

Cambridge International AS & A Level

CANDIDATE NAME			
CENTRE NUMBER		CANDIDATE NUMBER	
CHEMISTRY			9701/22
Paper 2 AS Lev	el 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.

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, Mg₃N₂, 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 ₃ N ₂
oxidation number		

[1]

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

(iii)	Define enthalpy change of formation.
(iv)	When 3.645g of Mg(s) burns in excess $N_2(g)$ to form Mg ₃ N ₂ (s), 23.05kJ of energy is released.

Calculate the enthalpy change of formation, ΔH_{f} , of Mg₃N₂. Show your working.

 $\Delta H_{\rm f} \left({\rm Mg}_3 {\rm N}_2 \right) = \dots$ [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.

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......[1]
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(b) Draw a dot-and-cross diagram to show the arrangement of outer electrons in $RaCl_2$.

(c) Solid Ra and Ca show similar reactions with H₂O, 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 H₂O 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 H₂O at a faster rate. Suggest how the observations of each reaction would differ.

......[1]

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

(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.

(d) A sample of aqueous calcium halide, CaX₂(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.

step	method	observation with CaCl ₂	observation with CaBr ₂	observation with CaI ₂
step 1				
step 2				

Table 2.1

[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.

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

bond	bond energy/kJmol ⁻¹
H–H	436
I—I	151
H–I	299

Table 3.1

 $\Delta H = \dots k J \, mol^{-1}$ [2]

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

......[1]

(d) HCl(g) is prepared by adding NaCl(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 HCl 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 C₄H₅Br 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

- (ii) Identify the type of structural isomerism shown in (a)(i).
 -[1]

[2]

(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.





[1]

(c) X is an addition polymer.



Fig. 4.3

- (i) Draw the monomer of X.
- Suggest one reason why the disposal of items made from X is difficult.
 [1]
 [1]

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.

ab	le	5.	1

- -

reaction	reagent and conditions	type of reaction
1		
2		
3		

[6]

(b) A sample of 2-iodopropane, CH₃CH(I)CH₃, reacts under the same conditions as reaction 1 to produce CH₃CH(OH)CH₃.

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.



(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 HCl(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]
[1]
[1]
[1]
[1]

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).

reagent added to Z (aq)	observation
Br₂(aq)	
Na ₂ CO ₃ (s)	

Table 6.1

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

Та	ble	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.

[2]

[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**.

(ii)	Use Fig. 6.1 to suggest the formulae of the fragments with m/e peaks at 45 and at 71	۱.
	m/e 45	
	m/e 71	
		[2]

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

[1]

[1]

[Total: 7]

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Important values	constants a	and standards
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molar gas constant	$R = 8.31 \mathrm{J}\mathrm{K}^{-1}\mathrm{mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \mathrm{C}\mathrm{mol}^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23} \text{mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \mathrm{C}$
molar volume of gas	$V_{\rm m}$ = 22.4 dm ³ mol ⁻¹ at s.t.p. (101 kPa and 273 K) $V_{\rm m}$ = 24.0 dm ³ mol ⁻¹ at room conditions
ionic product of water	$K_{\rm w}$ = 1.00 × 10 ⁻¹⁴ mol ² dm ⁻⁶ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1} (4.18 \text{ Jg}^{-1} \text{ K}^{-1})$

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