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 29th May 2026

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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P 7 9 2 2 1 A 0 1 2 8

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 What is the conjugate base of HPO_4^{2-}?

☒ **A** H_3PO_4

☒ **B** $H_2PO_4^-$

☒ **C** PO_4^{3-}

☒ **D** PO_3^-

(Total for Question 1 = 1 mark)

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2 What is the pH of the solution formed when 50 cm^3 of 0.010 mol dm^{-3} HCl(aq) is mixed with 50 cm^3 of 0.010 mol dm^{-3} HNO_3(aq)?

☒ **A** 1.0

☒ **B** 1.7

☒ **C** 2.0

☒ **D** 2.3

(Total for Question 2 = 1 mark)

---

3 What is the concentration, in mol dm^{-3}, of hydrogen ions, $[H^+]$, in a 0.15 mol dm^{-3} aqueous solution of CH_3COOH?

[Data: $K_a(CH_3COOH) = 1.8 \times 10^{-5}$ mol dm^{-3}]

☒ **A** 2.7×10^{-6}

☒ **B** 1.6×10^{-3}

☒ **C** 0.15

☒ **D** 2.8

(Total for Question 3 = 1 mark)

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

4 What is the pH of a 0.075 mol dm^{-3} aqueous solution of $Ba(OH)_2$?

- ☒ **A** 0.82
- ☒ **B** 1.12
- ☒ **C** 12.88
- ☒ **D** 13.18

(Total for Question 4 = 1 mark)

5 The pH of pure water is 7.0 at 25 °C and 6.6 at 50 °C.

Which of these statements is **not** true?

- ☒ **A** pure water is acidic at 50 °C
- ☒ **B** in pure water, $[H^+] = [OH^-]$ at any temperature
- ☒ **C** in pure water, $[H^+]$ is greater at 50 °C than at 25 °C
- ☒ **D** K_w is greater at 50 °C than at 25 °C

(Total for Question 5 = 1 mark)

6 Which would **not** form a buffer solution when added to 500 cm^3 of water?

- ☒ **A** 0.1 mol CH_3COOH and 0.1 mol CH_3COOK
- ☒ **B** 0.1 mol CH_3COOH and 0.05 mol $(CH_3COO)_2Mg$
- ☒ **C** 0.2 mol CH_3COOH and 0.1 mol NaOH
- ☒ **D** 0.2 mol CH_3COOH and 0.1 mol $Mg(OH)_2$

(Total for Question 6 = 1 mark)

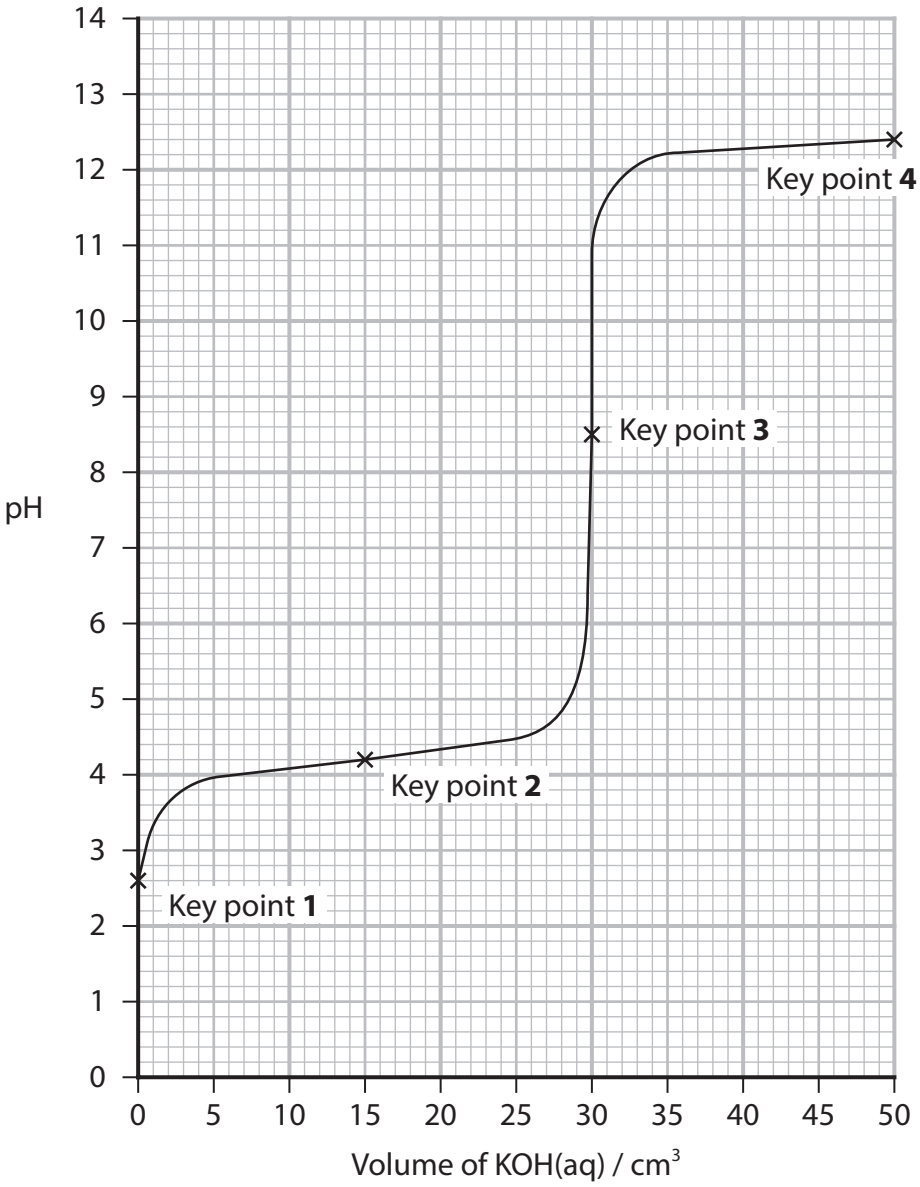
7 A buffer solution containing CH_3CH_2COOH ($pK_a = 4.88$) and $CH_3CH_2COO^-$ has a pH of 4.40.

Which expression about this buffer solution is true?

- ☒ **A** $[H^+] = K_a$
- ☒ **B** $[CH_3CH_2COOH] = [CH_3CH_2COO^-]$
- ☒ **C** $[H^+] < K_a$
- ☒ **D** $[CH_3CH_2COOH] > [CH_3CH_2COO^-]$

(Total for Question 7 = 1 mark)

8 A titration curve for the reaction of 0.100 mol dm^{-3} methanoic acid, HCOOH, with 0.040 mol dm^{-3} potassium hydroxide, KOH, is shown.



(a) Which indicator should be used to determine the end-point in this titration? Refer to the Data Booklet.

(1)

- ☒ **A** bromophenol blue
- ☒ **B** bromocresol green
- ☒ **C** methyl orange
- ☒ **D** phenol red

(b) What volume, in cm^3, of methanoic acid was used in this titration?

(1)

- ☒ **A** 12.0
- ☒ **B** 15.0
- ☒ **C** 30.0
- ☒ **D** 75.0

(c) At which key point is the pH equal to the pK_a of methanoic acid?

(1)

- ☒ **A** Key point **1**
- ☒ **B** Key point **2**
- ☒ **C** Key point **3**
- ☒ **D** Key point **4**

(d) Which expression about the concentration of hydroxide ions, $[OH^-]$, at Key point **4** is correct?

(1)

- ☒ **A** $[OH^-] = 0.040$
- ☒ **B** $[OH^-] > 0.040$
- ☒ **C** $[OH^-] < 0.040$
- ☒ **D** $[OH^-] = 10^{-12.4}$

(Total for Question 8 = 4 marks)

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

9 Iron(III) ions, Fe^{3+}, oxidise iodide ions, I^-, in aqueous solution.

$$2Fe^{3+} + 2I^- \rightarrow 2Fe^{2+} + I_2$$

The rate equation for the reaction is shown.

$$\text{rate} = k\,[Fe^{3+}]\,[I^-]^2$$

(a) An experiment is performed in which $[I^-] \gg [Fe^{3+}]$ and the overall order of the reaction is determined under these conditions.

What would be the observed overall order?

(1)

☒ **A** zero

☒ **B** first

☒ **C** second

☒ **D** third

(b) A possible mechanism for this reaction is:

Step **1** $Fe^{3+} + I^- \rightarrow FeI^{2+}$

Step **2** $FeI^{2+} + I^- \rightarrow Fe^{2+} + I_2^-$

Step **3** $I_2^- + Fe^{3+} \rightarrow Fe^{2+} + I_2$

For this mechanism, which step would have the highest activation energy?

(1)

☒ **A** Step **1**

☒ **B** Step **2**

☒ **C** Step **3**

☒ **D** all three steps must have the same activation energy

(Total for Question 9 = 2 marks)

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

10 Which statement(s) is/are correct?

Propanal, CH_3CH_2CHO, reacts with

1 Fehling's solution forming a blue precipitate

2 Tollens' reagent forming a silver mirror

3 2,4-dinitrophenylhydrazine forming a green solution

☒ **A** 1, 2 and 3

☒ **B** only 1 and 2

☒ **C** only 1 and 3

☒ **D** only 2

(Total for Question 10 = 1 mark)

11 What is the organic product formed when 2-chloropropanenitrile, $CH_3CHClCN$, is refluxed with excess NaOH(aq)?

☒ **A** $CH_3CHOHCOONa$

☒ **B** $CH_3CHClCOOH$

☒ **C** $CH_3CHOHCOOH$

☒ **D** $CH_3CHClCOONa$

(Total for Question 11 = 1 mark)

12 Separate samples of ethanoyl chloride, CH_3COCl, are reacted with an excess of three reagents:

1 H_2O

2 CH_3NH_2

3 NH_3

Which reagent(s) would react to produce a white smoke?

☒ **A** 1, 2 and 3

☒ **B** only 1 and 2

☒ **C** only 2 and 3

☒ **D** only 3

(Total for Question 12 = 1 mark)

13 Which organic compound is formed when propanoyl chloride, CH_3CH_2COCl, reacts with ethylamine, $CH_3CH_2NH_2$?

- ☒ **A** $CH_3CONHCH_2CH_2CH_3$
- ☒ **B** $CH_3CH_2CH_2NHCOCH_3$
- ☒ **C** $CH_3CH_2CONHCH_2CH_3$
- ☒ **D** $CH_3NHCOCH_2CH_2CH_3$

(Total for Question 13 = 1 mark)

14 What are the products of the **acid** hydrolysis of ethyl propanoate?

- ☒ **A** CH_3CH_2OH and CH_3CH_2COOH
- ☒ **B** CH_3COOH and $CH_3CH_2CH_2OH$
- ☒ **C** CH_3CH_2COOH and $CH_3CH_2CH_2OH$
- ☒ **D** CH_3CH_2OH and $CH_3CH_2CH_2COOH$

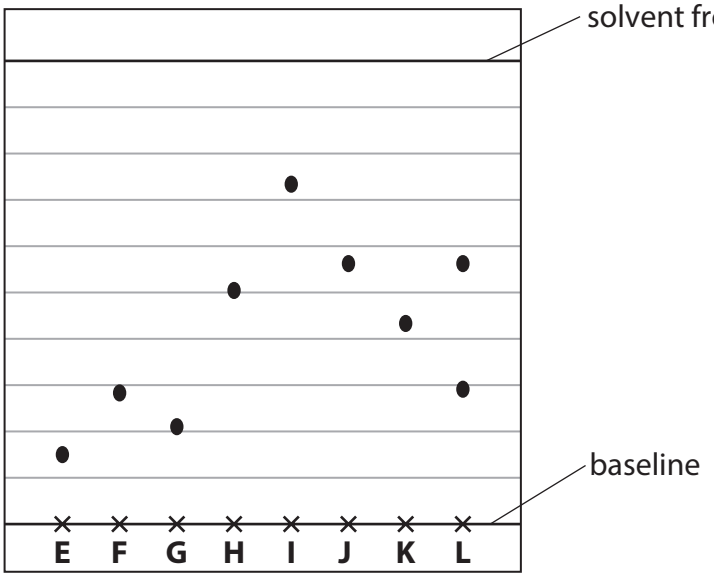
(Total for Question 14 = 1 mark)

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

15 A mixture, **L**, of two unknown compounds was placed on a thin-layer chromatography (TLC) plate.

Samples of seven possible compounds present in the mixture, **E** to **K**, were also placed on the TLC plate for reference.

A diagram of the developed TLC plate is shown.



(a) How many of the compounds, **E** to **K**, have an R_f value between 0.1 and 0.3?

(1)

- ☒ **A** none
- ☒ **B** one
- ☒ **C** three
- ☒ **D** four

(b) Which two compounds are present in mixture **L**?

(1)

- ☒ **A** **F** and **H**
- ☒ **B** **F** and **J**
- ☒ **C** **G** and **H**
- ☒ **D** **G** and **J**

(Total for Question 15 = 2 marks)

TOTAL FOR SECTION A = 20 MARKS

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SECTION B

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

16 The kinetics of the alkaline hydrolysis of a halogenoalkane were investigated.

$$RX + OH^- \rightarrow ROH + X^-$$

Some initial rates data are shown.

Experiment	[RX] / mol dm^{-3}	[OH$^-$] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.020	0.010	3.2×10^{-6}
2	0.040	0.010	6.4×10^{-6}
3	0.010	0.020	3.2×10^{-6}

(a) Determine the order of reaction with respect to RX and to OH$^-$.
Justify your answer.

(2)

(b) Complete the rate equation for this reaction, using your answer to (a).

(1)

rate =

(c) State and justify, with reference to your answer to (b), whether RX is more likely to be a primary or a tertiary halogenoalkane.

(1)

.....

.....

.....

(d) Calculate the value of the rate constant, *k*, for Experiment 1 using your answer to (b) and data from the table.
Include units in your answer.

(3)

(Total for Question 16 = 7 marks)

17 Sulfur trioxide, SO_3, is made from sulfur dioxide, SO_2.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

The expression for K_p for this equilibrium is shown.

$$K_p = \frac{p(SO_3)^2}{p(SO_2)^2 \times p(O_2)}$$

(a) 1.00 kg of SO_2 and 57.0 dm^3 of O_2 were left to reach equilibrium in a sealed container at 427 °C and 8.00×10^5 Pa.

At equilibrium the mixture was found to contain 15.3 mol of SO_3.

(i) Calculate the number of moles in 1.00 kg of SO_2.

(1)

(ii) Calculate the number of moles in 57.0 dm^3 of O_2 at 427 °C and 8.00×10^5 Pa.

(3)

(iii) Determine the number of moles of SO_2 and O_2 at equilibrium.

(2)

(iv) Calculate the partial pressures of SO_2, O_2 and SO_3 at equilibrium.

(2)

(v) Calculate the value for K_p, including units.

(2)

(b) Explain, in terms of the expression for K_p, the effect of increasing pressure on the equilibrium yield of SO_3 for this reaction.

$$K_p = \frac{p(SO_3)^2}{p(SO_2)^2 \times p(O_2)}$$

(3)

(Total for Question 17 = 13 marks)

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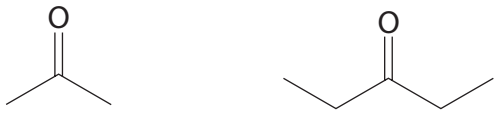
18 This question is about the ketones propanone and pentan-3-one.



propanone pentan-3-one

(a) Explain why the boiling temperature of pentan-3-one is **higher** than that of propanone.

(2)

(b) Describe how the precipitates formed in the reactions with 2,4-dinitrophenylhydrazine could be used to distinguish between separate samples of propanone and pentan-3-one.
Detailed descriptions of the practical procedures are **not** required.

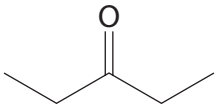
(2)

(c) State the expected observations when separate samples of propanone and pentan-3-one are mixed with aqueous iodine in the presence of alkali.

(2)

(d) Draw the mechanism for the reaction of pentan-3-one with HCN, in the presence of KCN.
Include curly arrows and relevant lone pairs and dipoles.

(4)



(e) Predict the expected *m* / *z* values of two significant peaks in the mass spectrum of propanone and two significant peaks in the mass spectrum of pentan-3-one.

(2)

Ketone	*m* / *z* of peak 1	*m* / *z* of peak 2
propanone		
pentan-3-one		

*(f) Compare and contrast the **carbon-13** (^{13}C) and the **high resolution proton** (^{1}H) NMR spectra of propanone with those of pentan-3-one.
Your answer should refer to the number of peaks, expected chemical shifts, relative peak areas and splitting patterns.
Refer to the Data Booklet.

(6)

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(Total for Question 18 = 18 marks)

19 This question is about lactic acid, $CH_3CHOHCOOH$.

(a) Lactic acid is a chiral molecule, existing as a pair of enantiomers.

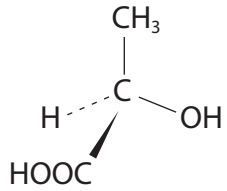
(i) State what is meant by the term **enantiomers**.

(1)

.....

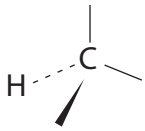
.....

(ii) A diagram of one of the enantiomers of lactic acid is shown.

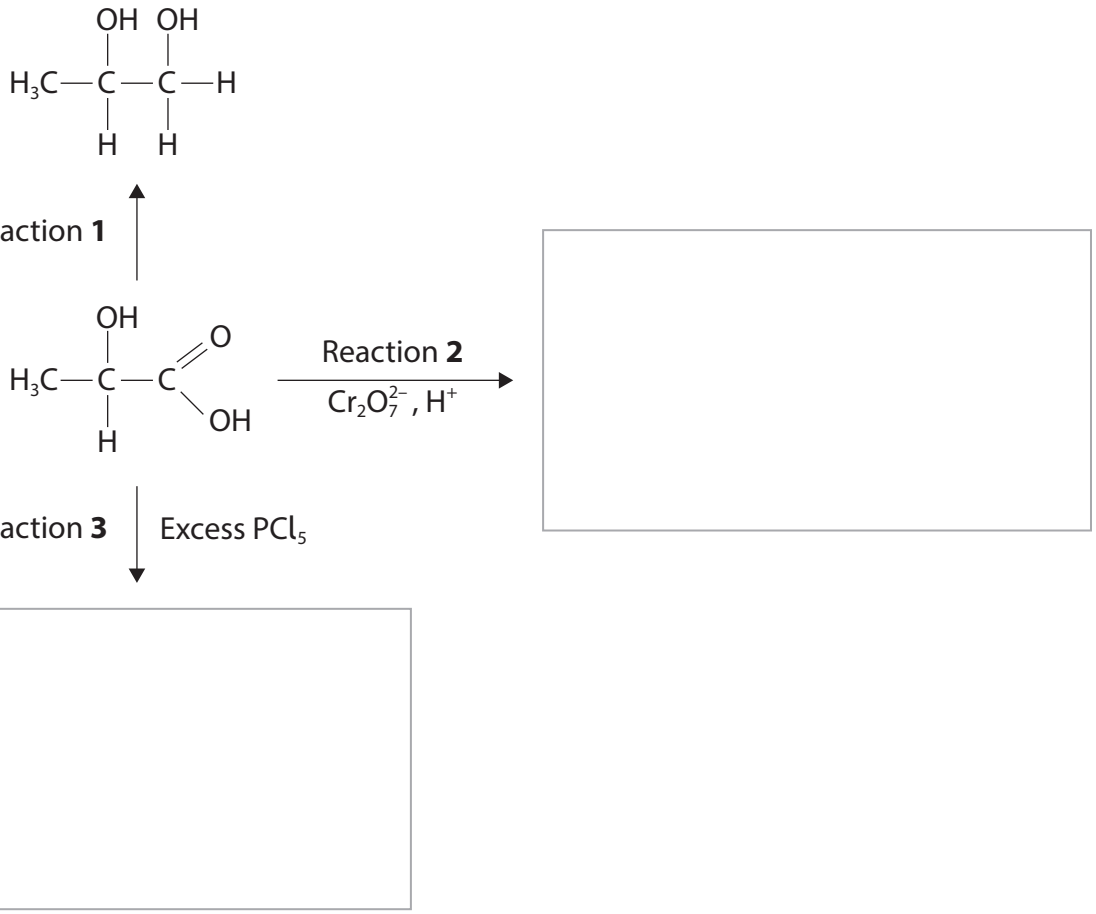


Complete the 3D diagram of the other enantiomer of lactic acid.

(1)



(b) Some reactions of lactic acid are shown.



(i) Give the reagents and conditions for Reaction **1**.

(2)

.....

.....

(ii) Draw the structures of the organic products for Reactions **2** and **3** in the boxes provided.

(2)

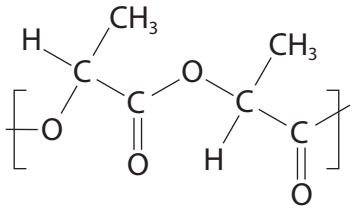
(iii) Write the equation for Reaction **3**.
State symbols are **not** required.

(2)

(c) Lactic acid reacts in condensation reactions to form esters.

A condensation polymer, poly(lactic acid), may be formed from lactic acid.

Two repeat units of poly(lactic acid) are shown.



2000 monomers are polymerised to form poly(lactic acid).

Show that the relative molecular mass of this polymer is 144 018.

(2)

(d) Another condensation reaction of lactic acid produces a cyclic ester, **X**, with a molar mass of 144.0 g mol^{-1}.

(i) Complete the equation for the formation of **X**, using **molecular formulae**.

(2)

$2C_3H_6O_3 \longrightarrow$

(ii) Give the structure of **cyclic** ester **X**.

(2)

(Total for Question 19 = 14 marks)

TOTAL FOR SECTION B = 52 MARKS

SECTION C

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

20 This question is about the thermodynamics of processes involving aluminium and aluminium chloride.

(a) Aluminium chloride, $AlCl_3$, can be made from its elements.

Equation **1** $2Al(s) + 3Cl_2(g) \rightarrow 2AlCl_3(s)$ $\Delta_r H^{\ominus} = -1408\,kJ\,mol^{-1}$

(i) State why the value of $\Delta_r H^{\ominus}$ for Equation **1** is twice that of the standard enthalpy change of formation, $\Delta_f H^{\ominus}$, of $AlCl_3(s)$.

(1)

(ii) Calculate the entropy change of the system, $\Delta S^{\ominus}_{system}$, in $J\,K^{-1}\,mol^{-1}$, for Equation **1**, using the data shown.

(2)

Species	Al(s)	$Cl_2(g)$	$AlCl_3(s)$
$S^{\ominus}$ / $J\,K^{-1}\,mol^{-1}$	28.3	223	109

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(iii) Explain, in terms of disorder, whether the **sign** of your answer to (a)(ii) is as expected.

(2)

(iv) Calculate the total entropy change, ΔS_{total}, in **J K^{-1} mol^{-1}**, for Equation **1** at 298 K, using your answer to (a)(ii) and the value for $\Delta_r H^{\ominus}$.

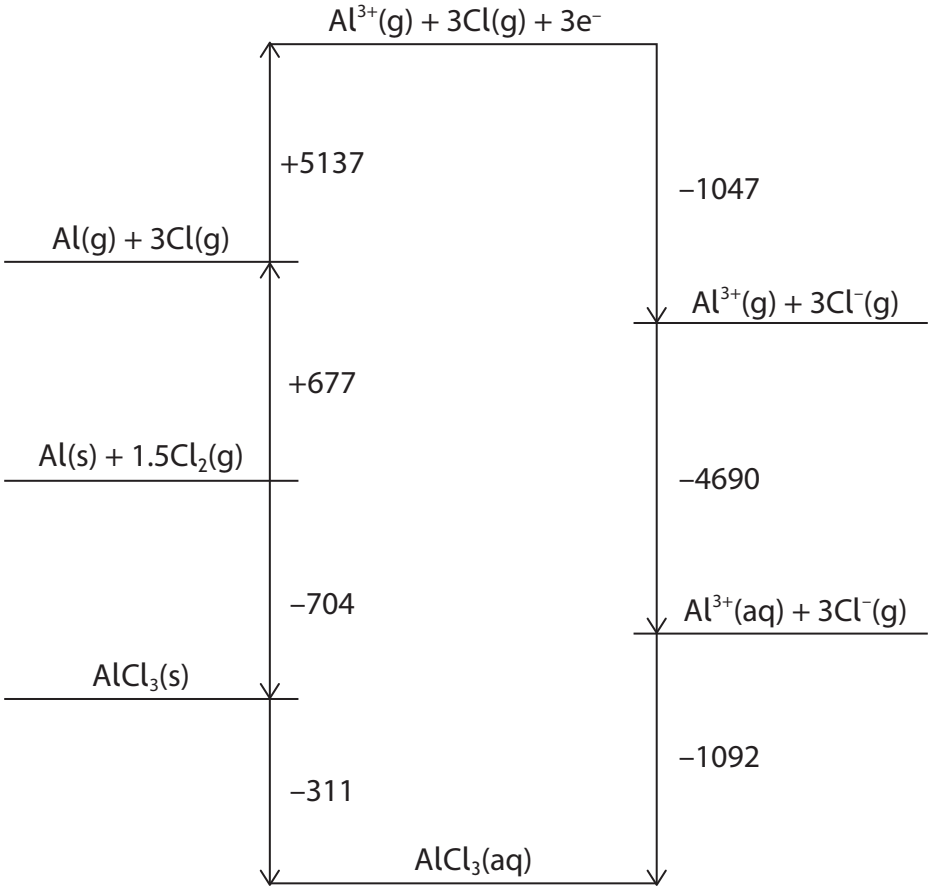
(3)

Equation **1** $2Al(s) + 3Cl_2(g) \rightarrow 2AlCl_3(s)$ $\Delta_r H^{\ominus} = -1408\,kJ\,mol^{-1}$

(v) Give the reason why **no** visible reaction is observed when aluminium metal and chlorine gas are mixed at 298 K.

(1)

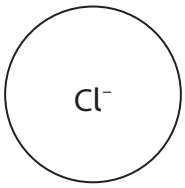
(b) An enthalpy cycle for $AlCl_3$ is shown.
All values are in kJ mol^{-1}. The diagram is **not** to scale.



(i) When $AlCl_3(s)$ dissolves in water, its ions become hydrated.

Complete the diagram to show a hydrated chloride ion, $Cl^-(aq)$.

(1)



(ii) Use the enthalpy cycle to determine the enthalpy change of hydration, in kJ mol^{-1}, of $Cl^-(g)$.

(1)

(iii) Explain why the enthalpy change of hydration of the aluminium ion, Al^{3+}, is **more** exothermic than that of the chloride ion, Cl^-.

(2)

(iv) Use the enthalpy cycle to calculate the **third** ionisation energy of aluminium, given that the first and second ionisation energies are +577 kJ mol^{-1} and +1820 kJ mol^{-1} respectively.

(1)

(v) Explain why the ionisation energies of aluminium become more endothermic with each successive ionisation.

(2)

(vi) Calculate the lattice energy, in kJ mol^{-1}, of $AlCl_3(s)$ using the enthalpy cycle.

(2)

(Total for Question 20 = 18 marks)

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

The Periodic Table of Elements

1	2											3	4	5	6	7	0 (8)
							1.0 H hydrogen 1										(18) 4.0 He helium 2
(1)	(2)		Key: relative atomic mass / atomic symbol / name / atomic (proton) number									(13)	(14)	(15)	(16)	(17)	
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							

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