Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

4784933053

CHEMISTRY **9701/21**

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.

© UCLES 2022

1 Calcium, magnesium and radium are Group 2 elements. Radium follows the same trends as the other members of Group 2.

(a) Identify the highest energy orbital which contains electrons in a calcium atom. Sketch the shape of this orbital.

identity of highest energy orbital in Ca .....

shape

[1]

(b) (i) Write the equation for the thermal decomposition of calcium nitrate.

..... [1]

(ii) Suggest which of the Group 2 nitrates, calcium, magnesium or radium, requires the highest temperature to decompose. Explain your answer.

.....

.....

..... [1]

(c) Predict what you would observe when aqueous radium chloride is added to aqueous sodium sulfate.
Do **not** refer to temperature changes in your answer.

.....

..... [1]

(d) (i) $^{25}_{12}Mg$ is an isotope of magnesium.

Determine the number of protons and neutrons in an atom of $^{25}_{12}Mg$.

number of protons .....

number of neutrons .....
[1]

(ii) State the full electronic configuration of an atom of $^{25}_{12}Mg$.

..... [1]

© UCLES 2022

(e) A sample of magnesium contains three isotopes, ^{25}Mg, ^{26}Mg and **X**.

The percentage abundance of the three isotopes is shown in Table 1.1.

Table 1.1

isotope of Mg	mass / a.m.u.	percentage abundance / %
X		78.99
^{25}Mg	24.99	10.00
^{26}Mg	25.98	11.01

(i) The relative atomic mass, A_r, is calculated by comparing the average mass of the isotopes of an element to the unified atomic mass unit.

Define the unified atomic mass unit.

..... [1]

(ii) Calculate the mass of **X**. Use data from Table 1.1 and A_r (magnesium) = 24.31 in your calculation. Show your working.

mass of **X** = ...
[2]

(iii) State **one** similarity and **one** difference in the properties of these isotopes of magnesium. Explain your answer.

.....

.....

..... [2]

(f) Magnesium, Mg, burns in oxygen, O_2.
The activation energy, E_a, for this reaction is +148 kJ mol^{-1}.

(i) State **one** observation when magnesium burns in oxygen.
Do **not** refer to temperature changes in your answer.

..... [1]

(ii) On Fig. 1.1:

- sketch a reaction pathway diagram for the reaction that occurs when Mg burns in O_2
- label the diagram to show the enthalpy change, ΔH, and the activation energy, E_a, for the reaction.

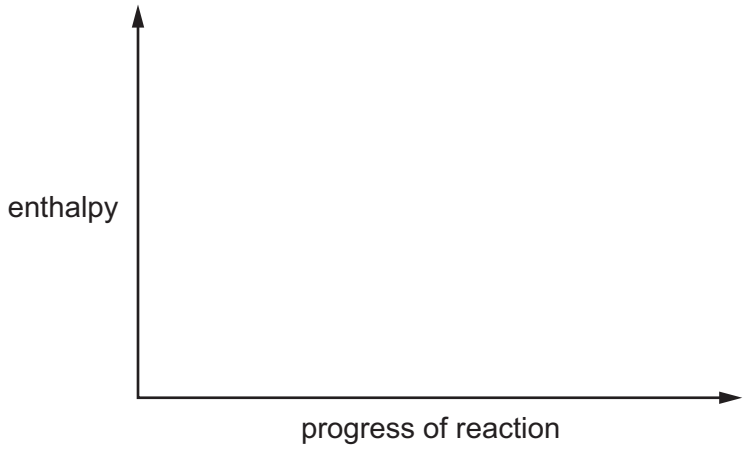


Fig. 1.1

[3]

(g) Cold water reacts slowly with a piece of Mg to produce bubbles of $H_2(g)$.
Cold water reacts rapidly with burning Mg to produce $H_2(g)$ in an explosive mixture.

$$Mg + 2H_2O \rightarrow Mg(OH)_2 + H_2$$

Explain why the rate of reaction of cold water with burning magnesium is greater.

.....

..... [2]

[Total: 17]

© UCLES 2022

2 Nitrogen molecules, $N_2(g)$, contain two atoms attracted to each other by a triple covalent bond.

(a) Describe how the triple covalent bond forms in a $N_2(g)$ molecule. Refer to orbital overlap and hybridisation in your answer.

.....

.....

.....

..... [3]

(b) Nitrogen oxides, NO_2 and NO, are produced in internal combustion engines. Release of these gases into the atmosphere leads to the formation of photochemical smog.

(i) Outline how nitrogen oxides are involved in the formation of photochemical smog.

.....

.....

..... [2]

(ii) Construct an equation to demonstrate how a catalytic converter reduces the amount of nitrogen oxide gases released into the atmosphere.

..... [1]

(c) $N_2(g)$ is very unreactive. It is difficult to make ammonia, $NH_3(g)$, directly from its elements but it can be made from $NH_4Cl(s)$.

Identify a reagent and the conditions required to make $NH_3(g)$ from $NH_4Cl(s)$.

..... [1]

© UCLES 2022

[Turn over

(d) 25 cm^3 of 0.10 mol dm^{-3} HCl(aq) is added to a beaker and its pH is recorded.

50 cm^3 of 0.10 mol dm^{-3} NH_3(aq) is added to the HCl(aq) in 5 cm^3 portions.

The pH of the mixture is monitored until all the NH_3(aq) is added.

HCl is a strong Brønsted-Lowry acid.

(i) Describe what is meant by a strong Brønsted-Lowry acid.

.....

..... [2]

(ii) NH_3 is a weak base.

Construct an equation that shows the behaviour of NH_3 as a weak Brønsted-Lowry base when dissolved in water.

..... [1]

(iii) On Fig. 2.1 sketch a graph to show the change in pH which occurs when HCl(aq) is titrated with NH_3(aq) as described in **(d)**.

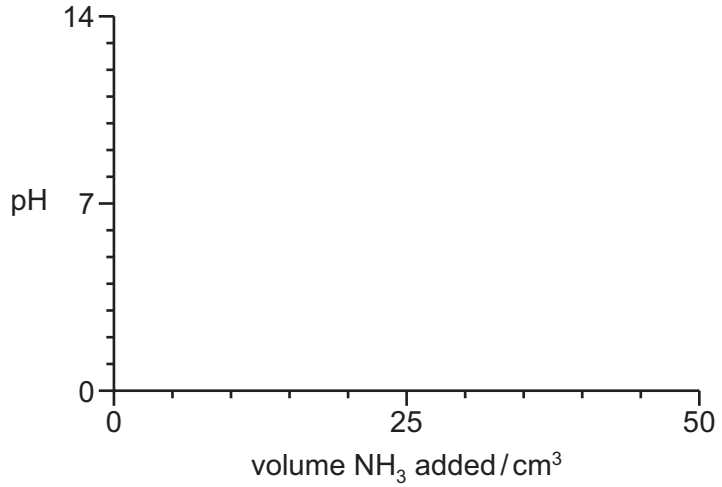


Fig. 2.1

[2]

[Total: 12]

© UCLES 2022

3 Liquids that contain molecules of **T** smell like lemons.

T

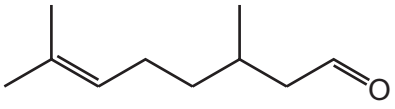


Fig. 3.1

(a) Molecules of **T** exist as a pair of stereoisomers.

Name the type of stereoisomerism shown by molecules of **T**. Explain your answer.

.....

..... [2]

(b) Two organic products are produced when a sample of **T** is heated under reflux with excess acidified concentrated $KMnO_4$.

Draw the structure of the two organic products, from this reaction, in the boxes.

organic product 1	organic product 2

[2]

(c) Fig. 3.2 shows two reactions of **T**.

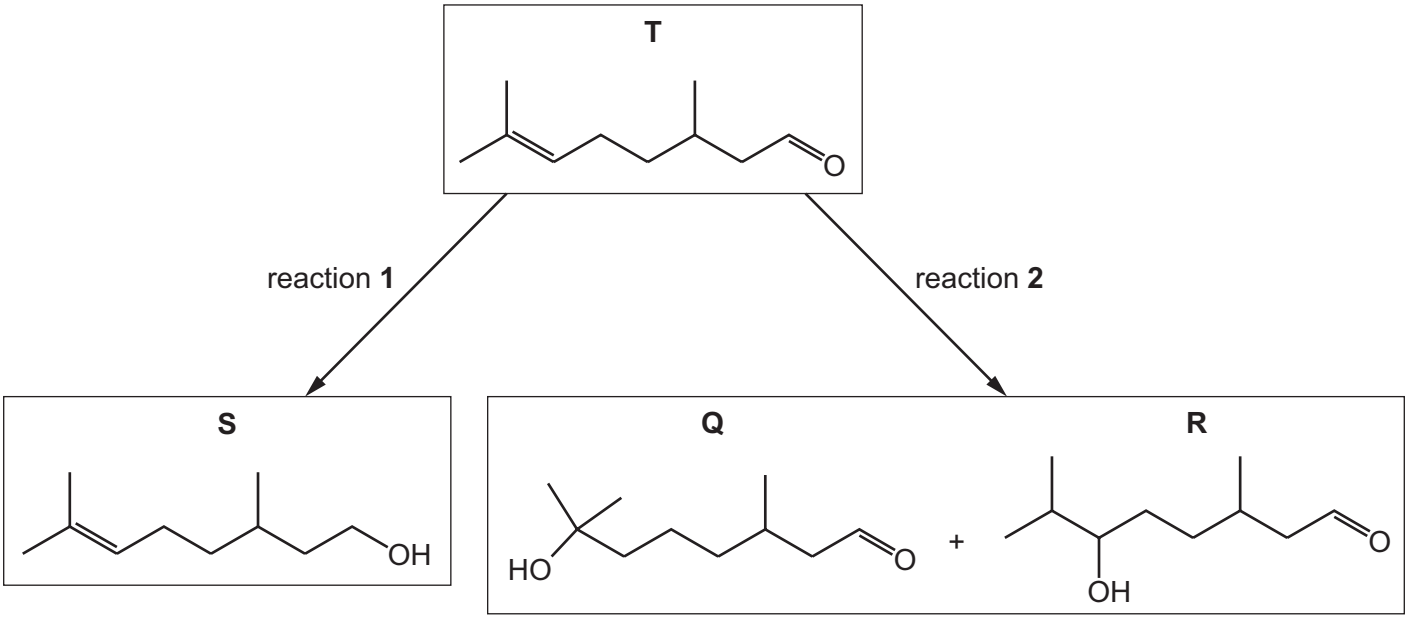


Fig. 3.2

(i) Identify a suitable reagent for reaction **1**.

..... [1]

(ii) Identify the reagent and conditions needed for reaction **2**.

.....

..... [2]

(iii) Suggest which product formed in reaction **2** has a higher yield. Explain your answer.

.....

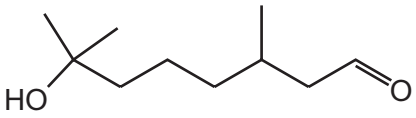
.....

..... [3]

© UCLES 2022

(d) Separate samples of **Q** and **R** are added to separate test-tubes containing acidified $K_2Cr_2O_7$(aq) and heated.

Q



R

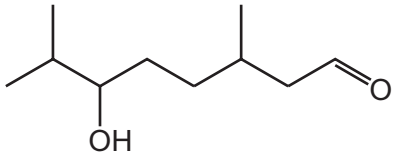


Fig. 3.3

(i) Predict the observations for each test-tube. Explain your answer in terms of the functional groups present in **Q** and **R**.

.....

.....

.....

..... [3]

(ii) When PCl_5(s) is added to separate samples of **Q** and **R** at room temperature, both react vigorously.

Complete the equation shown in Fig. 3.4 to describe the reaction that occurs when **R** reacts with PCl_5(s).

R

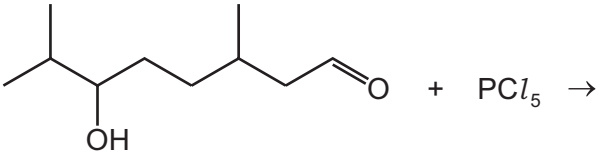


Fig. 3.4

[2]

(iii) Suggest why samples of **Q** and **R** must be dried before PCl_5 is added. Include a relevant equation to support your answer.

.....

.....

..... [2]

[Total: 17]

4 Compound **V** is a liquid.

V contains 77.2% carbon, 11.4% hydrogen and 11.4% oxygen by mass.

V has a relative molecular mass of 280.

(a) Calculate the molecular formula of **V**. Show your working.

molecular formula of **V** = ... [3]

(b) **V** contains two types of functional group: a carboxylic acid and an alkene.

(i) Describe a chemical test and observation which confirms the presence of a carboxyl functional group.

.....

..... [2]

(ii) A 3.196 g sample of Br_2 reacts completely with 2.800 g of **V**.

Calculate how many alkene functional groups are present in one molecule of **V**. Show your working.

number of alkene functional groups in **V** = ... [1]

© UCLES 2022

(c) **W**, **X** and **Y** have the same molecular formula, $C_5H_{10}O$.

W, **X** and **Y** are added separately to different reagents. Observations for these reactions are described in Table 4.1.

Table 4.1

	+ 2,4-dinitrophenylhydrazine	+ alkaline I_2(aq)	+ Fehling's reagent and warm
W	orange precipitate seen	no change	orange-red precipitate seen
X	orange precipitate seen	yellow precipitate seen	no change
Y	orange precipitate seen		

(i) **W**, **X** and **Y** each contain a common functional group.

Name the functional group that is present in all three compounds.

..... [1]

(ii) State the formula of the yellow precipitate produced when **X** is added to alkaline I_2(aq).

..... [1]

(iii) **W** could be one of four structural isomers.

- Draw the skeletal formulae for two possible structural isomers of **W**.
- Describe the type of structural isomerism shown.

isomer 1

isomer 2

type of structural isomerism

.....
[3]

(d) Fig. 5.1 shows the mass spectrum of ketone **Z**, $C_5H_{10}O$.

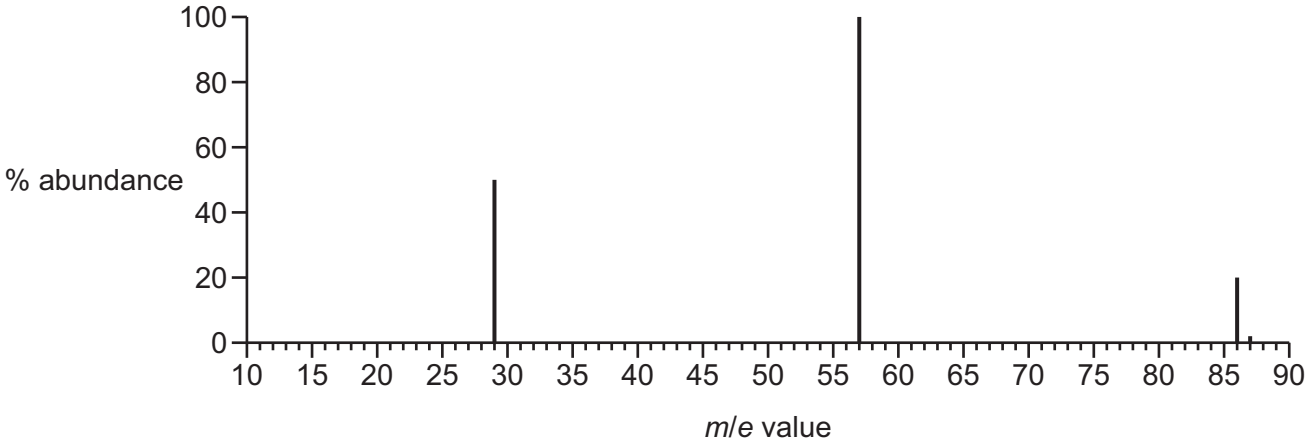


Fig. 5.1

Use the information in Fig. 5.1 to suggest the formulae of the fragments with *m/e* peaks at 29 and 57. Deduce the identity of **Z**.

m/*e* = 29 .....

m/*e* = 57 .....

identity of **Z** .....

[3]

[Total: 14]

© UCLES 2022

BLANK PAGE

© UCLES 2022

BLANK PAGE

© UCLES 2022

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	$c = 4.18\,\text{kJ kg}^{-1}\,\text{K}^{-1}$ ($4.18\,\text{J g}^{-1}\,\text{K}^{-1}$)

© UCLES 2022

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											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 –

To avoid the issue of disclosure of answer-related information to candidates, all copyright acknowledgements are reproduced online in the Cambridge Assessment International Education Copyright Acknowledgements Booklet. This is produced for each series of examinations and is freely available to download at www.cambridgeinternational.org after the live examination series.