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 **WCH14/01**

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 ▶

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C:1/1/1/

P 7 9 1 3 6 A 0 1 3 2

Pearson

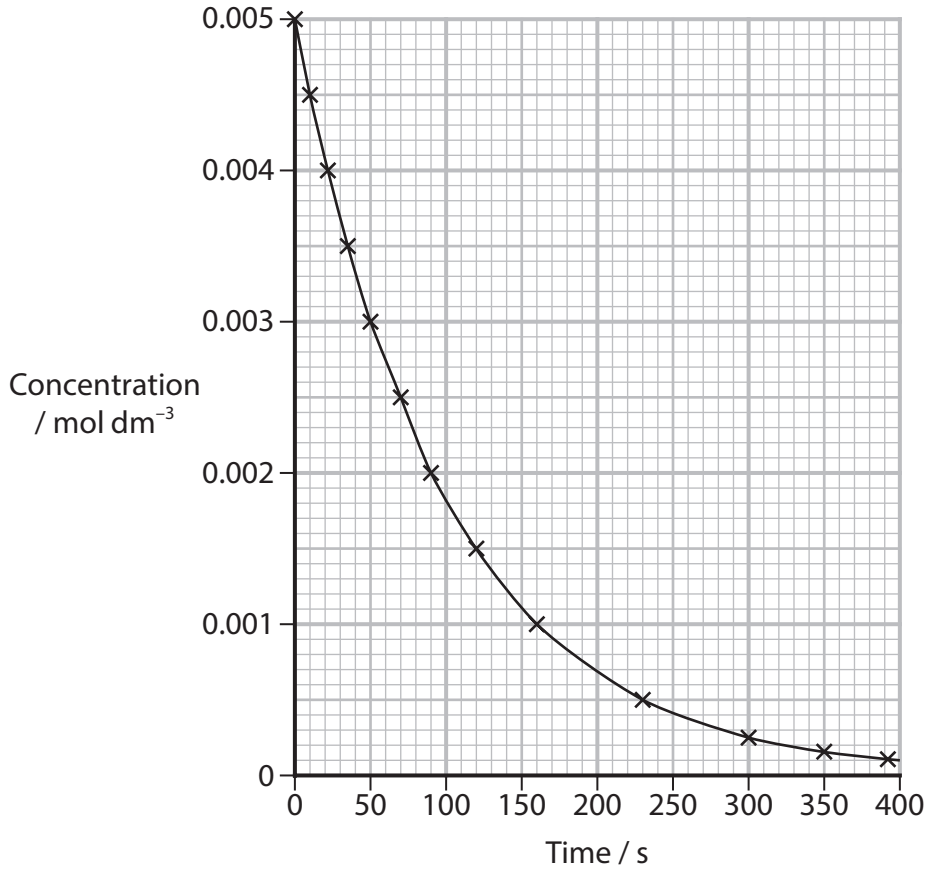
SECTION A

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 The graph shows how the concentration of a reactant changes with time as a reaction proceeds.



(a) Which is the half-life of the reaction in seconds?

(1)

☒ **A** 0.0007

☒ **B** 0.0025

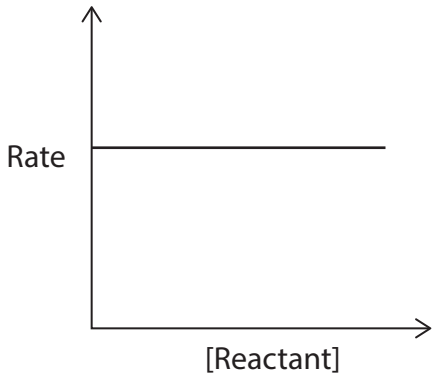
☒ **C** 70

☒ **D** 200

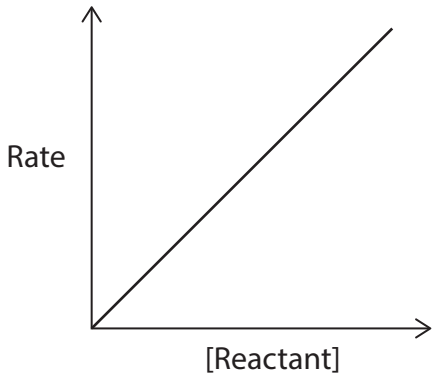
(b) Which graph shows how the rate changes with reactant concentration for this reaction?

(1)

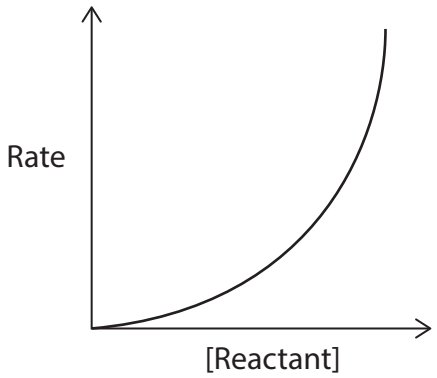
☒ **A**



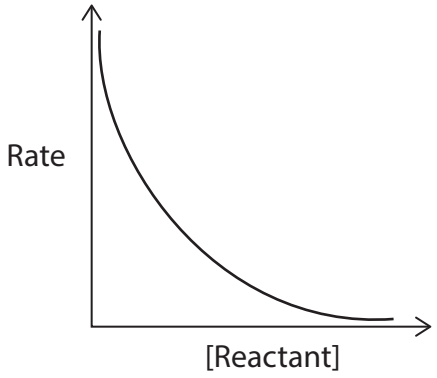
☒ **B**



☒ **C**



☒ **D**



(Total for Question 1 = 2 marks)

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2 Which measurement could be used to obtain rate data for the reaction shown?

$$H_2(g) + I_2(g) \rightarrow 2HI(g)$$

The change in

- ☒ **A** colour intensity
- ☒ **B** pH
- ☒ **C** pressure in a fixed volume
- ☒ **D** volume at a fixed pressure

(Total for Question 2 = 1 mark)

3 The rate equation for the hydrolysis of a halogenoalkane is shown.

$$\text{rate} = k[(CH_3)_2CHBr]$$

Which row is correct?

	Class of halogenoalkane	Reaction mechanism
☒ **A**	primary	S_N1
☒ **B**	primary	S_N2
☒ **C**	secondary	S_N1
☒ **D**	secondary	S_N2

(Total for Question 3 = 1 mark)

4 A two-step reaction is shown.

$$H_2O_2(aq) + I^-(aq) \rightarrow H_2O(l) + OI^-(aq)$$

$$H_2O_2(aq) + OI^-(aq) \rightarrow H_2O(l) + O_2(g) + I^-(aq)$$

(a) What is the role of $I^-(aq)$ in the overall reaction?

(1)

- ☒ **A** heterogeneous catalyst
- ☒ **B** homogeneous catalyst
- ☒ **C** oxidising agent
- ☒ **D** product

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(b) Which is the equation for the overall reaction?

(1)

☒ **A** $2H_2O_2(aq) + I^-(aq) + OI^-(aq) \rightarrow 2H_2O(l) + OI^-(aq) + I^-(aq) + O_2(g)$

☒ **B** $2H_2O_2(aq) + OI^-(aq) \rightarrow 2H_2O(l) + OI^-(aq) + O_2(g)$

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

☒ **D** $2H_2O_2(aq) + 2I^-(aq) \rightarrow 2H_2O(l) + OI^-(aq) + I^-(aq) + \frac{1}{2}O_2(g)$

(Total for Question 4 = 2 marks)

5 Which expression relates entropy and equilibrium constant?

☒ **A** $\Delta S_{total} = -R \ln K$

☒ **B** $\Delta S_{total} = R \ln K$

☒ **C** $\Delta S_{sys} = -R \ln K$

☒ **D** $\Delta S_{sys} = R \ln K$

(Total for Question 5 = 1 mark)

6 What is the equation for the first electron affinity of sulfur?

☒ **A** $S(g) \rightarrow S^+(g) + e^-$

☒ **B** $S(g) + e^- \rightarrow S^-(g)$

☒ **C** $S(g) + 2e^- \rightarrow S^{2-}(g)$

☒ **D** $S^-(g) + e^- \rightarrow S^{2-}(g)$

(Total for Question 6 = 1 mark)

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

7 Which ionic compound would be predicted to have the **least** exothermic lattice energy?

Assume that the bonding is 100% ionic.

- ☒ **A** calcium sulfide
- ☒ **B** lithium fluoride
- ☒ **C** magnesium oxide
- ☒ **D** sodium chloride

(Total for Question 7 = 1 mark)

8 The equation for a reversible reaction is shown.

$$2NO(g) + Br_2(g) \rightleftharpoons 2NOBr(g) \qquad \Delta H = -16.1\ kJ\,mol^{-1}$$

(a) What is the K_c expression for this reaction?

(1)

- ☒ **A** $K_c = \dfrac{[NO]^2[Br_2]}{[NOBr]^2}$
- ☒ **B** $K_c = \dfrac{[NO][Br_2]}{[NOBr]}$
- ☒ **C** $K_c = \dfrac{[NOBr]^2}{[Br_2][NO]^2}$
- ☒ **D** $K_c = \dfrac{[NOBr]}{[Br_2][NO]}$

(b) Which row shows the changes that occur when the temperature is **decreased**?

(1)

		Value of K_c	Yield of NOBr
☒	**A**	increases	increases
☒	**B**	increases	decreases
☒	**C**	decreases	increases
☒	**D**	decreases	decreases

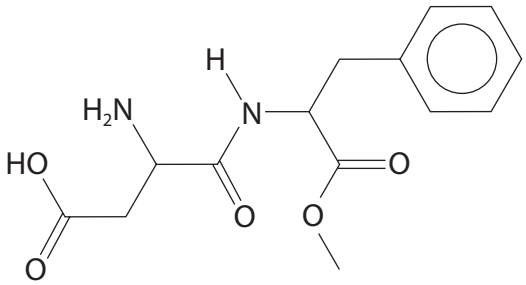
(Total for Question 8 = 2 marks)

9 Which concentration of aqueous calcium hydroxide has a pH of 12.32?

- ☒ **A** 4.79×10^{-13} mol dm^{-3}
- ☒ **B** 1.04×10^{-2} mol dm^{-3}
- ☒ **C** 2.09×10^{-2} mol dm^{-3}
- ☒ **D** 2.09×10^{12} mol dm^{-3}

(Total for Question 9 = 1 mark)

10 The structure of the sweetener aspartame is shown.



(a) How many chiral carbon atoms are there in a molecule of aspartame?

(1)

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

(b) How many hydrogen atoms are there in a molecule of aspartame?

(1)

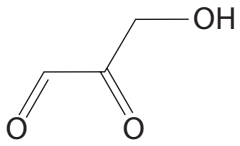
- ☒ **A** 12
- ☒ **B** 16
- ☒ **C** 17
- ☒ **D** 18

(Total for Question 10 = 2 marks)

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

11 Compound **X** has been detected in human red blood cells.

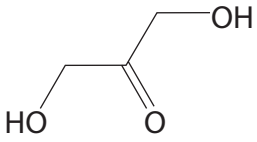
The structure of **X** is shown.



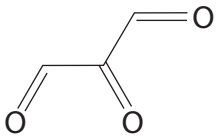
(a) Which compound is formed when **X** reacts with lithium tetrahydridoaluminate(III)?

(1)

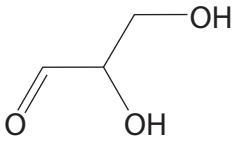
☒ **A**



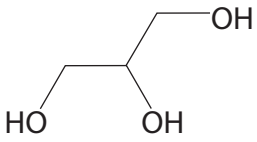
☒ **B**



☒ **C**



☒ **D**



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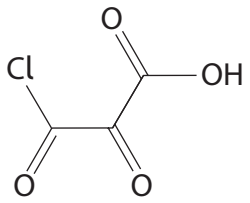
(b) Compound **X** is oxidised under reflux to form compound **Y**.
Y is reacted with excess phosphorus(V) chloride.

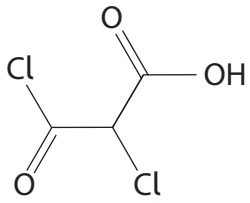
What is the structure of the **final** organic product?

(1)

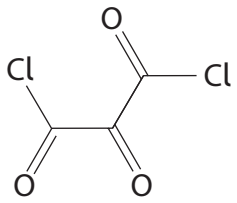
☒ **A**



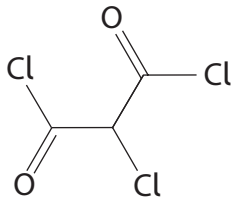
☒ **B**



☒ **C**



☒ **D**



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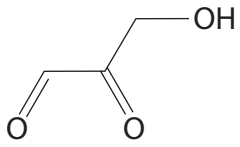
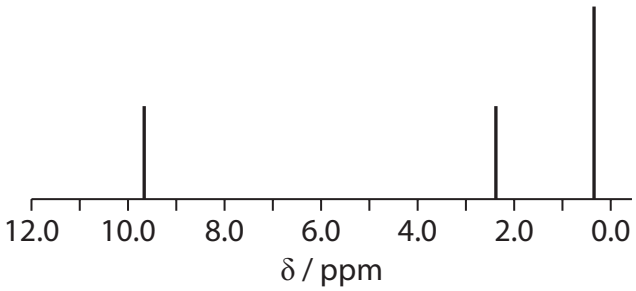
(c) Which could be the low resolution proton NMR spectrum for **X**?

Use your Data Booklet.

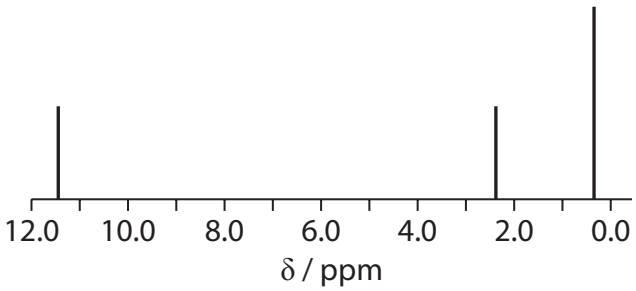


(1)

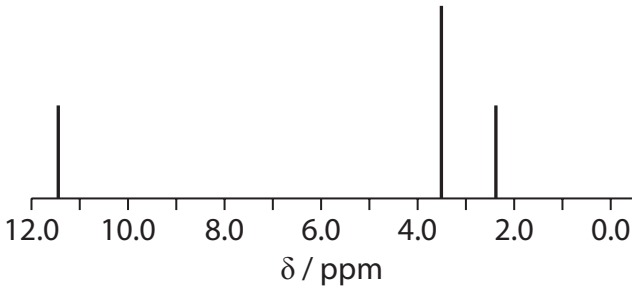
☒ **A**



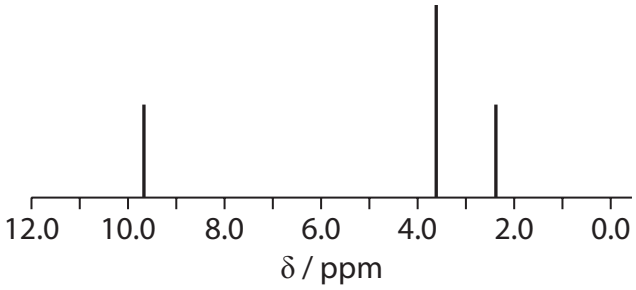
☒ **B**



☒ **C**



☒ **D**



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(d) What is the splitting pattern of the peak due to the protons of the CH_2 group in the high resolution proton NMR spectrum of **X**?

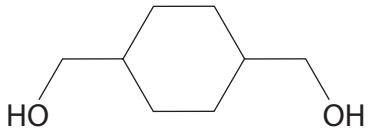
(1)

- ☒ **A** singlet
- ☒ **B** doublet
- ☒ **C** triplet
- ☒ **D** quartet

(Total for Question 11 = 4 marks)

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

12 The structure of compound **Z** is shown.



(a) How many peaks are there in the ^{13}C NMR spectrum of **Z**?

(1)

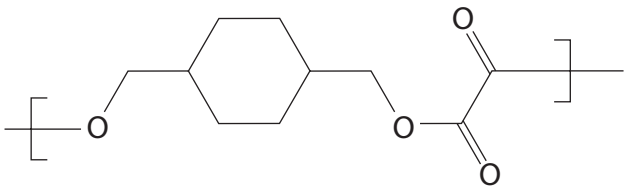
- ☒ **A** 3
- ☒ **B** 4
- ☒ **C** 6
- ☒ **D** 8

(b) The diol reacts with ethanedioic acid to form a polyester.

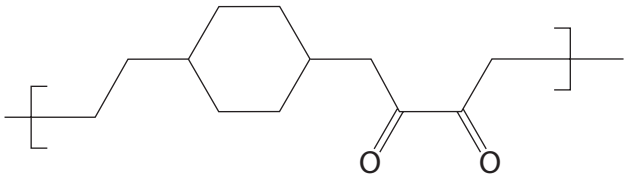
What is the structure of the repeat unit of this polyester?

(1)

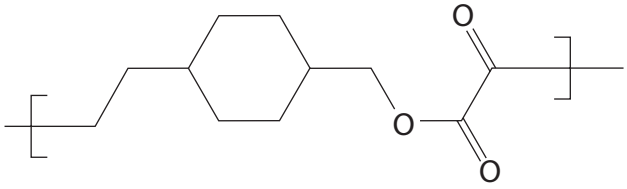
☒ **A**



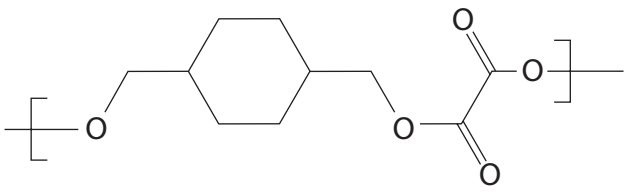
☒ **B**



☒ **C**



☒ **D**



(Total for Question 12 = 2 marks)

TOTAL FOR SECTION A = 20 MARKS

SECTION B

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

13 This question is about nitrogen monoxide.

(a) Nitrogen monoxide reacts with oxygen to form nitrogen dioxide.

$$2NO + O_2 \rightarrow 2NO_2$$

Some initial rate data are shown.

Experiment	[NO] / mol dm^{-3}	[O_2] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.00100	0.00100	0.00802
2	0.00100	0.00200	0.01604
3	0.00400	0.00200	0.25664

(i) Deduce the rate equation. Justify your answer.

(4)

(ii) Calculate the rate constant for this reaction.
Include units in your answer.

(2)

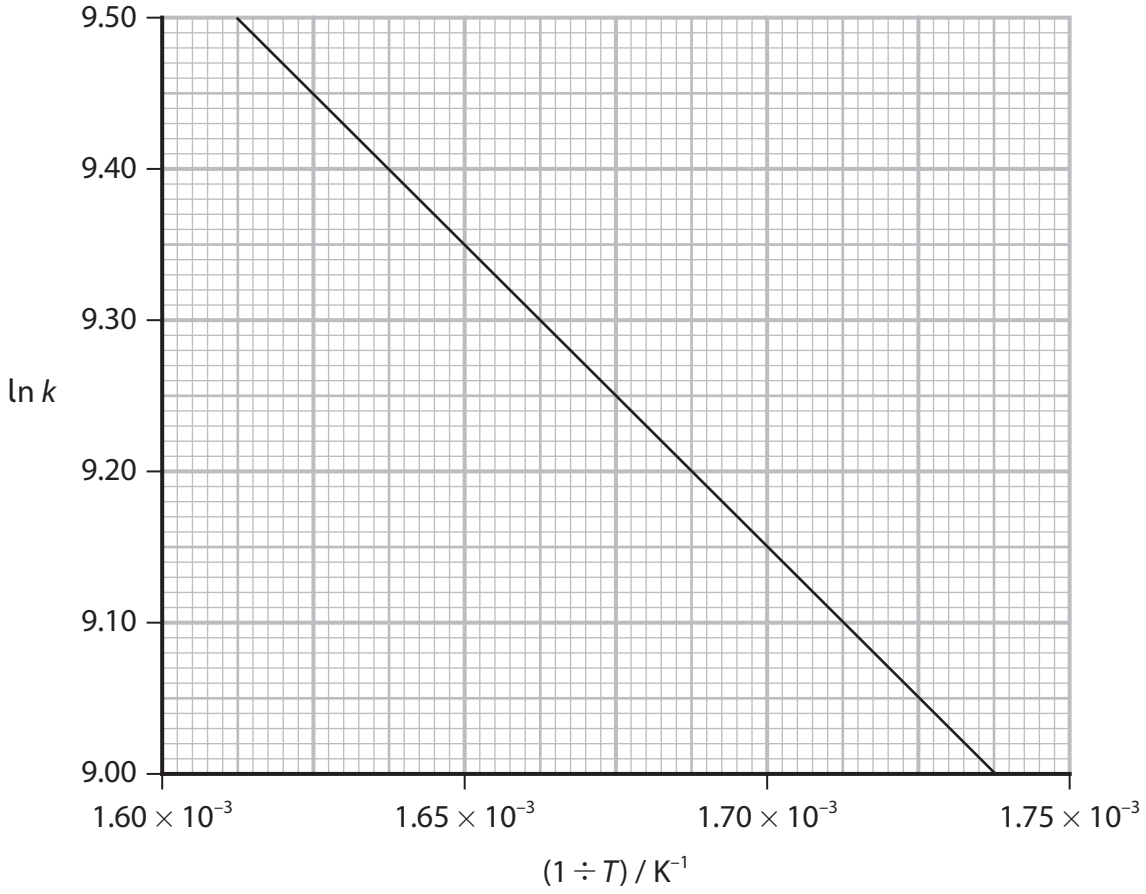
(iii) The reaction of nitrogen monoxide with oxygen is thought to be a two-step reaction mechanism.
The first step of a proposed mechanism is shown.

$$2NO \rightleftharpoons N_2O_2$$

Suggest an equation for the second (rate-determining) step of the mechanism. Justify your answer using your rate equation from (a)(i).

(3)

(b) The rate constant for the reaction of nitrogen monoxide with oxygen was determined for a range of temperatures to find the activation energy of the reaction. A graph is shown.



Calculate the activation energy, E_a, for this reaction, using the Arrhenius equation.

(3)

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

Include a sign and units in your answer.

(c) Nitrogen monoxide reacts with oxygen and water to form a single product with $K_a = 4.0 \times 10^{-4}\,\text{mol}\,\text{dm}^{-3}$.

Deduce the identity of the product. Justify your answer.

(2)

.....

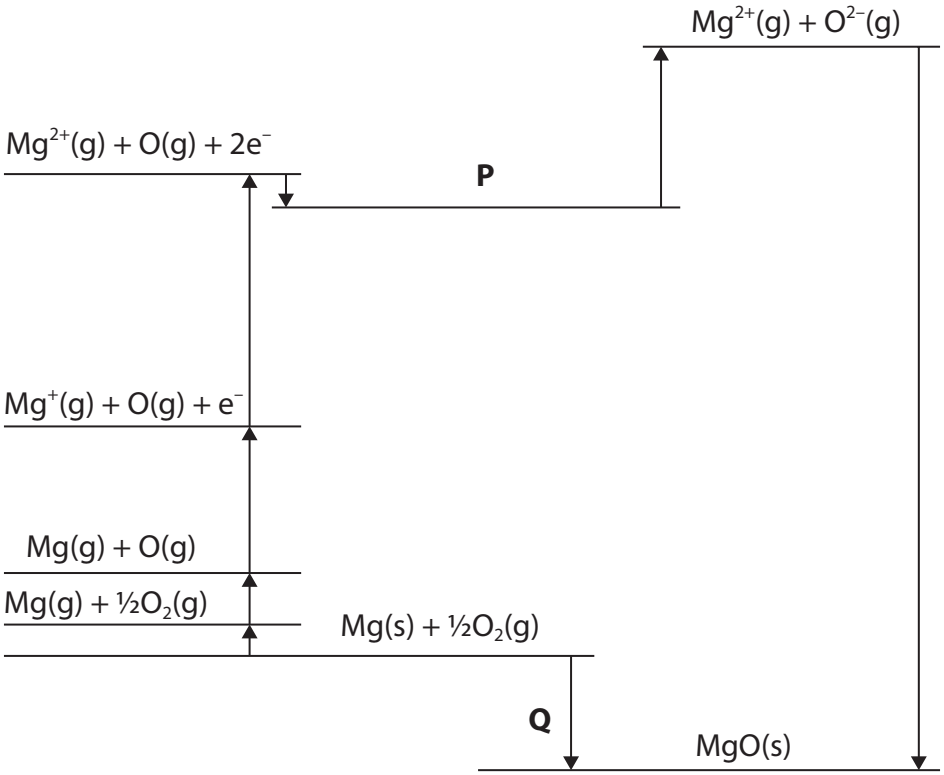
.....

.....

(Total for Question 13 = 14 marks)

14 This question is about ionic compounds of magnesium.

(a) An incomplete Born–Haber cycle and relevant data for magnesium oxide are shown.



Energy change	Value / kJ mol^{-1}
Lattice energy of magnesium oxide	−3795
First electron affinity of oxygen	−141
Second electron affinity of oxygen	+798
First ionisation energy of magnesium	+738
Second ionisation energy of magnesium	+1451
Enthalpy change of atomisation of oxygen	+249
Enthalpy change of atomisation of magnesium	+148

(i) Give the formulae and state symbols of the set of particles labelled '**P**'.

(1)

.....

(ii) Name the energy change **Q**.

(1)

.....

(iii) Calculate the value of **Q**.
You must show your working. Include a sign and units in your answer.

(2)

(iv) The values of the experimental and theoretical lattice energies for magnesium oxide are very similar.

However, the values for magnesium sulfide are significantly different.

Explain these two statements.

(4)

(b) Ionic compounds may be soluble or insoluble in water.

(i) Write an expression that could be used to calculate the enthalpy change of solution for an ionic compound.

(1)

$\Delta_{sol}H^{\ominus}$ = ...

(ii) The enthalpy change of hydration of the chloride ion can be calculated from the data in the table.

Energy change	Value / kJ mol^{-1}
Enthalpy change of solution of magnesium chloride	−155
Lattice energy of magnesium chloride	−2526
Enthalpy change of hydration of the magnesium ion	−1956

Calculate the enthalpy change of hydration of the chloride ion.

(2)

(Total for Question 14 = 11 marks)

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15 The Haber process is used to manufacture ammonia.

An equation is shown.

$$\tfrac{1}{2}N_2(g) + 1\tfrac{1}{2}H_2(g) \rightleftharpoons NH_3(g) \qquad \Delta H = -46\,kJ\,mol^{-1}$$

(a) Write the K_p expression for the reaction shown in this equation.

(1)

(b) An equilibrium mixture contains 20.0 mol of nitrogen, 80.0 mol of hydrogen and 50.0 mol of ammonia at 195 atm.

Calculate the mole fraction of hydrogen in the equilibrium mixture.
Give your answer to 3 significant figures.

(1)

(c) Calculate the value of K_p, using your answers to (a) and (b), for the reaction under these conditions.
Include units in your answer.

(4)

(d) A system at equilibrium may be affected by changes in reaction conditions.

(i) Explain the effect, if any, on the equilibrium composition (or yield) of the Haber process when

- the temperature is increased
- the pressure is increased
- a catalyst is added

(3)

(ii) Explain the effect, if any, on the equilibrium constant, K_p, of the Haber process when

- the temperature is increased
- the pressure is increased
- a catalyst is added

(2)

(Total for Question 15 = 11 marks)

16 Buffers are very important in biological systems.

(a) Describe how a carbonic acid-hydrogencarbonate buffer system maintains the pH of blood as the concentration of dissolved carbon dioxide changes.
Include relevant equations in your answer.

(5)

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(b) Within body cells the pH is maintained by a different buffer system.
An equation for this is shown.

$$H_2PO_4^- \rightleftharpoons H^+ + HPO_4^{2-} \qquad K_a = 6.21 \times 10^{-8}\,\text{mol dm}^{-3}$$

Scientists studying cells prepared a buffer solution with the same pH as that inside a specific type of cell. They dissolved 29.48 g of NaH_2PO_4 in 3.18 dm^3 of 0.0800 mol dm^{-3} Na_2HPO_4 solution and made it up to 5.00 dm^3 with deionised water.

Calculate the pH of the buffer solution formed.

[Data: M_r NaH_2PO_4 = 120.0]

(5)

(Total for Question 16 = 10 marks)

***17** Some reactions are always feasible, some reactions are never feasible and some reactions are feasible in the right conditions.

Discuss how these different possibilities are determined by the values of the entropy changes.

(6)

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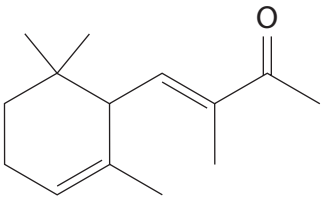
(Total for Question 17 = 6 marks)

TOTAL FOR SECTION B = 52 MARKS

SECTION C

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

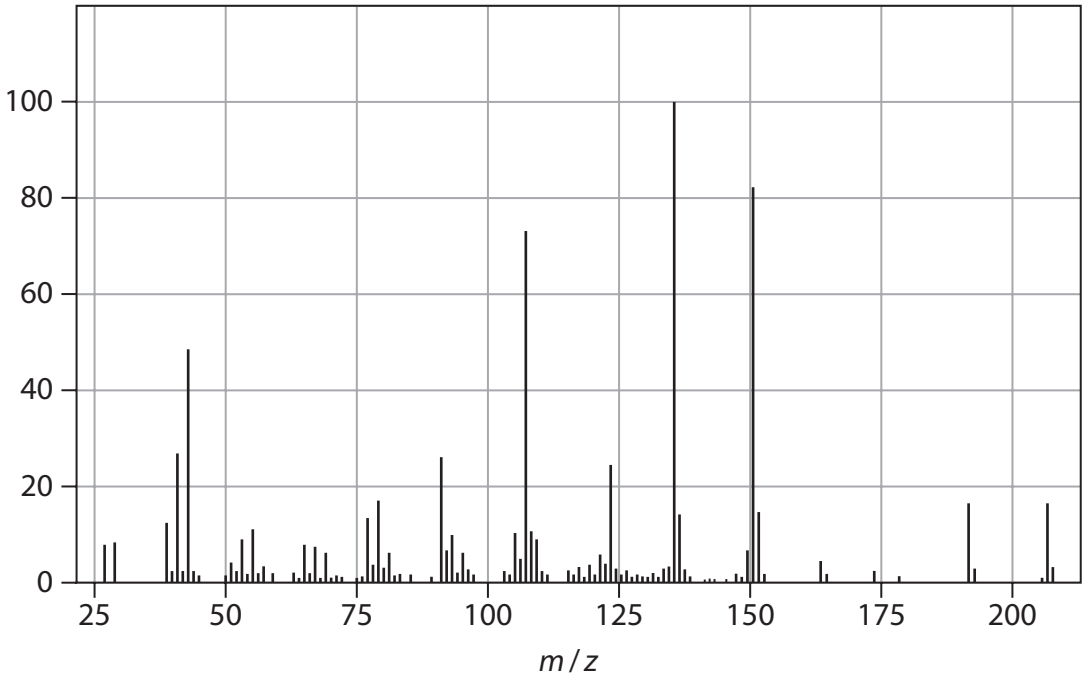
18 Scientists have isolated a volatile compound responsible for the special smell of babies. This has been identified as alpha-isomethylionone.



alpha-isomethylionone

$M_r = 206$

(a) The mass spectrum of alpha-isomethylionone is shown.



(i) Describe how fragments are formed in the mass spectrometer.

(2)

.....

.....

.....

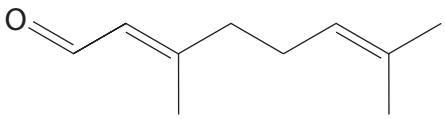
.....

(ii) The most abundant peak is at $m/z = 136$.

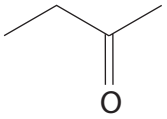
Draw a possible structure of the fragment of alpha-isomethylionone causing the peak at $m/z = 136$.

(1)

(b) Alpha-isomethylionone can be synthesised in the laboratory.
One mole of geranial reacts with one mole of butanone in this synthesis.



geranial



butanone

(i) Calculate the **maximum** mass of alpha-isomethylionone that can be produced from 25.0 kg of butanone.

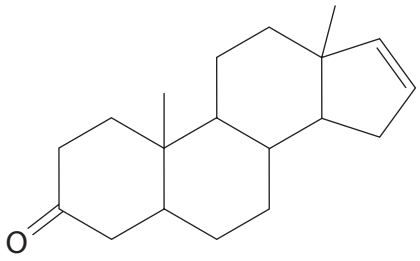
(2)

(ii) Calculate the atom economy for the reaction.

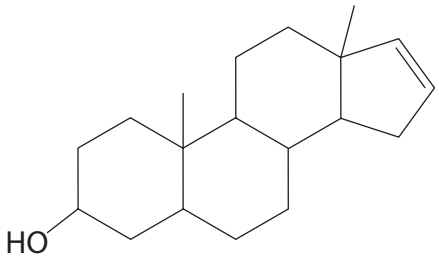
(1)

(c) Scientists have also isolated some of the compounds responsible for the smells produced by teenagers.
The samples were collected from many individuals, separated by chromatography and identified by mass spectrometry.

Many compounds were present in both infant and teenager sweat, but in different ratios. Some compounds in teenager sweat were not found in infant sweat. These compounds included the molecules **A** and **B**.

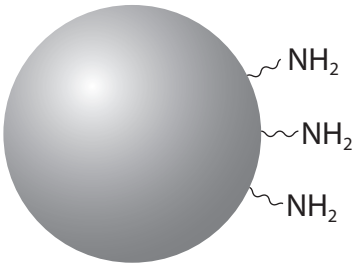


A



B

(i) A high-performance liquid chromatography (HPLC) column is packed with material that has amine groups attached as shown.



State which of the molecules, **A** or **B**, would take longer to move through the column. Justify your answer.

(2)

(ii) Name a different column chromatography technique that could be used to separate **A** and **B**.

(1)

(d) Some of the compounds isolated only from the teenagers were carboxylic acids. The solubility in water of two of these acids is shown.

Name of isolated acid	Solubility in H_2O at 20 °C / g dm^{-3}
4-ethyloctanoic acid	0.13
3-methylbutanoic acid	25.00

(i) Explain how the structures of the acids affect their solubility in water.

(3)

(ii) The K_a for 3-methylbutanoic acid is 1.58×10^{-5} mol dm^{-3} at 298 K.

Calculate the pH of a saturated solution of 3-methylbutanoic acid.

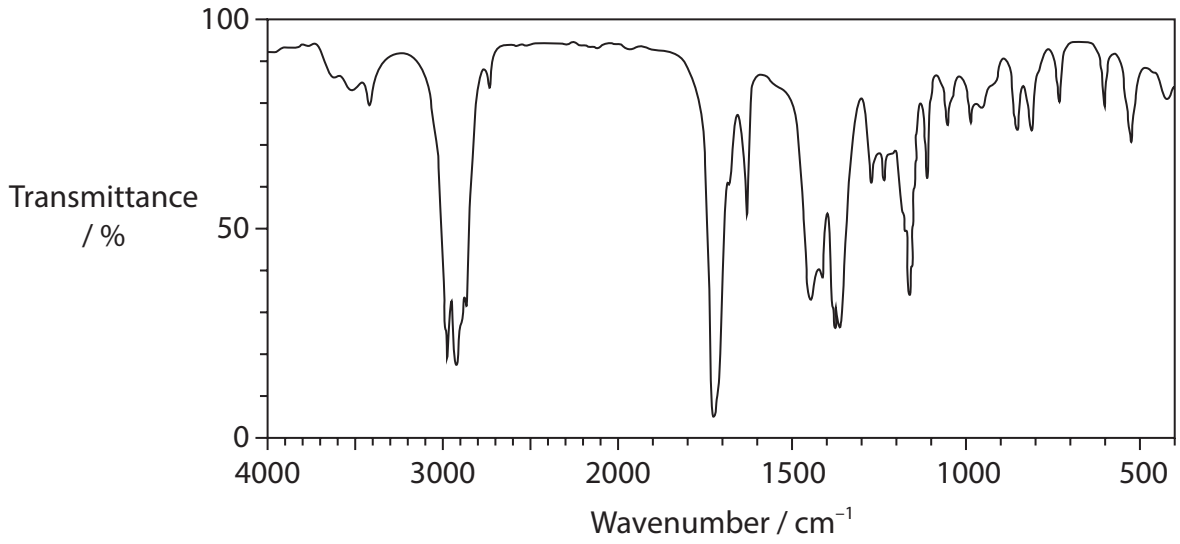
(3)

(e) One of the compounds present in samples from both teenagers and infants was 6-methylhept-5-en-2-one.

(i) Draw the **skeletal** formula of 6-methylhept-5-en-2-one.

(1)

(ii) The infrared spectrum of 6-methylhept-5-en-2-one is shown.



Give the bond and wavenumber range of **three** absorbances in the spectrum that are **not** in the fingerprint region.
Use your Data Booklet.

(2)

(Total for Question 18 = 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									(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

* 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