Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

6311887042

CHEMISTRY **9701/21**

Paper 2 AS Level Structured Questions **October/November 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.

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[Turn over

1 Atoms with nuclei containing an odd number of protons tend to have fewer isotopes than those with an even number of protons.

(a) Gallium has two stable isotopes, ^{69}Ga and ^{71}Ga.

(i) Complete Table 1.1 to show the numbers of protons, neutrons and electrons in the two stable isotopes of gallium.

Table 1.1

isotope	number of protons	number of neutrons	number of electrons
^{69}Ga			
^{71}Ga			

[2]

(ii) Define relative atomic mass.

....

....

.... [2]

(iii) The relative atomic mass of gallium, A_r, is 69.723.
The relative isotopic masses of ^{69}Ga and ^{71}Ga are:

^{69}Ga, 68.926; ^{71}Ga, 70.925.

Use this information to calculate the percentage abundance of ^{69}Ga in elemental gallium.
Show your working.
Assume that the element contains only the ^{69}Ga and ^{71}Ga isotopes.
Give your answer to **four** significant figures.

percentage abundance of ^{69}Ga = ... %
[2]

(b) Potassium also has two stable isotopes. Both isotopes have the same chemical properties.

(i) Explain why both isotopes of potassium have the same chemical properties.

....

.... [1]

(ii) State the full electronic configuration of an atom of potassium.

.... [1]

(iii) The first, second and third ionisation energies of potassium are 418, 3070 and 4600 $kJ\,mol^{-1}$, respectively.

Use this information to explain why potassium is in Group 1.

....

....

....

.... [2]

[Total: 10]

2 Magnesium shows reactions typical of a Group 2 metal.

(a) Draw a labelled diagram to show the bonding in magnesium metal.

[2]

(b) Fig. 2.1 shows some reactions of magnesium and its compounds.

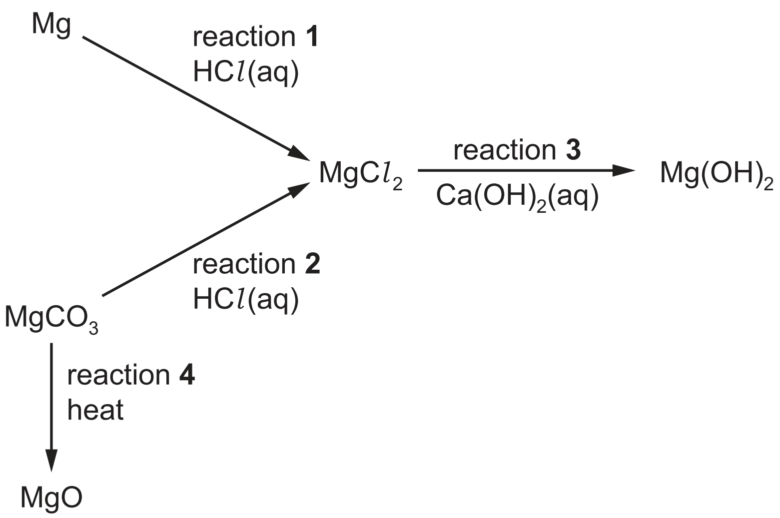


Fig. 2.1

(i) Identify the other products of reactions **1** and **2**.

reaction **1** ....

reaction **2** ....
[2]

(ii) Reaction **3** is used to form a precipitate of $Mg(OH)_2$ from $MgCl_2$(aq).

State why $Ca(OH)_2$(aq) would **not** form a precipitate of $Ba(OH)_2$ from $BaCl_2$(aq).

....

.... [1]

(iii) State the type of reaction that occurs in reaction **4**.

.... [1]

(c) 1 cm^3 of $MgCl_2$(aq) is placed in a test-tube. A few drops of $AgNO_3$(aq) are added, followed by 1 cm^3 of dilute NH_3(aq).

State in full what is observed in this experiment.

....

.... [2]

(d) When 1 cm^3 of $MgCl_2$(aq) is added to 1 cm^3 of Br_2(aq) in a test-tube, the solution remains orange.

Explain this observation.

....

....

.... [1]

[Total: 9]

3 Some of the common chlorides of Period 3 elements are shown in the list.

$NaCl$ $MgCl_2$ $AlCl_3$ $SiCl_4$ PCl_5

(a) From this list, identify:

(i) all the chlorides that have giant ionic structures in the solid state

.... [1]

(ii) all the chlorides that react vigorously with water to form strongly acidic solutions

.... [1]

(iii) the chloride that dissolves in water to form a neutral solution

.... [1]

(iv) the chloride formed from the **element** with the highest melting point.

.... [1]

(b) $NaCl$ is one product of the reaction of chlorine gas and cold aqueous sodium hydroxide.

Identify the other products.

.... [1]

(c) PCl_5 reacts with alcohols to form chloroalkanes.

(i) Identify this type of reaction.

.... [1]

(ii) Draw the structure of the organic product formed in the reaction of an excess of PCl_5 with butane-1,3-diol.

[1]

(d) Sulfur, S_8, reacts with chlorine to form several different chlorides. The most common are S_2Cl_2 and SCl_2. SCl_2 forms when sulfur reacts with an excess of chlorine.

reaction **1** $S_8(s) + 4Cl_2(g) \rightarrow 4S_2Cl_2(l)$ $\Delta H_r = -58.2\,kJ\,mol^{-1}$

reaction **2** $S_2Cl_2(l) + Cl_2(g) \rightleftharpoons 2SCl_2(l)$ $\Delta H_r = -40.6\,kJ\,mol^{-1}$

(i) SCl_2 is a cherry-red liquid that reacts vigorously with water to form an acidic solution.

Use this information to deduce the bonding and structure shown by SCl_2.
Explain your answer.

....

....

.... [2]

(ii) Calculate the enthalpy change of formation, ΔH_f, of $SCl_2(l)$. You may find it useful to use Hess's Law to construct an energy cycle.

enthalpy change of formation of $SCl_2(l)$, ΔH_f = ... $kJ\,mol^{-1}$
[2]

(iii) State the effect of a decrease in pressure on the position of equilibrium in reaction **2**. Explain your answer.

....

....

.... [1]

Fig. 3.1 shows the two structural isomers of S_2Cl_2.

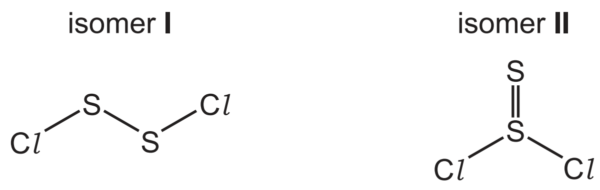


Fig. 3.1

(iv) Define the term structural isomer.

....

.... [2]

(v) Suggest a value for the Cl–S–S bond angle in isomer **I**. Explain your answer.

bond angle = ... °

explanation ....

....

....

....

[2]

(vi) Draw a dot-and-cross diagram to show the bonding in isomer **II**. Show outer shell electrons only.

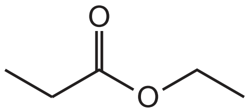
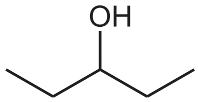
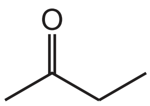
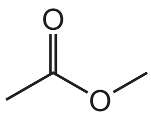
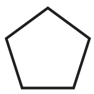
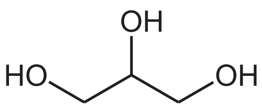
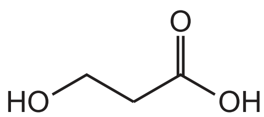
[2]

[Total: 18]

Question 4 starts on the next page.

4 Organic compounds can be distinguished using chemical tests.
Table 4.1 shows four pairs of compounds.

Table 4.1

organic compounds		reagent	positive result of chemical test on identified compound
A1 	**A2** 		
B1 	**B2** 		
C1 	**C2** 		
D1 	**D2** 		

(a) Complete Table 4.1 to:
- identify a reagent that could distinguish between the compounds in each pair
- give the **positive** result of the chemical test **and** identify which compound shows this result.

Use a different reagent for each test. [8]

(b) **C1** has melting point –94 °C and boiling point +49 °C.

Explain these properties by referring to the type of van der Waals' forces between molecules.

....

....

.... [2]

(c) Draw the structure of the cis isomer of **C2**.

[1]

(d) **C2** forms a polymer when heated gently.

(i) Identify the type of polymer that forms from **C2**.

.... [1]

(ii) Draw one repeat unit of the polymer formed from **C2**.

[2]

[Total: 14]

5 Lactones are cyclic esters. Under suitable conditions, lactones form from molecules that have both an alcohol and a carboxylic acid functional group.
Equation **1** shows an example of the formation of a lactone.

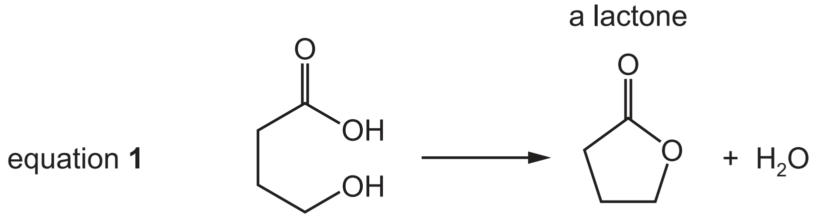


Fig. 5.1 shows the synthesis of lactone **P** from compound **M**.

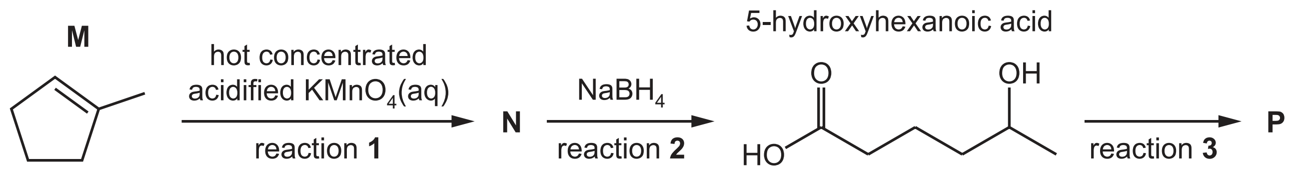


Fig. 5.1

(a) (i) **M** reacts with hot concentrated acidified $KMnO_4$(aq) to form **N**, $C_6H_{10}O_3$, in reaction **1**.

Draw the structure of **N**.

[1]

(ii) **N** is reduced by $NaBH_4$ to form 5-hydroxyhexanoic acid in reaction **2**.

Construct an equation for reaction **2** using molecular formulae.
In the equation, use [H] to represent one atom of hydrogen from the reducing agent.

.... [1]

(iii) Reaction **2** is a nucleophilic addition.

Suggest why reaction **2** creates a mixture of two organic compounds.

....

.... [2]

(iv) Draw lactone **P**, the product of reaction **3**.

[1]

(b) A student monitors the progress of reaction **2** using infrared spectroscopy.

Use Table 5.1 to suggest why it is difficult to distinguish between **N** and 5-hydroxyhexanoic acid using infrared spectroscopy.

....

.... [2]

Table 5.1

bond	functional group 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	2850–3100
N–H	amine, amide	3300–3500
O–H	carboxyl hydroxy	2500–3000 3200–3650

(c) Unknown lactone **Q** is analysed using mass spectrometry.
Table 5.2 shows information from the mass spectrum.

Table 5.2

peak	*m*/*e*	abundance
M+	72	95.5
M+1	73	3.15

Use these data to deduce the structure of **Q**.
Show your working.

Q

....

.... [2]

[Total: 9]

Important values, constants and standards

molar gas constant	$R = 8.31\,J\,K^{-1}\,mol^{-1}$
Faraday constant	$F = 9.65 \times 10^{4}\,C\,mol^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23}\,mol^{-1}$
electronic charge	$e = -1.60 \times 10^{-19}\,C$
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	$K_w = 1.00 \times 10^{-14}\,mol^2\,dm^{-6}$ (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

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 144.4	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 –