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CHEMISTRY **9701/22**

Paper 2 AS Level Structured Questions **February/March 2026**

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen. Do **not** use correction fluid or tape.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [ ].
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.

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This document has **16** pages. Any blank pages are indicated.

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1 The Group 2 elements Mg to Ba show trends in their physical properties down the group.

(a) Table 1.1 shows some information about the elements Mg to Ba.

Table 1.1

element	proton number	shorthand electronic configuration	sum of first and second ionisation energies / kJ mol^{-1}	third ionisation energy / kJ mol^{-1}
Mg	12	[Ne] $3s^2$	2186	7740
Ca	20	[Ar] $4s^2$	1740	4940
Sr	38	[Kr] $5s^2$	1608	4120
Ba	56	[Xe] $6s^2$	1468	3390

(i) Give the full electronic configuration of a calcium atom.

..... [1]

(ii) Explain the trend shown in the sum of the first and second ionisation energies, as proton number increases.

.....

.....

.....

..... [2]

(iii) Write an equation to represent the third ionisation energy of barium.

..... [1]

(iv) Explain why the third ionisation energy of magnesium is much greater than the sum of its first and second ionisation energies.

.....

.....

.....

..... [2]

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(b) When strontium reacts with water, an alkaline solution is produced.

(i) Write an equation for this reaction. Include state symbols.

..... [2]

(ii) Samples of the alkaline solution produced in **1(b)(i)** are tested with dilute HC*l*(aq) and separately with dilute H_2SO_4(aq).

State what you would observe in each test.

observation with dilute HC*l*(aq)

.....

observation with dilute H_2SO_4(aq)

.....
[2]

(c) The nitrates and carbonates of Group 2 elements decompose on heating.

(i) State the trend in the thermal stability of the Group 2 carbonates down the group.

..... [1]

(ii) Write an equation for the thermal decomposition of $Ca(NO_3)_2$.

..... [1]

(d) Calcium chlorate(I), $Ca(ClO)_2$, is used for water purification in the same way as sodium chlorate(I), NaC*l*O.

$Ca(ClO)_2$ can be prepared by the reaction of aqueous $Ca(OH)_2$ with Cl_2.

(i) Write an ionic equation for the reaction of cold dilute OH^- ions with Cl_2.

..... [1]

(ii) State why NaC*l*O and $Ca(ClO)_2$ are used in water purification.

..... [1]

[Total: 14]

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2 Nitrogen monoxide, NO, is an atmospheric pollutant.

(a) Figure 2.1 shows the dot-and-cross diagram of NO.

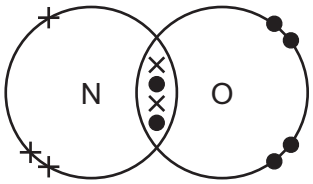

Figure 2.1

(i) NO has an unpaired electron.

State the term for a molecule with an unpaired electron.

..... [1]

(ii) In NO, the N and O atoms are bonded by a sigma (σ) and a pi (π) bond.

Complete Figure 2.2 to show the pi bond in NO that is formed from orbital overlap.

N——O

Figure 2.2

[1]

(b) In the laboratory, NO is made in the reaction of copper metal with dilute nitric acid. The reaction is kept cold to prevent the oxidation of NO.

$$8HNO_3(aq) + 3Cu(s) \rightarrow 3Cu(NO_3)_2(aq) + 4H_2O(l) + 2NO(g)$$

A student reacts 0.00393 mol Cu with excess dilute $HNO_3(aq)$ at 5 °C and 101 kPa.

Calculate the maximum volume, in cm^3, of NO(g) that is produced under these conditions.

volume of NO(g) produced = ... cm^3 [4]

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(c) **(i)** State a natural process that creates atmospheric NO.

..... [1]

(ii) Photochemical smog forms when NO reacts with unburned hydrocarbons.

Identify the major component of photochemical smog.

..... [1]

(iii) NO has a catalytic role in the oxidation of atmospheric SO_2.

$$SO_2 + \frac{1}{2}O_2 \rightleftharpoons SO_3$$

Show, using relevant equations, the catalytic role that NO has in this oxidation.

.....

..... [2]

(d) Reaction 1 occurs during the catalytic removal of NO from car exhaust gases.

reaction 1 $\quad NO(g) + CO(g) \rightleftharpoons \frac{1}{2}N_2(g) + CO_2(g) \qquad \Delta H = -373\,kJ\,mol^{-1}$

The activation energy, E_a, of this reaction is $570\,kJ\,mol^{-1}$.

(i) Complete Figure 2.3 to sketch the energy profile for reaction 1.

Show the enthalpy change, ΔH, and the activation energy, E_a.

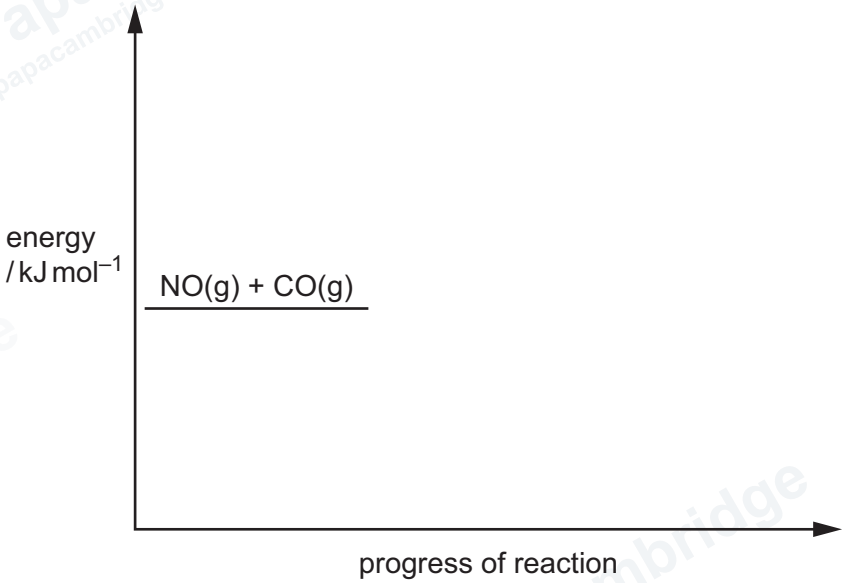

Figure 2.3

[2]

(ii) On your diagram in Figure 2.3, show how the addition of a catalyst affects reaction 1. [1]

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3 Secondary halogenoalkanes are important building blocks in organic chemistry.

2-chlorobutane is an example of a secondary halogenoalkane.

2-chlorobutane

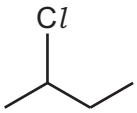

Figure 3.1

(a) Explain why 2-chlorobutane is classified as a secondary halogenoalkane.

.....

..... [1]

(b) 2-chlorobutane can be formed by the electrophilic addition of HCl to different isomers of C_4H_8. Compound **A** is one of these isomers.

A



Figure 3.2

(i) Draw a structural isomer of **A** that can also form 2-chlorobutane when it reacts with HCl.

structural isomer of **A**

[1]

(ii) Draw and give the systematic name of the geometrical isomer of **A**.

geometrical isomer of **A**

systematic name ..... [2]

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(iii) State and explain the origin of geometrical isomerism in alkenes.

.....

.....

..... [2]

(c) Butane, C_4H_{10}, reacts with Cl_2 in the presence of ultraviolet light to form 2-chlorobutane, which has molecular formula C_4H_9Cl.

$$C_4H_{10} + Cl_2 \rightarrow C_4H_9Cl + HCl$$

(i) Name the mechanism of this reaction.

..... [1]

(ii) Complete the reaction scheme given to show the formation of 2-chlorobutane.

You may use molecular formulas in your answer.

initiation $Cl_2 \rightarrow 2Cl\bullet$

propagation .....

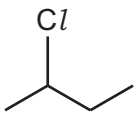
propagation $C_4H_9\bullet + Cl_2 \rightarrow C_4H_9Cl + Cl\bullet$

termination .....

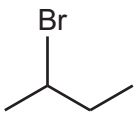
[2]

(d) The rates of hydrolysis of three secondary halogenoalkanes, **B**, **C** and **D**, are compared.

B



C



D

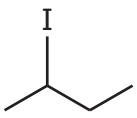


Figure 3.3

Each halogenoalkane is dissolved in ethanol and reacted with $AgNO_3(aq)$.

Identify the order of the rates of hydrolysis of compounds **B**, **C** and **D**. Explain your answer.

..... > ..... > .....

fastest slowest

explanation .....

..... [2]

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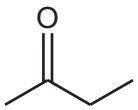
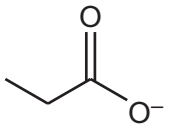
(e) The organic product of hydrolysis of each of **B**, **C** and **D** is butan-2-ol.

Complete Table 3.1 to give details of some typical chemical reactions of butan-2-ol.

Table 3.1

reagent and conditions	observation with butan-2-ol	organic product(s)
acidified $K_2Cr_2O_7$		
Na(s)	effervescence	
	yellow precipitate	 and CHI_3

[3]

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4 Cyanoethanoic acid, $CH_2(CN)COOH$, is a weak organic acid.

(a) At room temperature, $CH_2(CN)COOH$ undergoes an acid–base reaction with NaOH(aq).

(i) Define weak acid.

.....

..... [1]

(ii) Sketch the pH titration curve on Figure 4.1 for the reaction of:

- $25.00\,cm^3$ of $0.10\,mol\,dm^{-3}$ $CH_2(CN)COOH(aq)$ and
- $0.10\,mol\,dm^{-3}$ NaOH(aq), added to excess.

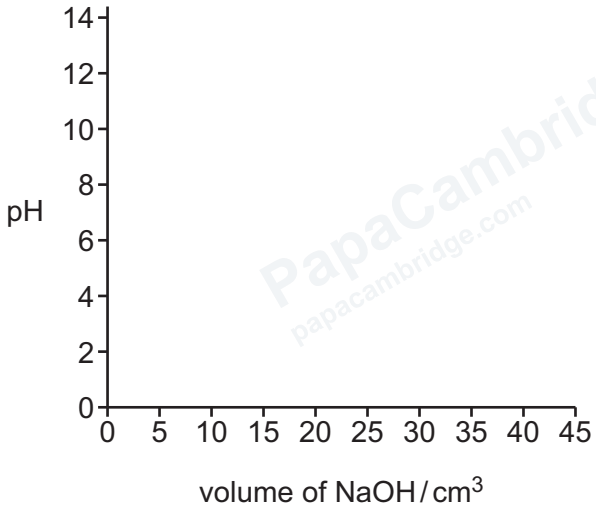

Figure 4.1

[3]

(iii) Write the overall ionic equation for the neutralisation of $CH_2(CN)COOH(aq)$ by NaOH(aq) in **4(a)(ii)**.

Include state symbols.

..... [1]

(iv) Suggest the formula of the organic product when $CH_2(CN)COOH(aq)$ is heated under reflux with NaOH(aq).

..... [1]

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(b) $CH_2(CN)COOH$ is very soluble in water because it can form hydrogen bonds with water.

Complete Figure 4.2 to show **one** hydrogen bond between a molecule of $CH_2(CN)COOH$ and a molecule of H_2O.

Label the hydrogen bond clearly, and show any relevant partial charges and lone pairs of electrons.

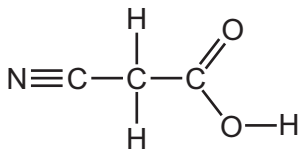

Figure 4.2

[3]

(c) Figure 4.3 shows a synthesis of $CH_2(CN)COOH$.

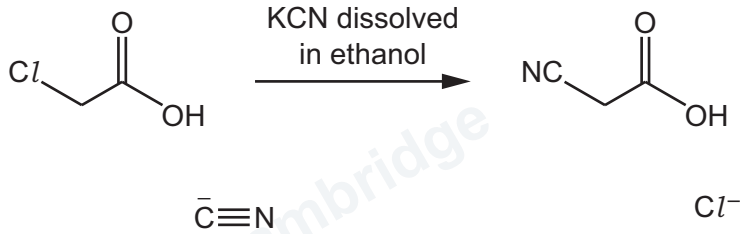

Figure 4.3

(i) The reaction mechanism of the synthesis in Figure 4.3 has a single step.

Complete Figure 4.3 to show this mechanism. Include lone pairs, charges, dipoles and curly arrows as appropriate.

[2]

(ii) Identify the nucleophile in Figure 4.3.

..... [1]

(iii) Identify the mechanism of the reaction in Figure 4.3.

..... [1]

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(d) Figure 4.4 describes a sequence of reactions, starting with $CH_2(CN)COOH$, to form **E**.

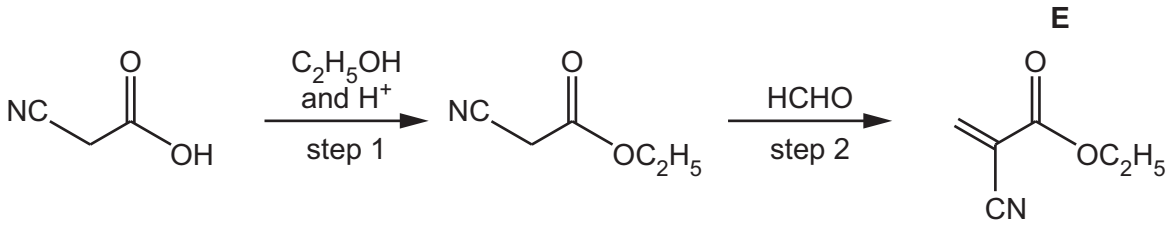

Figure 4.4

(i) Identify the type of reaction that occurs in step 1.

..... [1]

(ii) Name HCHO, the reactant used in step 2.

..... [1]

(iii) Deduce the molecular formula of **E**.

..... [1]

(iv) **E** can be polymerised to form **F**.

Draw the structure of **one** repeat unit of polymer **F**.

[1]

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(v) Figure 4.5 shows the infrared spectrum of **E**.

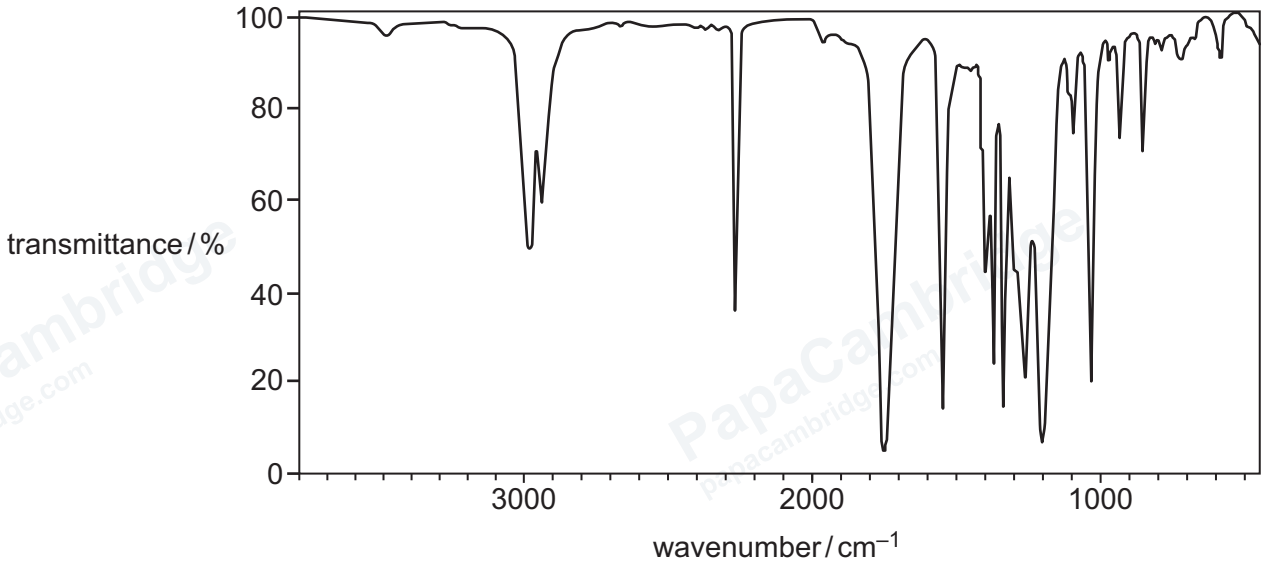

Figure 4.5

Table 4.1

bond	functional groups containing the bond	characteristic infrared absorption range (in wavenumbers) / cm^{-1}
C–O	hydroxy, ester	1040–1300
C=C	aromatic compound, alkene	1500–1680
C=O	amide carbonyl,carboxyl ester	1640–1690 1670–1740 1710–1750
C≡N	nitrile	2200–2250
C–H	alkane	2850–2950
N–H	amine, amide	3300–3500
O–H	carboxyl hydroxy	2500–3000 3200–3650

Using the information given in Table 4.1, identify with a cross (×) on Figure 4.5 an absorption that can be used to monitor the progress of the polymerisation of **E** to form **F**.

Explain your answer with reference to the relevant bond.

.....

.....

..... [2]

[Total: 19]

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Important values, constants and standards

molar gas constant	$R = 8.31\,\text{J K}^{-1}\,\text{mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^{4}\,\text{C mol}^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23}\,\text{mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19}\,\text{C}$
molar volume of gas	$V_m = 22.4\,\text{dm}^3\,\text{mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0\,\text{dm}^3\,\text{mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14}\,\text{mol}^2\,\text{dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18\,\text{kJ kg}^{-1}\,\text{K}^{-1}$ ($4.18\,\text{J g}^{-1}\,\text{K}^{-1}$)

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The Periodic Table of Elements

Group																	
1	2											13	14	15	16	17	18
							1 H hydrogen 1.0										2 He helium 4.0
3 Li lithium 6.9	4 Be beryllium 9.0											5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2
11 Na sodium 23.0	12 Mg magnesium 24.3	3	4	5	6	7	8	9	10	11	12	13 Al aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium –	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids	72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium –	85 At astatine –	86 Rn radon –
87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –	113 Nh nihonium –	114 Fl flerovium –	115 Mc moscovium –	116 Lv livermorium –	117 Ts tennessine –	118 Og oganesson –

Key

atomic number
atomic symbol
name
relative atomic mass

lanthanoids	57 La lanthanum 138.9	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.2	61 Pm promethium –	62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.1	71 Lu lutetium 175.0
actinoids	89 Ac actinium –	90 Th thorium 232.0	91 Pa protactinium 231.0	92 U uranium 238.0	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –

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