Pearson Edexcel International Advanced Level

Friday 9 January 2026

Afternoon (Time: 1 hour 45 minutes)

Paper reference WCH14/01A

▲ △

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

You must have:
Answer Book (sent separately)
Scientific calculator, Data Booklet, ruler

Turn over ▶

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C:1/1/1/1/1/

P 8 7 6 2 6 A

Pearson

SECTION A

Answer ALL the questions in this section in the Answer Book.

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 ☒ in the Answer Book. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1   The halogenoalkane, 2-bromo-2-methylbutane, was hydrolysed with sodium hydroxide solution, NaOH(aq).

Which suggestion about the mechanism of this reaction is correct?

	Type of mechanism	Number of steps in mechanism
A	S_N2	one
B	S_N2	two
C	S_N1	one
D	S_N1	two

(Total for Question 1 = 1 mark)

2   Which of these gases would have the greatest standard molar entropy?

A H_2

B N_2

C NH_3

D SO_2

(Total for Question 2 = 1 mark)

3   Which of these changes has the largest **increase** in the entropy of the system?

A $H_2O(s) \rightarrow H_2O(l)$

B $Hg(l) \rightarrow Hg(g)$

C $C(graphite) \rightarrow C(diamond)$

D $H_2O(l) + HCl(g) \rightarrow H_3O^+(aq) + Cl^-(aq)$

(Total for Question 3 = 1 mark)

4 What is the standard entropy change of the system, in $J\,K^{-1}\,mol^{-1}$, for the reaction between nitrogen and hydrogen to form ammonia?

$$N_2 + 3H_2 \rightarrow 2NH_3$$
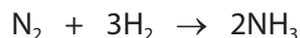
	Standard molar entropy / $J\,K^{-1}\,mol^{-1}$
H_2	130.6
N_2	191.6
NH_3	192.3

A −198.8

B −129.9

C +129.9

D +198.8

(Total for Question 4 = 1 mark)

5 The enthalpy change of solution of sodium sulfate, Na_2SO_4, may be calculated using three pieces of data.

Which of these pieces of data is **not** required?

A lattice energy of Na_2SO_4

B enthalpy change of formation of Na_2SO_4

C enthalpy change of hydration of Na^+

D enthalpy change of hydration of SO_4^{2-}

(Total for Question 5 = 1 mark)

6 Equal amounts of W and X are mixed and allowed to reach equilibrium.

$$W + X \rightarrow Y + Z$$
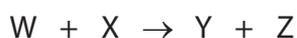
The value of the equilibrium constant $K_c = 4.85$.
At equilibrium, the mixture will contain

A almost all Y and Z

B almost all W and X

C W, X, Y and Z but there is less Y and Z than W and X

D W, X, Y and Z but there is more Y and Z than W and X

(Total for Question 6 = 1 mark)

7 A student carried out an experiment to determine the equilibrium constant for the reaction to form ethyl ethanoate from ethanol and ethanoic acid.

$$CH_3COOH + CH_3CH_2OH \rightleftharpoons CH_3COOCH_2CH_3 + H_2O$$
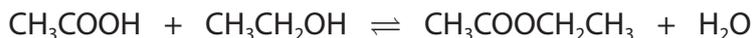
Different amounts of each substance were added to conical flasks, each containing $2.0\,cm^3$ of $1.0\,mol\,dm^{-3}$ hydrochloric acid as shown in the table.

Conical flask	Volume added / cm^3				
	HCl (aq)	H_2O (l)	CH_3COOH (l)	$CH_3COOCH_2CH_3$ (l)	CH_3CH_2OH (l)
1	2.0	1.0	0	2.0	0
2	2.0	0	5.0	0	5.0
3	2.0	0	4.0	0	3.0
4	2.0	0	0	3.0	0

The flasks were then stoppered and left for a week to reach equilibrium.

Each mixture was then titrated with $1.0\,mol\,dm^{-3}$ sodium hydroxide.

(a) In which flask(s) was the equilibrium approached from the right-hand side of the equation?

(1)

    A   flask 1 only

    B   flask 4 only

    C   flasks 1 and 4 only

    D   flasks 2 and 3 only

(b) Which of these statements is the **best** explanation for the ability to titrate reaction mixture directly to find the equilibrium concentrations?

(1)

    A   the equilibrium reaction is slow

    B   the sodium hydroxide quickly hydrolyses the ester

    C   all the reactant concentrations remain constant during the titration
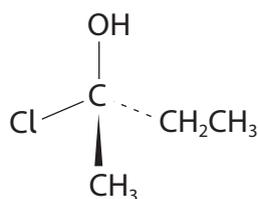
    D   a buffer solution forms in the reaction
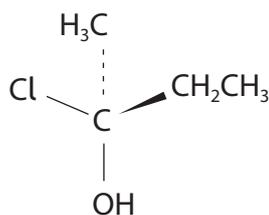
(Total for Question 7 = 2 marks)

8 What is the similarity between 20 cm³ of 0.05 mol dm⁻³ H_2SO_4(aq) and 20 cm³ of 0.10 mol dm⁻³ CH_3COOH(aq)?

  A   they have the same pH

  B   they have the same total concentration of ions

  C   they have the same total concentration of negative ions

  D   they are neutralised by 20 cm³ of 0.10 mol dm⁻³ NaOH(aq)

(Total for Question 8 = 1 mark)

9 Which of these structures is not identical to the others?

Structure A: central C with OH (top), Cl (left), CH_2CH_3 (right), CH_3 (bottom, bold wedge)

Structure B: central C with H_3C (top), Cl (left, dashed), CH_2CH_3 (right, bold wedge), OH (bottom)

Structure C: central C with OH (top), Cl (left, dashed), CH_2CH_3 (right, bold wedge), CH_3 (bottom)

Structure D: central C with OH (top), H_3CH_2C (left, dashed), Cl (right, dashed), H_3C (bottom, bold wedge)
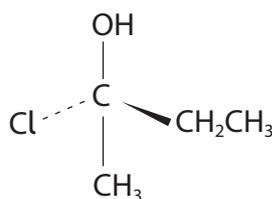
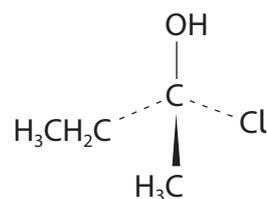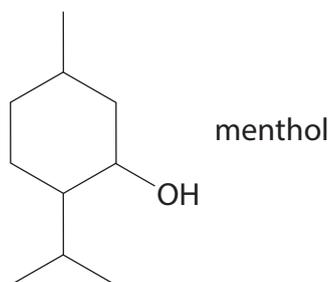| | | | |
| Structure A | Structure B | Structure C | Structure D |

  A   Structure A

  B   Structure B

  C   Structure C

  D   Structure D

(Total for Question 9 = 1 mark)

10 The compound menthol has the structure shown.

menthol

(a) What is the number of chiral centres in a molecule of menthol?

(1)

   A   1

   B   2

   C   3

   D   4

(b) Four groups of students warmed samples of menthol with sodium dichromate(VI) in acid.

They purified the reaction mixture and carried out a series of tests on the organic product.

The findings of each group are shown.

Group	Qualitative test		
	Add 2,4-dinitrophenylhydrazine	Warm with Fehling's solution	Add PCl_5
One	✓	✗	✓
Two	✓	✗	✗
Three	✓	✓	✗
Four	✗	✗	✓

A tick shows a positive result; a cross shows a negative result.
Which group recorded the results expected?

(1)

   A   One

   B   Two

   C   Three

   D   Four

(Total for Question 10 = 2 marks)

11 This question is about four organic compounds, each with five carbon atoms but different functional groups.

Compound	Skeletal formula
1	
2	
3	
4	
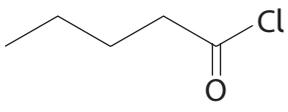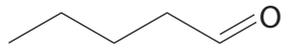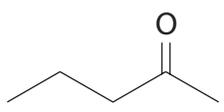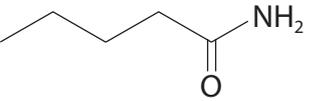
(a) Which compound, when mixed with water, produces the solution with the **lowest** pH?

(1)

   A   compound 1

   B   compound 2

   C   compound 3

   D   compound 4

(b) Which compound reacts with ethylamine, $CH_3CH_2NH_2$, to form an N-substituted amide?

(1)

   A   compound 1

   B   compound 2

   C   compound 3

   D   compound 4

(c) Which compound reacts with aqueous iodine and sodium hydroxide to form a pale yellow precipitate?

(1)

   A   compound 1

   B   compound 2

   C   compound 3

   D   compound 4

(Total for Question 11 = 3 marks)

12 Which of these compounds reacts directly with ethanoic acid to form ethanoyl chloride?

    A   chlorine

    B   chloroethane

    C   hydrogen chloride

    D   phosphorus(V) chloride

(Total for Question 12 = 1 mark)

13 The compound HOOCCH=CHCOOH reacts with excess sodium hydroxide solution. What is the organic product formed in this reaction?

    A   NaOOCCH=CHCOONa

    B   HOOCCH=CHCOONa

    C   NaOOCC(OH)HC(OH)HCOONa

    D   NaOOCCH=CHCHO

(Total for Question 13 = 1 mark)

14 A polymer is prepared by the reaction between hexanedioyl chloride and hexane-1-6-diamine. What is the type of polymerisation?

    A   addition

    B   condensation

    C   free-radical

    D   substitution

(Total for Question 14 = 1 mark)

15 This question is about four ionic compounds.

(a) Which of these compounds would be expected to have the **least** exothermic lattice energy?

(1)

    A   calcium chloride

    B   magnesium chloride

    C   potassium bromide

    D   sodium bromide

(b) Which of these compounds would be expected to have the **largest** difference between their experimental (Born–Haber) and theoretical lattice energies?

(1)

    A   calcium chloride

    B   magnesium chloride

    C   potassium bromide

    D   sodium bromide

(Total for Question 15 = 2 marks)

TOTAL FOR SECTION A = 20 MARKS

Turn over ▶

SECTION B

Answer ALL questions in the Answer Book provided.

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

$$Na_2S_2O_3 + 2HCl \rightarrow 2NaCl + SO_2 + S + H_2O$$

(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 ($1 \div t$) was used as a measure of the rate of the reaction.

sodium thiosulfate and hydrochloric acid

white paper with large black 'X'
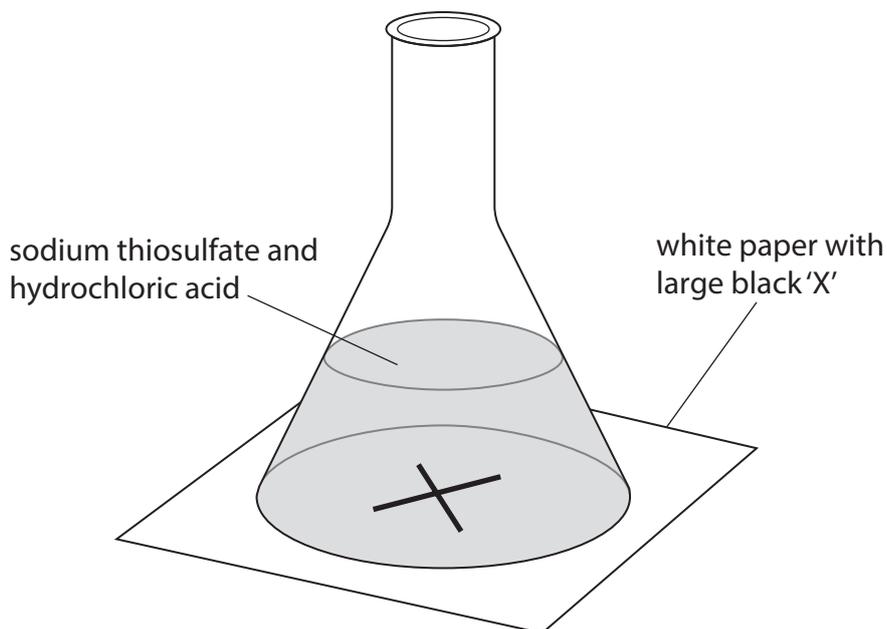
(i) State why the solution becomes cloudy.

(1)

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

(2)

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

Temperature (T) / K	$1 \div T$ / K^{-1}	Time (t) / s	$1 \div t$ / s^{-1}	$\ln(1 \div t)$
298		58		
308	3.25×10^{-3}	36	0.0278	−3.58
317	3.15×10^{-3}	23	0.0435	−3.14
328	3.05×10^{-3}	14	0.0714	−2.64
338	2.96×10^{-3}	9	0.1111	−2.20

(i) Complete the table in the Answer Book.

(2)

(ii) Determine the activation energy, E_a, in **kJ mol⁻¹**, by plotting a graph of $\ln(1 \div t)$ against $1 \div T$ on the grid in your Answer Book.

You should include the value of the gradient of the line and its units.

The Arrhenius equation for this experiment can be expressed as

$$\ln(1 \div t) = -\frac{E_a}{R} \times \frac{1}{T} + \text{constant} \qquad R = 8.31\,JK^{-1}mol^{-1}$$

(7)

(c) Another series of experiments was carried out at constant temperature to determine the order of reaction with respect to thiosulfate ions, $S_2O_3^{2-}$.

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 ($1 \div t$) as a measure of rate.
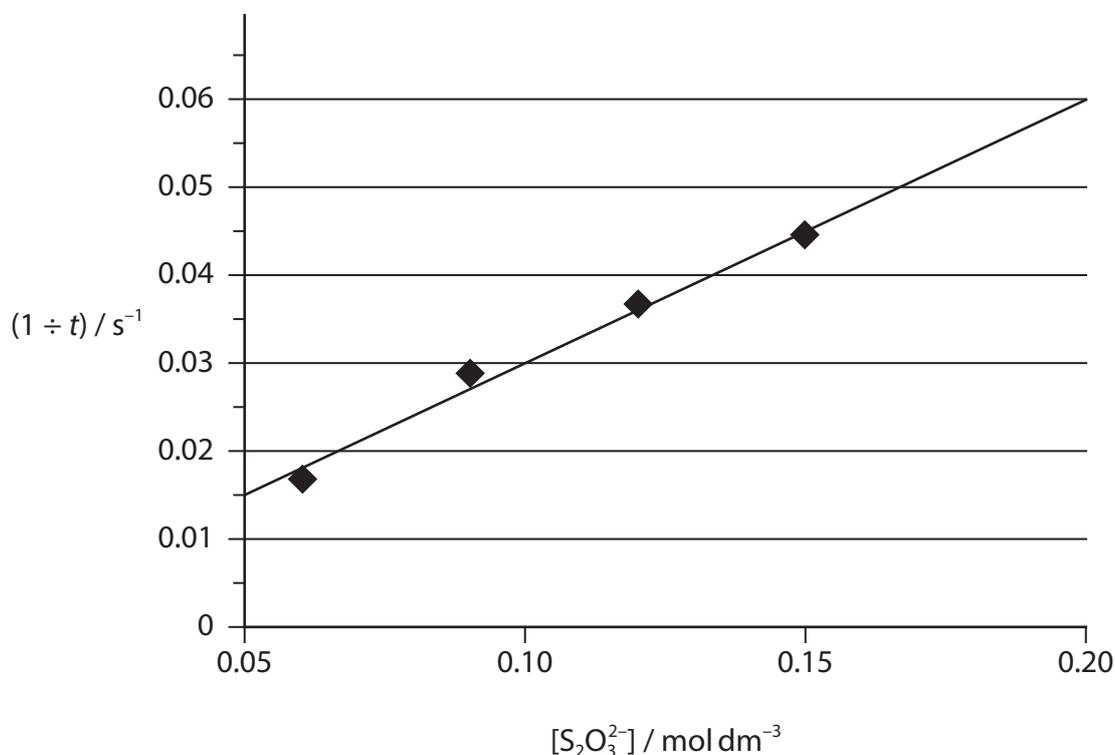
(i) Suggest why the acid used in these experiments was in considerable excess.

(1)

(ii) State the order of reaction with respect to sodium thiosulfate.
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 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)

(ii) The reaction is first order with respect to H^+ ions.
Suggest the formula of the intermediate formed during the rate-determining step. Use your answer to (c)(ii).

(1)

(Total for Question 16 = 17 marks)

17 Nitrosyl chloride, NOCl, is a yellow gas which decomposes on heating.

$$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g) \qquad \Delta H^\ominus = +52.2\,kJ\,mol^{-1}$$
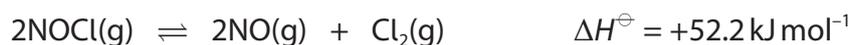
(a) A sample of 2.00 mol of NOCl was heated in a sealed vessel to a certain temperature, T.

The volume of the vessel was 4.00 dm^3. When equilibrium was reached, 0.222 mol of NO had been formed.

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

(1)

(ii) Calculate the value of K_c under these conditions.
Give your answer to an appropriate number of significant figures.
Include units.

(4)

(b) (i) Explain why the total entropy change, ΔS_{total}, becomes less negative as the temperature increases.

(2)

(ii) Explain how the equilibrium constant changes as the temperature increases. Justify your answer.

(2)

(iii) Calculate the minimum temperature, in kelvin, to which the nitrosyl chloride must be heated for the reaction to be feasible.

[Data: $\Delta S^\ominus_{system}$, $= +40.4\,J\,K^{-1}\,mol^{-1}$]

(2)

(Total for Question 17 = 11 marks)

*18 Compare and contrast the reactions of propanal and propanone with
one oxidising agent, **one** reducing agent and 2,4-dinitrophenylhydrazine.

In your answer include any relevant observations for the reactions you discuss and
equations for any reactions classified as oxidation, using [O] for the oxygen from the
oxidising agent.

(6)

(Total for Question 18 = 6 marks)

19 This is a question about butanone, $CH_3CH_2COCH_3$.

(a) Butanone is fairly soluble in water due to a strong intermolecular force between
butanone molecules and water molecules.

Complete the diagram in the Answer Book by adding **one** water molecule to
show the intermolecular force between butanone and water.
Include relevant dipoles and lone pairs. Label the intermolecular force.

(3)

(b) Butanone can be converted into 2-hydroxy-2-methylbutanoic acid,
$CH_3CH_2C(OH)(CH_3)COOH$, in two steps.
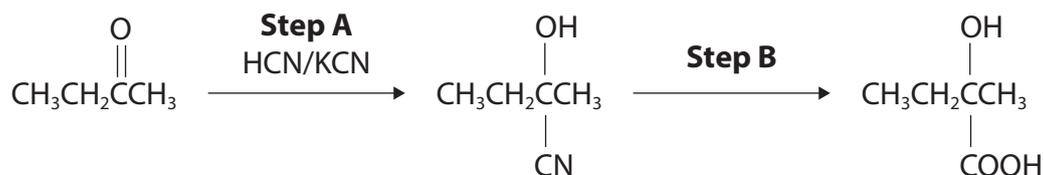
(i) State the type and mechanism of the reaction taking place in **Step A**.

(2)

(ii) Identify the reagent(s) and conditions for the reaction taking place in **Step B**.

(2)

(iii) The incomplete mechanism for **Step A** is shown in the Answer Book. Draw the curly arrows **and** the relevant lone pairs of electrons to complete the mechanism in the Answer Book.

(3)

(iv) Explain why the 2-hydroxy-2-methylbutanoic acid produced in this reaction is **not** optically active.

(3)

(v) Draw **two** repeat units of the polymer that could be formed from **only** 2-hydroxy-2-methylbutanoic acid.

(2)

(Total for Question 19 = 15 marks)

TOTAL FOR SECTION B = 49 MARKS

SECTION C

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

20 Benzoic acid is a weak acid used as a food preservative.

Data: Structural formula C_6H_5COOH

Molar mass = 122.1 g mol^{-1}

Solubility in water at 25 °C = 3.44 g dm^{-3}

Solubility in water at 100 °C = 56.3 g dm^{-3}

pK_a = 4.20

(a) (i) Write the equation for the dissociation of benzoic acid in water. Include state symbols.

(1)

(ii) Write the K_a expression for benzoic acid.

(1)

(iii) Calculate the pH of a saturated solution of benzoic acid at 25 °C.

(4)

(iv) State **two** approximations used in the calculation of pH in (a)(iii).

(2)

(b) An aqueous solution of sodium hydroxide of concentration $0.0020\,mol\,dm^{-3}$ was added to a flask containing $25.0\,cm^3$ of a $0.0015\,mol\,dm^{-3}$ solution of benzoic acid.

The pH of the solution in the flask was continuously monitored as the sodium hydroxide was added and the results plotted on a graph.
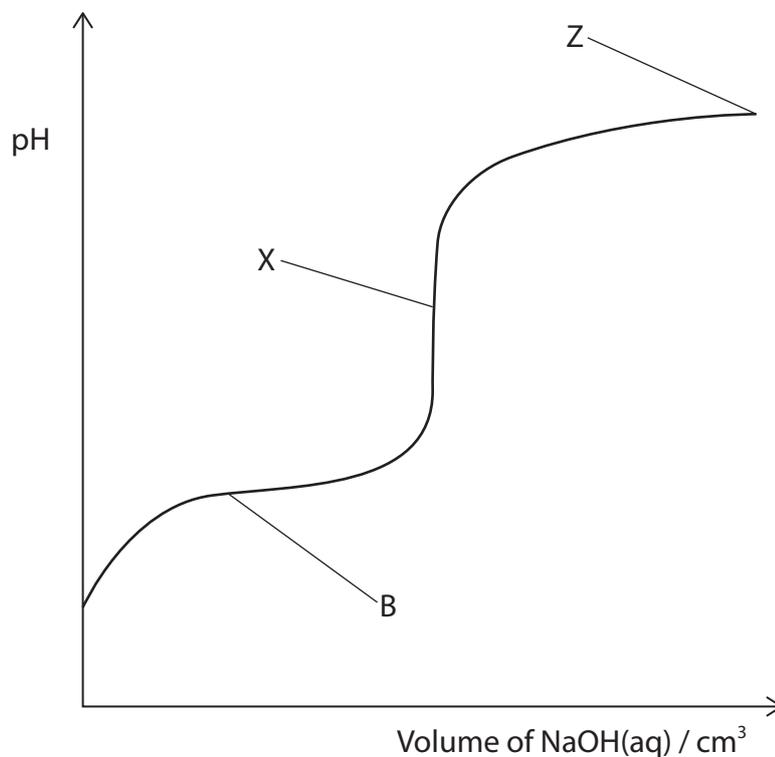
(i) Suggest a value for the pH at X. Justify your answer.

(2)

(ii) Calculate the volume of NaOH(aq) added, in **cm³**, when X is reached.

(2)

(iii) Calculate the maximum possible pH at Z, when a very large excess of sodium hydroxide solution has been added.

[Data: $K_w = 1.00 \times 10^{-14}\,mol^2\,dm^{-6}$]

(2)

(c) The region labelled B in the graph is referred to as the 'buffer region'.

(i) Explain why B is a buffer region.

(2)

(ii) Explain how the solution acts as a buffer.

Include the identity of the species present in the solution at B which are responsible for the buffering action.
Equations are not required.

(4)

(d) Buffers occur in many biochemical systems, for example blood.

Suggest a reason why buffers occur in blood.

(1)

(Total for Question 20 = 21 marks)

TOTAL FOR SECTION C = 21 MARKS
TOTAL FOR PAPER = 90 MARKS

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Please check the examination details below before entering your candidate information

Candidate surname

Other names

Centre Number

Candidate Number

Pearson Edexcel International Advanced Level

Friday 9 January 2026

Afternoon (Time: 1 hour 45 minutes)

Paper reference WCH14/01A

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

You must have:
Question paper (sent separately)
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 ▶

Pearson

SECTION A

Answer ALL questions.

You should aim to spend no more than 20 minutes on this section.

For questions 1–15, in Section A, 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

☒ A

☒ B

☒ C

☒ D

(Total for Question 1 = 1 mark)

2

☒ A

☒ B

☒ C

☒ D

(Total for Question 2 = 1 mark)

3

☒ A

☒ B

☒ C

☒ D

(Total for Question 3 = 1 mark)

4

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 4 = 1 mark)

5

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 5 = 1 mark)

6

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 6 = 1 mark)

7 (a)

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(b)

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 7 = 2 marks)

8

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 8 = 1 mark)

9

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 9 = 1 mark)

P 8 7 6 3 0 A 0 4 2 0

10 (a)

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(b)

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 10 = 2 marks)

11 (a)

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(b)

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(c)

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 11 = 3 marks)

12

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 12 = 1 mark)

13

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 13 = 1 mark)

14

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 14 = 1 mark)

15 (a)

(1)

- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(b)

(1)

- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(Total for Question 15 = 2 marks)

TOTAL FOR SECTION A = 20 MARKS

SECTION B

Answer ALL questions in the spaces provided.

16 (a) (i)

(1)

....

....

....

(ii)

(2)

....

....

....

....

....

(b) (i)

(2)

298		58		

(ii)

(7)

This space is for the calculation of the answer to part (ii).

(c) (i)

(1)

....

....

(ii)

(2)

....

....

....

....

(d) (i)

(1)

....

....

(ii)

(1)

....

(Total for Question 16 = 17 marks)

17 (a) (i)

(1)

(ii)

(4)

(b) (i)

(2)

....

....

....

(ii)

(2)

....

....

....

....

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(iii)

(2)

(Total for Question 17 = 11 marks)

*18

P 8 7 6 3 0 A 0 1 3 2 0

(Total for Question 18 = 6 marks)

19 (a)

(3)

(b) (i)

(2)

....

....

(ii)

(2)

....

....

(iii)

(3)

$$CH_3CH_2 - \overset{\overset{\displaystyle O}{\|}}{C} - CH_3 \quad \xrightarrow{\textbf{Step A}} \quad CH_3CH_2 - \overset{\overset{\displaystyle O^-}{|}}{\underset{\underset{\displaystyle CN}{|}}{C}} - CH_3$$

$$CN^-$$

$$H - CN$$

$$CH_3CH_2 - \overset{\overset{\displaystyle O^-}{|}}{\underset{\underset{\displaystyle CN}{|}}{C}} - CH_3 \quad \xrightarrow{\textbf{Step B}} \quad CH_3CH_2 - \overset{\overset{\displaystyle OH}{|}}{\underset{\underset{\displaystyle CN}{|}}{C}} - CH_3 \quad + \quad CN^-$$

(iv)

(3)

....

....

....

....

....

(v)

(2)
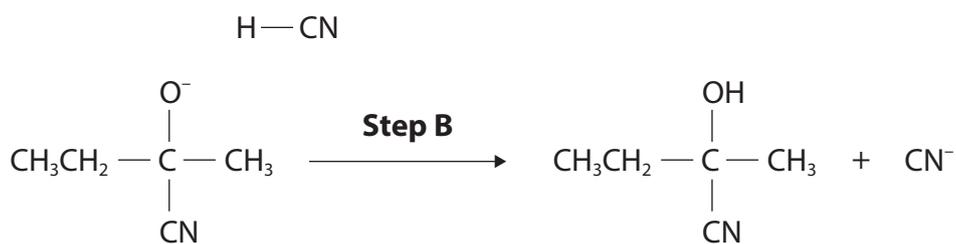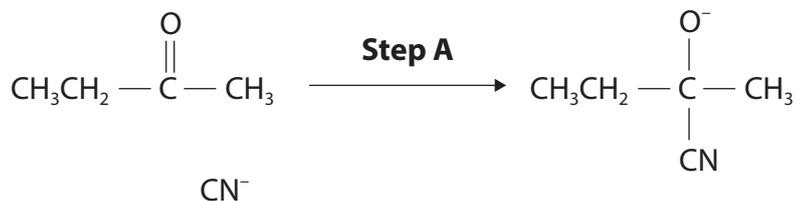
(Total for Question 19 = 15 marks)

TOTAL FOR SECTION B = 49 MARKS

SECTION C

Answer ALL questions in the spaces provided.

20 (a) (i)

(1)

(ii)

(1)

(iii)

(4)

(iv)

(2)

....

....

....

....

(b) (i)

(2)

....

....

....

(ii)

(2)

(iii)

(2)

(c) (i)

(2)

(ii)

(4)

(d)

(1)

(Total for Question 20 = 21 marks)

TOTAL FOR SECTION C = 21 MARKS
TOTAL FOR PAPER = 90 MARKS

The Periodic Table of Elements

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

1.0
H
hydrogen
1

(1)	(2)											(13)	(14)	(15)	(16)	(17)	0 (8) (18)
																	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	(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							

* 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

P 8 7 6 3 0 A 0 2 0 2 0