Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

5046493367

CHEMISTRY **9701/22**

Paper 2 AS Level Structured Questions **May/June 2022**

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.

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1 **(a)** Magnesium has a melting point of 650 °C and high electrical conductivity.

Explain these properties of magnesium by referring to its structure and bonding.

....

.... [2]

(b) When magnesium is heated in air, magnesium oxide, MgO, is the major product. Smaller amounts of magnesium nitride, Mg_3N_2, are also made.

(i) Calculate the oxidation number for magnesium and for the nitrogen species in Mg_3N_2 to complete Table 1.1.

Table 1.1

species	magnesium in Mg_3N_2	nitrogen in Mg_3N_2
oxidation number		

[1]

(ii) Identify the type of reaction which takes place between magnesium and nitrogen. Explain your answer.

....

.... [1]

(iii) Define enthalpy change of formation.

....

.... [2]

(iv) When 3.645 g of Mg(s) burns in excess N_2(g) to form Mg_3N_2(s), 23.05 kJ of energy is released.

Calculate the enthalpy change of formation, ΔH_f, of Mg_3N_2. Show your working.

ΔH_f (Mg_3N_2) = ... [3]

[Total: 9]

Question 2 starts on the next page.

2 Radium, Ra, is an element found in Group 2 of the Periodic Table. It is a crystalline solid at room temperature and conducts electricity.

Radium chloride, $RaCl_2$, has a melting point of 900 °C and is soluble in water.

(a) Predict the lattice structure of $RaCl_2(s)$ based on the properties described.

.... [1]

(b) Draw a dot-and-cross diagram to show the arrangement of outer electrons in $RaCl_2$.

[1]

(c) Solid Ra and Ca show similar reactions with H_2O, but the reactions occur at different rates.

Separate samples, each containing a single piece of solid Ra or Ca, are added to equal volumes of cold water.

Each sample contains equal numbers of moles of solid and the H_2O is in excess.

(i) Construct an equation for the reaction of Ra with H_2O.

.... [1]

(ii) Identify which element, Ra or Ca, reacts with H_2O at a faster rate. Suggest how the observations of each reaction would differ.

....

.... [1]

(iii) Suggest why these reactions occur at different rates.

....

....

.... [2]

(iv) One of the solutions is cloudy when the reaction has finished.

At the end of each reaction, universal indicator is added to each reaction mixture.

Suggest pH values of the solutions made in both reactions. Explain your answer.

....

....

.... [2]

(d) A sample of aqueous calcium halide, $CaX_2(aq)$, contains either chloride, bromide or iodide ions.

Complete Table 2.1 to describe a two-step process that could be used to identify the halide ion present.

Table 2.1

step	method	observation with $CaCl_2$	observation with $CaBr_2$	observation with CaI_2
step **1**				
step **2**				

[3]

[Total: 11]

3 **(a)** 0.025 mol of HI(g) is added to a closed vessel and left to reach dynamic equilibrium. The total pressure of the vessel is 100 kPa.

equation **1** $2HI(g) \rightleftharpoons H_2(g) + I_2(g)$

(i) Explain what is meant by dynamic equilibrium.

....

....

.... [2]

(ii) Describe **one** difference in the initial appearance of the reaction mixture compared to the mixture at equilibrium.

.... [1]

(iii) Write an expression for K_p for the reaction described in equation **1**.

K_p =

[1]

(iv) At equilibrium the partial pressure of HI(g) is 86.4 kPa.

Calculate the amount of HI(g) present in the mixture at equilibrium. Show your working.

amount of HI(g) = ... mol [2]

(b) Use equation **1** and the bond energy values in Table 3.1 to calculate the change in enthalpy, ΔH, for the thermal decomposition of 1 mole of HI(g). Show your working.

Table 3.1

bond	bond energy / $kJ\,mol^{-1}$
H–H	436
I–I	151
H–I	299

ΔH = ... $kJ\,mol^{-1}$ [2]

(c) Describe the effect of increasing pressure on the value of K_p for the decomposition of HI(g).

.... [1]

(d) HC*l*(g) is prepared by adding NaC*l*(s) to concentrated H_2SO_4.

HI(g) is **not** prepared by adding NaI(s) to concentrated H_2SO_4 because the HI(g) produced also reacts with concentrated H_2SO_4.

(i) Identify the type of reaction that occurs when NaI(s) reacts with concentrated H_2SO_4 to form HI(g).

.... [1]

(ii) Write an equation for the reaction of HI(g) and concentrated H_2SO_4.

.... [1]

(iii) Explain why HI(g) reacts with concentrated H_2SO_4 whereas HC*l* does not.

.... [1]

[Total: 12]

4 **(a)** Bromine reacts with butane in the presence of ultraviolet light to form bromobutane.

Two structural isomers with the molecular formula C_4H_9Br are produced during this reaction.

(i) Draw the two structural isomers and state the systematic name of each isomer.

structural isomer **1**	structural isomer **2**
name	name ....

[2]

(ii) Identify the type of structural isomerism shown in **(a)(i)**.

.... [1]

(b) Halothane is an anaesthetic.

halothane

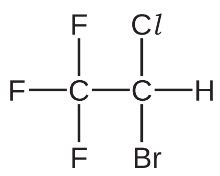

Fig. 4.1

(i) Identify the chiral centre in halothane and mark it with an asterisk (*). [1]

When halothane reacts in ultraviolet light, homolytic fission occurs and the C–Br bond is broken.

(ii) Construct an equation to show the homolytic fission of halothane, $CF_3CHBrCl$.

.... [1]

(iii) Complete Fig. 4.2 to show the arrangement of electrons in a bromine atom using the electrons in boxes notation.

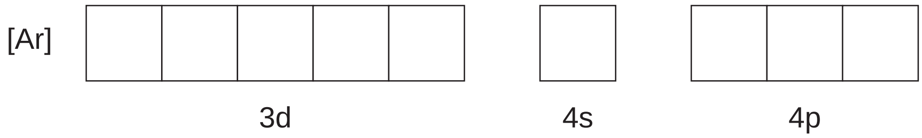

Fig. 4.2

[1]

(c) **X** is an addition polymer.

X

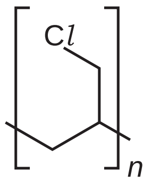

Fig. 4.3

(i) Draw the monomer of **X**.

[1]

(ii) Suggest **one** reason why the disposal of items made from **X** is difficult.

.... [1]

[Total: 8]

5 Fig. 5.1 shows three reactions of 2-bromopropane, $CH_3CH(Br)CH_3$.

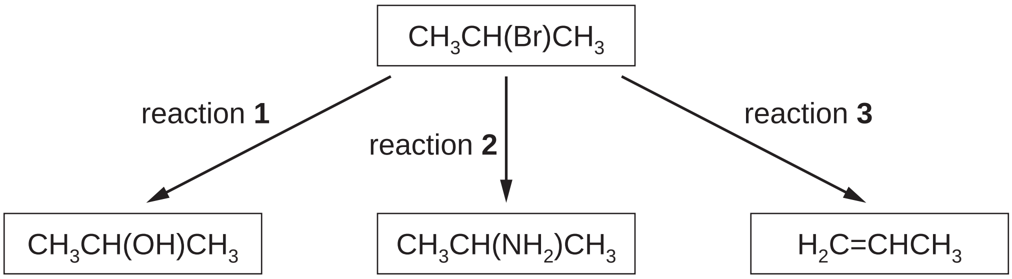

Fig. 5.1

(a) Complete Table 5.1 for each reaction, by:

- stating the reagent and conditions used
- identifying the type of reaction that occurs.

Table 5.1

reaction	reagent and conditions	type of reaction
1		
2		
3		

[6]

(b) A sample of 2-iodopropane, $CH_3CH(I)CH_3$, reacts under the same conditions as reaction **1** to produce $CH_3CH(OH)CH_3$.

Explain why 2-iodopropane reacts at a faster rate than 2-bromopropane.

....

....

.... [2]

(c) Fig. 5.2 shows how butan-1-ol can be made from 1-bromopropane in three steps.

Fig. 5.2

(i) In step **1**, 1-bromopropane reacts with CN^- to form butanenitrile.

Complete Fig. 5.3 to show the mechanism for step **1**. Include charges, dipoles, lone pairs of electrons and curly arrows as appropriate.

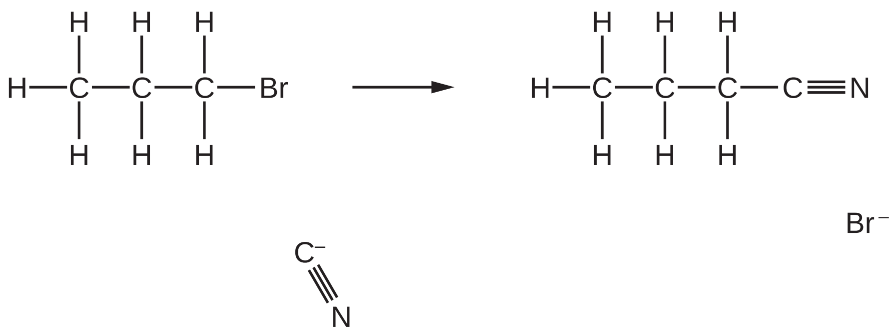

Fig. 5.3

[2]

(ii) In step **2**, butanenitrile is heated with HC*l*(aq). A hydrolysis reaction occurs.

Construct an equation for the reaction in step **2**.

.... [1]

(iii) Step **3** is a reduction reaction.

Construct an equation for the reduction reaction in step **3**. Use [H] to represent one atom of hydrogen from the reducing agent.

.... [1]

(iv) State the identity of a suitable reducing agent in step **3**.

.... [1]

[Total: 13]

6 **Z** is a molecule which contains the elements carbon, hydrogen and oxygen only.

Z contains only alkene and carboxyl functional groups.

(a) Complete Table 6.1 by describing the observations that occur when two different reagents are added to separate samples of **Z**(aq).

Table 6.1

reagent added to **Z**(aq)	observation
Br_2(aq)	
Na_2CO_3(s)	

[2]

(b) Table 6.2 shows the percentage by mass of each element present in **Z**.

Table 6.2

element	percentage by mass / %
carbon	41.38
hydrogen	3.45
oxygen	55.17

Using the data in Table 6.2, demonstrate that the empirical formula of **Z** is CHO.
Show your working.

[1]

(c) Fig. 6.1 shows the mass spectrum of **Z**.

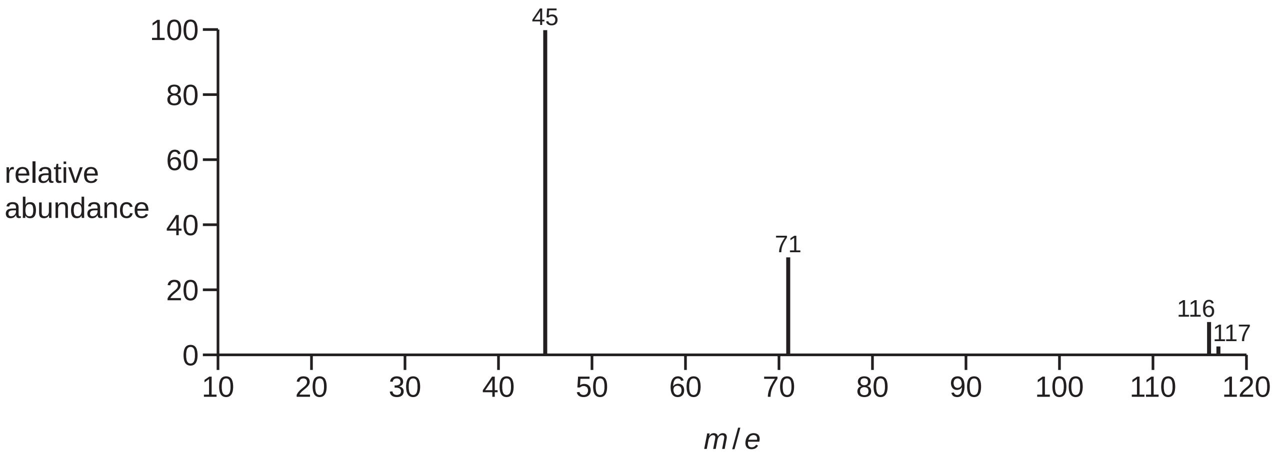

Fig. 6.1

(i) Deduce the molecular formula of **Z**. Explain your answer by referring to the molecular ion peak in Fig. 6.1 and the empirical formula of **Z**.

[1]

(ii) Use Fig. 6.1 to suggest the formulae of the fragments with *m* / *e* peaks at 45 and at 71.

m / *e* 45 ....

m / *e* 71 ....

[2]

(iii) Suggest the structure of **Z** using relevant information from Table 6.1, **(b)** and **(c)**.

[1]

[Total: 7]

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Important values, constants and standards

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

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 144.4	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 –