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Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER		CANDIDATE NUMBER	

9218288759

CHEMISTRY **9701/22**

Paper 2 AS Level Structured Questions **May/June 2024**

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 or correction fluid.
- 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.

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

1 **(a)** Complete Table 1.1 using relevant information from the Periodic Table.

Table 1.1

	nucleon number	proton number	number of electrons
Mg^{2+}	24		
Al^{3+}	27		

[2]

(b) State and explain the difference in the ionic radius of Al^{3+} compared to Mg^{2+}.

....

....

....

.... [3]

(c) Draw a labelled diagram to show the structure and bonding in sodium.

[1]

(d) Fig. 1.1 shows the variation in melting point of some Period 3 elements in their standard states at room temperature and pressure.

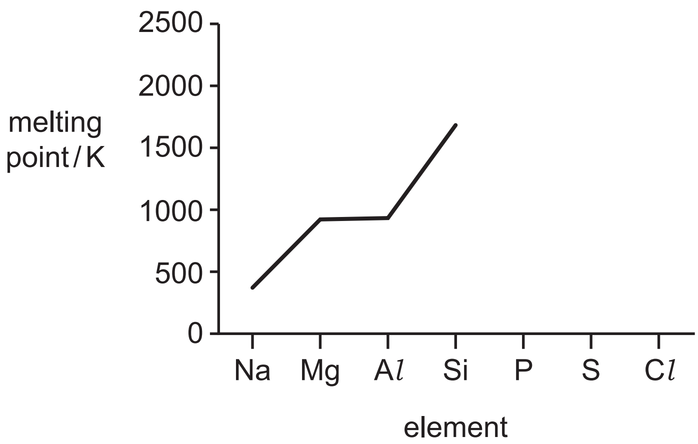

Fig. 1.1

(i) Explain why Si has a high melting point.

....

....

.... [1]

(ii) Complete Fig. 1.1 to show the variation in the melting points of the elements P, S and C*l*. [2]

(e) Two Period 3 elements react with an excess of oxygen at room pressure.

(i) Complete Table 1.2.

Table 1.2

1	2	3
Period 3 element	state of oxide at room temperature and pressure	approximate pH of solution made when oxide is added to water
Na		
S		

[2]

(ii) The solutions made in column 3 of Table 1.2 are mixed together.
Name the type of reaction that occurs.

.... [1]

(iii) Write an equation to describe the reaction between P_4O_{10} and an excess of water.

.... [1]

(f) Aluminium hydroxide is amphoteric.

(i) Explain what is meant by amphoteric.

....

.... [1]

(ii) Write an equation to describe the reaction that occurs when aluminium hydroxide, $Al(OH)_3$, reacts with NaOH(aq).

.... [1]

[Total: 15]

2 Separate samples of Na_2CO_3 and $NaHCO_3$ react with $HCl(aq)$ to produce the same products, as shown in Table 2.1.

Table 2.1

reaction	equation	ΔH / kJ mol^{-1}
1	$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$	ΔH_1
2	$NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$	$\Delta H_2 = +27.2$

(a) Complete the reaction pathway diagram in Fig. 2.1 for reaction 2.

Label the diagram to show the enthalpy change, ΔH_2, and the activation energy, E_A.

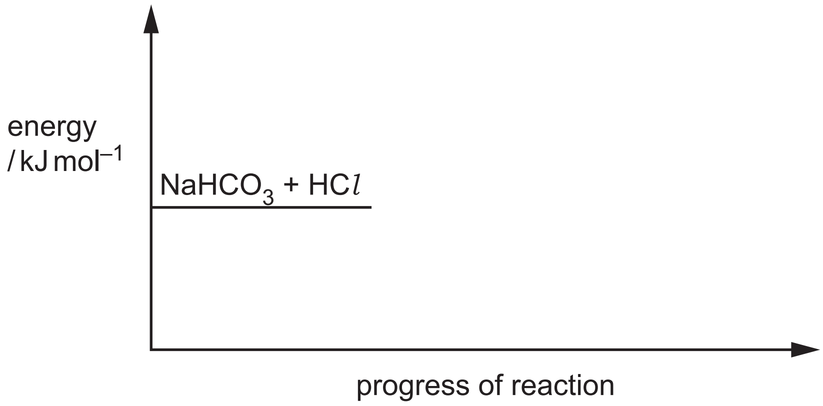

Fig. 2.1

[2]

(b) The value for ΔH_1 is determined by experiment using the following method.

- 50.0 cm^3 of 2.00 mol dm^{-3} $HCl(aq)$ is added to a polystyrene cup.
- The initial temperature of the acid is recorded as 19.6 °C.
- 0.0400 mol of Na_2CO_3 is added and the mixture is stirred.
- All the solid Na_2CO_3 disappears and a colourless solution is produced.

The maximum temperature recorded during the reaction is 26.2 °C.

(i) Describe **one** other observation that shows the reaction is complete.

.... [1]

(ii) Calculate the value of ΔH_1 in $kJ\,mol^{-1}$.

Assume the specific heat capacity of the reaction mixture is the same as for water and no heat is lost to the surroundings.

Show your working.

ΔH_1 = ... $kJ\,mol^{-1}$ [3]

(iii) Thermal decomposition occurs when $NaHCO_3$ is heated.

reaction 3 $2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$

Calculate the enthalpy change for reaction 3, ΔH_r, using the data in Table 2.1 and the value of ΔH_1 calculated in **(b)(ii)**.

(If you were unable to calculate a value for ΔH_1 in **(b)(ii)**, assume the enthalpy change is $-38.4\,kJ\,mol^{-1}$. This is **not** the correct value.)

ΔH_r = ... $kJ\,mol^{-1}$ [2]

(c) **Z** is a salt that contains a Period 4 element from Group 2. When **Z** is heated brown gas forms.

Identify the formula of **Z** and use it to write an equation for the reaction.

.... [2]

[Total: 10]

3 **(a)** Describe what is meant by dynamic equilibrium.

....

....

.... [2]

(b) Reaction 4 describes the reversible reaction between yellow $Fe^{3+}(aq)$ and colourless $SCN^{-}(aq)$ to produce red $FeSCN^{2+}(aq)$.

reaction 4 $\quad Fe^{3+}(aq) + SCN^{-}(aq) \rightleftharpoons FeSCN^{2+}(aq)$

yellow $\quad$ colourless $\quad$ red

An equilibrium mixture contains $Fe^{3+}(aq)$, $SCN^{-}(aq)$ and $FeSCN^{2+}(aq)$. A few colourless crystals of soluble KSCN(s) are added. The mixture is then left until it reaches equilibrium again. The temperature of both equilibrium mixtures is the same.

(i) Deduce the changes that occur, if any, in the equilibrium mixture after KSCN(s) is added compared to the original equilibrium mixture.

- change in appearance

  ....

- change in relative concentration of $Fe^{3+}(aq)$

  ....

- change in value of the equilibrium constant, K_c

  ....

[3]

(ii) The expression for the equilibrium constant, K_c, for reaction 4 is shown.

$$K_c = \frac{[FeSCN^{2+}(aq)]}{[Fe^{3+}(aq)] \times [SCN^-(aq)]}$$

5.00×10^{-5} mol of $Fe^{3+}(aq)$ and 5.00×10^{-5} mol of $SCN^-(aq)$ are added together and allowed to reach equilibrium. The total volume of the mixture is $25.0\,cm^3$.

At equilibrium the concentration of $FeSCN^{2+}(aq)$ is $4.23 \times 10^{-4}\,mol\,dm^{-3}$.

Calculate the equilibrium constant, K_c, for reaction 4.

Include the units in your answer.

K_c = ...

units ....

[4]

(c) Determine the full electronic configuration of Fe^{3+}.

.... [1]

(d) SCN^{-}(aq) is colourless.

Complete the dot-and-cross diagram in Fig. 3.1 to show the arrangement of outer electrons in an SCN^{-} ion.

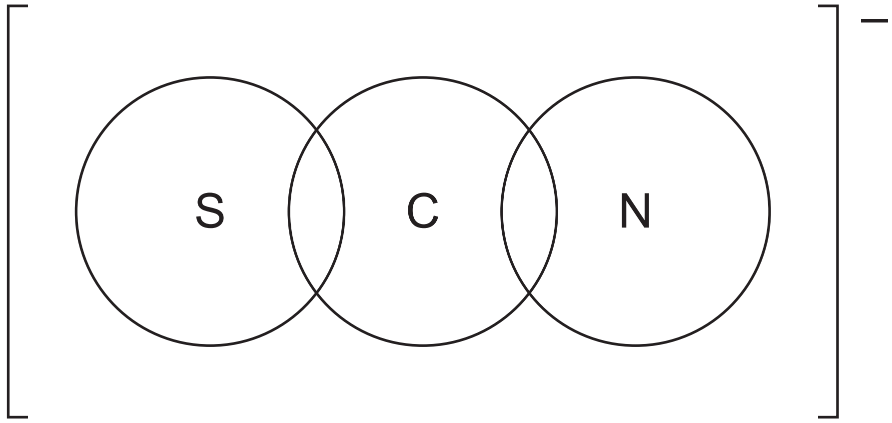

Fig. 3.1

[2]

[Total: 12]

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4 $CH_3(CH_2)_5CHBrCH_3$ exists as a pair of stereoisomers.

(a) Draw the three-dimensional structures of the **two** stereoisomers of $CH_3(CH_2)_5CHBrCH_3$. R can be used to represent $CH_3(CH_2)_5$.

[2]

(b) A sample of $CH_3(CH_2)_5CHBrCH_3$ reacts with NaOH to make $CH_3(CH_2)_5CH(OH)CH_3$ in an S_N1 mechanism.

Complete Fig. 4.1 to show the mechanism for the reaction of $CH_3(CH_2)_5CHBrCH_3$ and NaOH.

Include charges, dipoles, lone pairs of electrons and curly arrows, as appropriate.

Fig. 4.1

[3]

(c) Separate samples of $CH_3(CH_2)_5CHBrCH_3$, $CH_3(CH_2)_5CH(OH)CH_3$ and $CH_3(CH_2)_5CHCH_2$ are tested with different reagents.

Complete Table 4.1. If no reaction occurs, write × in the relevant box.

Table 4.1

reagent added	observation with $CH_3(CH_2)_5CHBrCH_3$	observation with $CH_3(CH_2)_5CH(OH)CH_3$	observation with $CH_3(CH_2)_5CHCH_2$
Br_2(l) in the dark			
PCl_5(s)			
$AgNO_3$(aq)			

[3]

(d) $CH_3(CH_2)_5CHBrCH_3$ is heated with **D** to produce three different molecules, **E**, **F** and **G**.

E **F** **G**

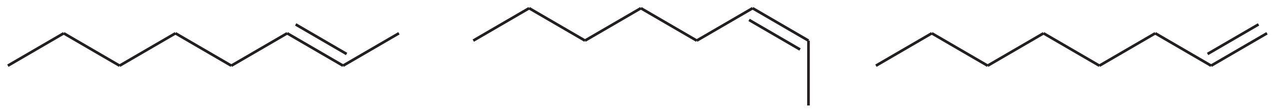

Fig. 4.2

(i) Name the type of reaction.

.... [1]

(ii) Identify **D** and the conditions used.

.... [1]

(e) (i) Both σ and π bonds are present in a molecule of **E** as a result of different types of hybridisation in the carbon atoms.

Complete Table 4.2 to show the number of carbon atoms with each type of hybridisation in a molecule of **E**.

Table 4.2

	number of carbon atoms		
	sp hybridised	sp^2 hybridised	sp^3 hybridised
E 			

[2]

(ii) Describe the essential feature of an unbranched hydrocarbon that causes its molecules to show stereoisomerism. Explain how this feature leads to stereoisomerism.

....

....

.... [3]

[Total: 15]

5 Compound **W** has molecular formula $C_4H_{10}O$. It contains only **one** functional group.

(a) Table 5.1 shows the two peaks with the greatest *m*/*e* values in the mass spectrum of **W**.

Table 5.1

m/*e*	relative abundance
74	50
75	x

(i) Calculate the relative abundance, x, of the peak at *m*/*e* = 75 using the information from Table 5.1.

x = ... [1]

(ii) The mass spectrum of **W** also shows peaks at *m*/*e* = 29 and *m*/*e* = 59.

Suggest the molecular formulae of these fragments.

m/*e* = 29 ....

m/*e* = 59 ....

[2]

(b) A sample of **W**, $C_4H_{10}O$, is heated under reflux with an excess of acidified $K_2Cr_2O_7$ until there is no further reaction. Only **one** organic product, **X**, is present in the mixture at the end of the reaction.

Fig. 5.1 shows the infrared spectrum of **W**.

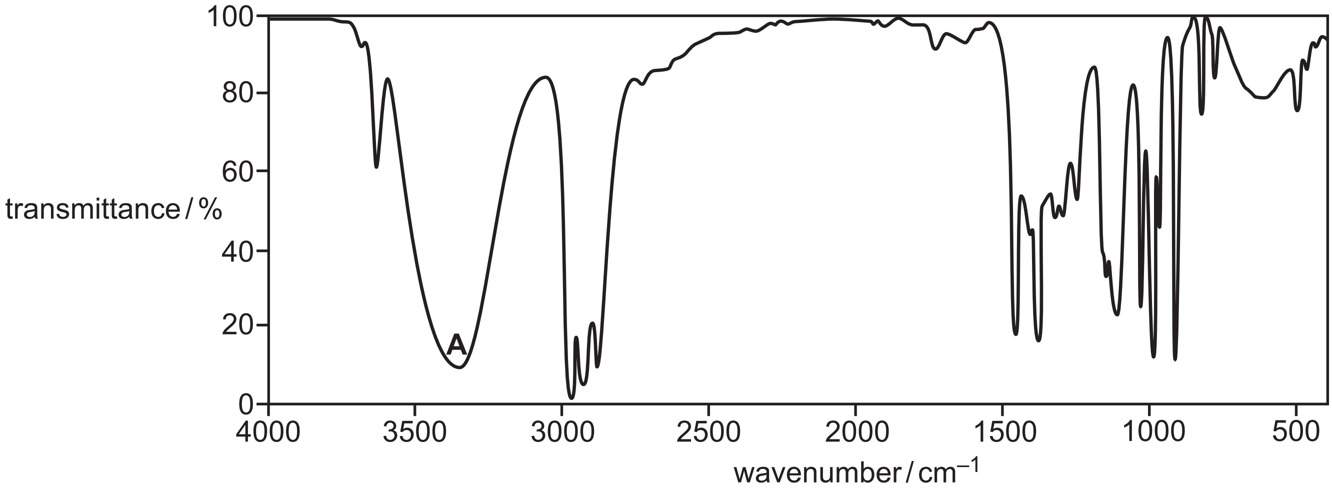

Fig. 5.1

Fig. 5.2 shows the infrared spectrum of **X**.

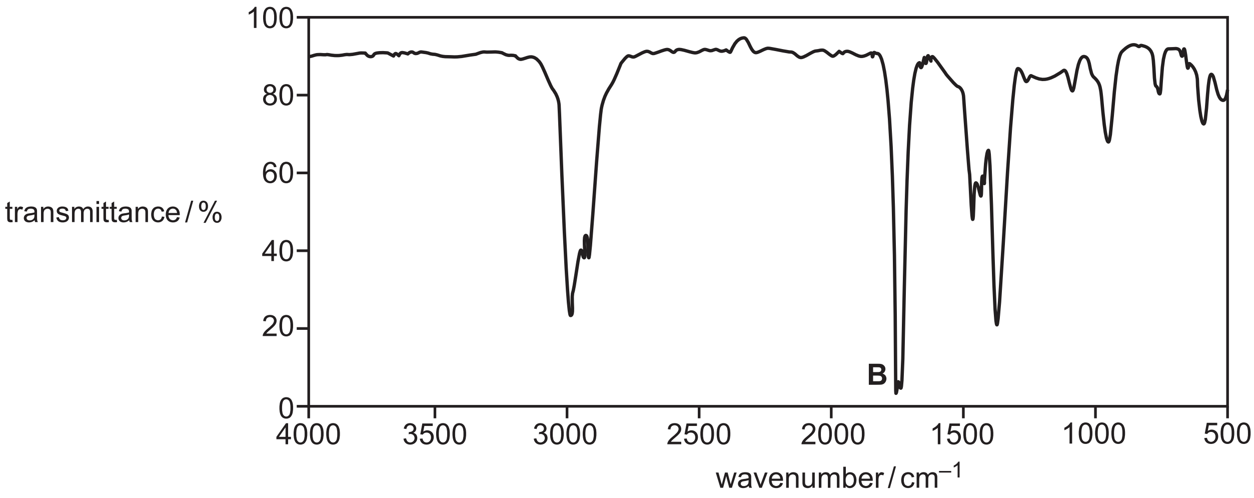

Fig. 5.2

Table 5.2

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

(i) Absorption **A** is shown in Fig. 5.1.
Absorption **B** is shown in Fig. 5.2.

Complete Table 5.3 using the information given in Fig. 5.1, Fig. 5.2 and Table 5.2.

Table 5.3

absorption	bond	functional group containing the bond
A		
B		

[1]

(ii) Use the information in **(a)** and **(b)(i)** to draw the structure of **X** in the box in Fig. 5.3.

$$\underset{C_4H_{10}O}{\mathbf{W}} \xrightarrow{+ \text{ acidified } K_2Cr_2O_7} \boxed{\mathbf{X}}$$

Fig. 5.3

[1]

(c) **Y** is a structural isomer of **W**.

Both **W** and **Y** produce colourless bubbles when sodium is added to them.

Y does **not** react when heated with acidified $K_2Cr_2O_7$.

Y does **not** react when warmed with alkaline $I_2(aq)$.

(i) Name the functional group present in **Y**.

.... [1]

(ii) Complete the equation to describe the reaction of **W** or **Y** with sodium.

..........$C_4H_{10}O$ + ...Na $\rightarrow$ .... [1]

(iii) Draw the structure of **Y**.

[1]

[Total: 8]

Important values, constants and standards

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

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The Periodic Table of Elements

Key

atomic number atomic symbol name relative atomic mass

Group 1	2	3	4	5	6	7	8	9	10	11	12	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											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 –

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 –