** but cannot be Step **3**.

(2)

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(ii) Suggest a reason why Step **2** is the rate-determining step, rather than Step **1**.

(1)

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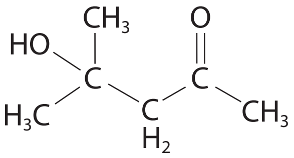
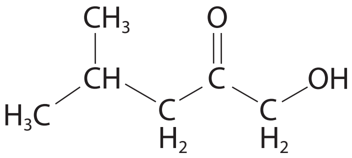
(Total for Question 11 = 12 marks)

12 The two isomeric compounds shown can be studied using NMR spectroscopy.



Compound **P**



Compound **Q**

(a) Give the IUPAC name for Compound **Q**.

(1)

....

(b) Explain why the ^{13}C NMR spectra of compounds **P** and **Q** can not be used to distinguish between them.

(2)

....

....

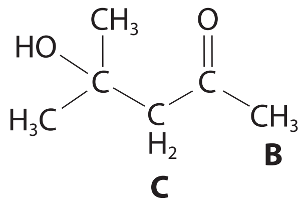
....

....

(c) The high resolution ^1H NMR spectrum of Compound **P** contains four peaks, while that of Compound **Q** contains five peaks.

(i) Some data for Compound **P** are shown.

Peak	**A**	**B**	**C**	**D**
Chemical shift / ppm	1.3	2.2	2.6	3.8
Splitting pattern	singlet	singlet	singlet	singlet
Relative peak area				

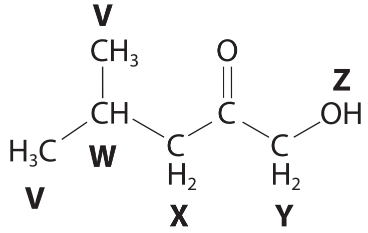


Complete the table for Compound **P**.

(2)

(ii) Some data for Compound **Q** are shown.

Peak	**V**	**W**	**X**	**Y**	**Z**
Chemical shift / ppm	0.95	2.2	2.3		3.2
Splitting pattern		multiplet			
Relative peak area	6	1	2	2	1



Complete the table for Compound **Q**.

(3)

(Total for Question 12 = 8 marks)

13 Compounds **S** and **T** are isomers containing carbon, hydrogen and oxygen only. They are non-cyclic, unbranched compounds containing four carbon atoms and two functional groups.
A series of tests was performed on separate samples of these compounds.

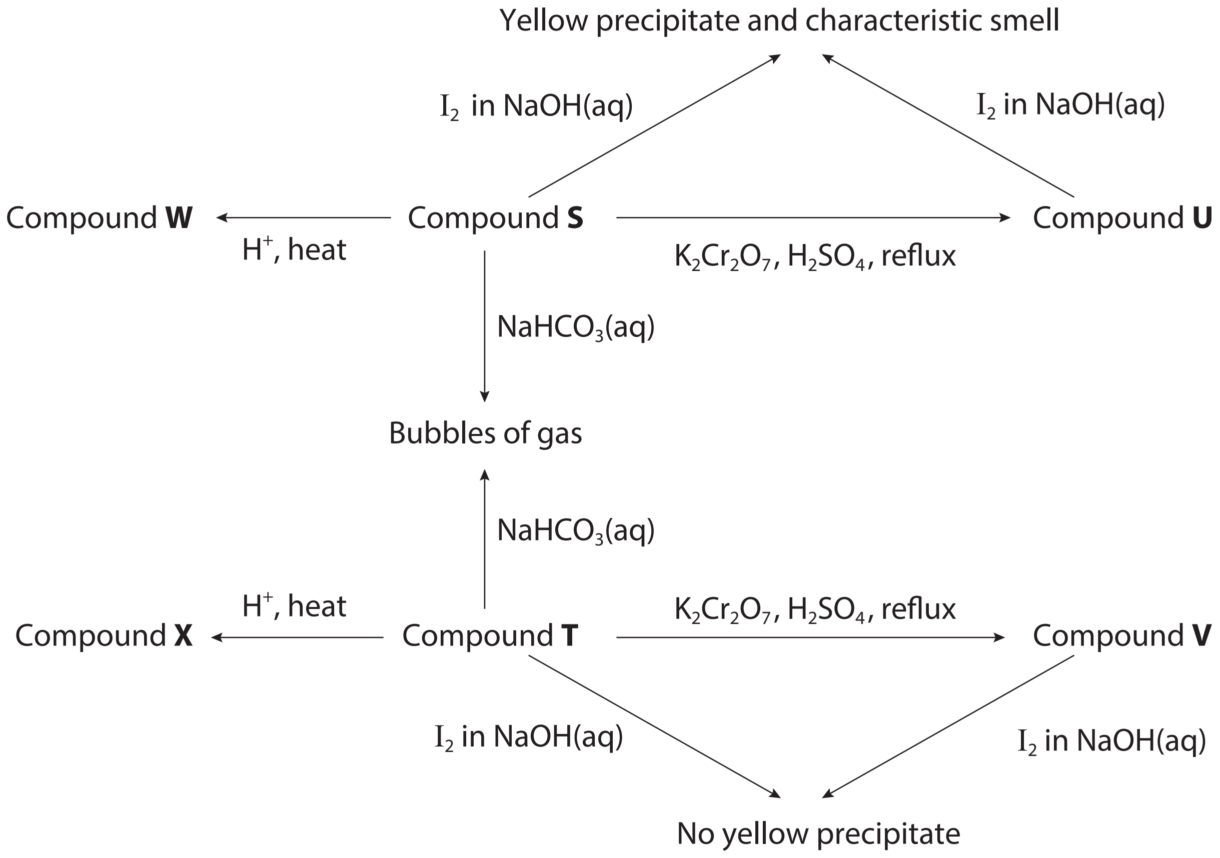
On reaction with sodium hydrogencarbonate solution, both **S** and **T** produced bubbles of gas.

On refluxing with acidified potassium dichromate(VI), both **S** and **T** produced a colour change from orange to green.
Compound **U** was obtained from the reaction of **S**.
Compound **V** was obtained from the reaction of **T**.

On heating both **S** and **T** in the presence of an acid catalyst, compounds **W** and **X** were formed.
W and **X** are cyclic compounds with the same functional group.

On warming with iodine in sodium hydroxide solution, **S** and **U** gave a yellow precipitate but **T** and **V** did not.

These reactions are summarised in the diagram.



*(a) Name the **functional groups** present in **S**, **T**, **U**, **V**, **W** and **X**.
Justify your answers using the results of **all** these tests.

(6)

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(b) Deduce a structure of compounds **S**, **T**, **U**, **V**, **W** and **X** using all the information in the question.

(3)

S	**T**
U	**V**
W	**X**

(Total for Question 13 = 9 marks)

TOTAL FOR SECTION B = 50 MARKS

SECTION C

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

14 This question is about equilibria.

One step in the manufacture of sulfuric acid is shown.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad K_c = 7.94 \times 10^4\ \text{dm}^3\ \text{mol}^{-1}$$

This equilibrium is not reached at a significant rate if a catalyst is not present. The original catalyst for this process was platinum metal, but this has since been replaced by vanadium(V) oxide.

(a) (i) State what is meant by the term ‘dynamic equilibrium’.

(2)

(ii) Explain why a high pressure might be expected for this step but given the value of K_c, a low pressure of 2 atm is used.
Include reference to the extent of the reaction in your answer.

(4)

(iii) Explain the effect, if any, on the value of K_c when the catalyst is changed from platinum metal to vanadium(V) oxide.

(2)

....

....

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(b) A reaction vessel containing platinum metal was filled with 2.00 mol of SO_2 and 1.00 mol of O_2.
After a short time the vessel was found to contain 1.20 mol of SO_3.
The total pressure was 3.00 atm.

Under these conditions at equilibrium

$$K_p = \frac{p(SO_3)^2}{p(SO_2)^2\ p(O_2)} = 35.2\,\text{atm}^{-1}$$

Show by calculation that the system was **not** yet at equilibrium.

(4)

(c) After allowing the contents of the vessel to reach equilibrium, the temperature was increased and a new equilibrium established.
The value of K_p at the higher temperature was lower.

(i) Explain how changes in the partial pressures of reactants and products, due to the change in temperature, result in a decrease in the value of K_p.
You should refer to the expression for K_p in your answer.

(2)

(ii) State what can be deduced about the values of enthalpy change and entropy change from this decrease in K_p.

(3)

(d) On heating, silver carbonate decomposes according to the equation shown.

$$Ag_2CO_3(s) \rightleftharpoons Ag_2O(s) + CO_2(g)$$

(i) Write the expression for the equilibrium constant, K_c, for this reaction.

(1)

(ii) K_c and K_p for this reaction are linked mathematically by the expression

$$K_c = K_p(RT)^{-1}$$

Silver carbonate is heated to a temperature of 450 K in a closed vessel.
At this temperature $K_p = 1.48$ atm and $R = 8.2053 \times 10^{-2}$ dm^3 atm mol^{-1} K^{-1}.

Calculate K_c under these conditions and include units.

(2)

Units ....

(Total for Question 14 = 20 marks)

TOTAL FOR SECTION C = 20 MARKS
TOTAL FOR PAPER = 90 MARKS

The Periodic Table of Elements

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

1	2											3	4	5	6	7	0 (8)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
							1.0 **H** hydrogen 1										4.0 **He** helium 2
6.9 **Li** lithium 3	9.0 **Be** beryllium 4											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											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

* Lanthanide 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
* Actinide series	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