Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME			
CENTRE NUMBER		CANDIDATE NUMBER	

1420253689

CHEMISTRY **9701/23**

Paper 2 AS Level Structured Questions **October/November 2023**

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 **20** pages. Any blank pages are indicated.

1 The elements phosphorus, sulfur and chlorine are in Period 3 of the Periodic Table.

Table 1.1 shows some properties of the elements P to C*l*.

The first ionisation energy of S is **not** shown.

Table 1.1

property	P	S	C*l*
number of electrons in 3p subshell			
total number of unpaired electrons			
first ionisation energy / kJ mol^{-1}	1060		1260
formula of most common anion	P^{3-}	S^{2-}	Cl^{-}

(a) **(i)** Complete Table 1.1 to show the number of electrons in the 3p subshell and the total number of unpaired electrons in an atom of P, S and C*l*. [2]

(ii) Construct an equation to represent the first ionisation energy of P.

.... [1]

(iii) Three possible values for the first ionisation energy of S are given.

1000 kJ mol^{-1} **1160 kJ mol^{-1}** **1320 kJ mol^{-1}**

Circle the correct value.

Explain your choice by comparing your chosen value to those of P and C*l*.

....

....

....

....

....

.... [4]

(b) P^{3-}, S^{2-} and Cl^{-} have the same number of electrons.

(i) Give the full electronic configuration of P^{3-}.

.... [1]

(ii) State the trend in ionic radius shown by P^{3-}, S^{2-} and Cl^{-}.

Explain your answer.

....

....

....

.... [2]

(c) A student does three tests on separate samples of NaCl(aq).

Complete Table 1.2 with the observations the student makes in each test.

Table 1.2

test	test	observations
1	addition of a few drops of Br_2(aq)	
2	addition of a few drops of concentrated H_2SO_4	
3	addition of a few drops of dilute $AgNO_3$(aq)	

[3]

(d) $POCl_3$ shows similar chemical properties to PCl_5.

$POCl_3$ has a melting point of 1 °C and a boiling point of 106 °C.

$POCl_3$ reacts vigorously with water, forming misty fumes and an acidic solution.

(i) Explain how the information in **(d)** suggests the structure and bonding of $POCl_3$ is simple covalent.

....

....

.... [2]

(ii) Construct an equation for the reaction of $POCl_3$ with water.

$POCl_3$ + ... $\rightarrow$ ....

[1]

(iii) $POCl_3$ contains a double covalent bond between P and O.

Complete the dot-and-cross diagram, in Fig. 1.1, to show the bonding in $POCl_3$.

Show outer shell electrons only.

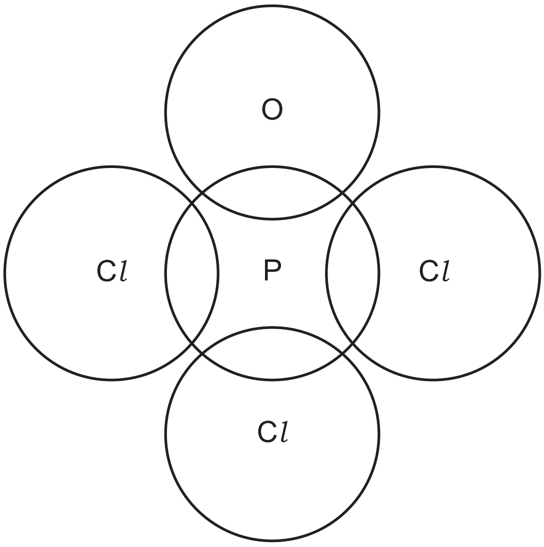

Fig. 1.1

[2]

(e) $POCl_3(g)$ forms when $PCl_3(g)$ reacts with $O_2(g)$.

$$2PCl_3(g) + O_2(g) \rightarrow 2POCl_3(g)$$

Table 1.3 gives some relevant data.

Table 1.3

process	value / kJ mol^{-1}
enthalpy change of formation of $PCl_3(g)$	–289
enthalpy change of formation of $POCl_3(g)$	–592
$O_2(g) \rightarrow 2O(g)$	+496

(i) Define enthalpy change of formation, ΔH_f.

....

....

.... [2]

(ii) Calculate the bond energy of P=O in $POCl_3$ using the data in Table 1.3.

Show your working.

bond energy of P=O = ... kJ mol^{-1}
[2]

[Total: 22]

2 Barium hydroxide, $Ba(OH)_2$, is a strong base used in inorganic and organic reactions.

Fig. 2.1 shows a reaction scheme involving $Ba(OH)_2$.

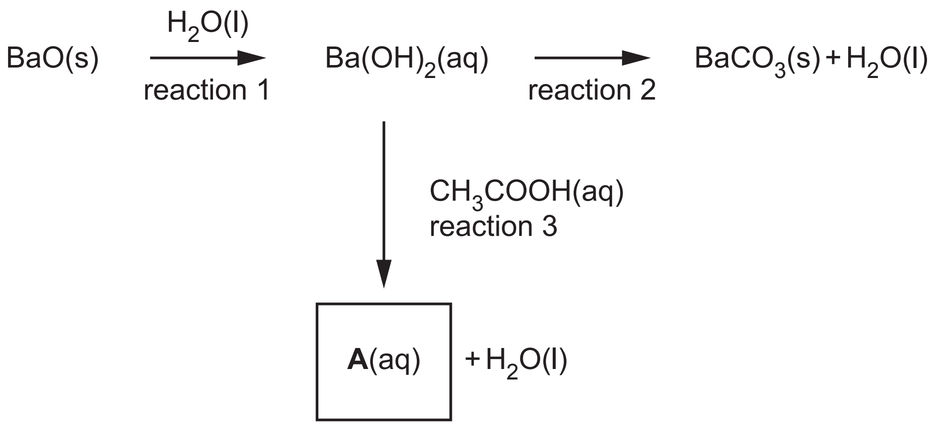

Fig. 2.1

(a) **(i)** State the variation in solubilities of group 2 hydroxides.

.... [1]

(ii) State what is observed in reaction 1.

.... [1]

(iii) Suggest a reactant for reaction 2.

.... [1]

(iv) Identify **A**.

.... [1]

(v) $Ba(OH)_2$ is made by the reaction of Ba with water.

Write an equation for this reaction.

.... [1]

(b) The mineral barytocalcite contains both $BaCO_3$ and $CaCO_3$. Both compounds decompose on heating.

(i) State which compound decomposes first when barytocalcite is heated.

Explain your answer.

....

.... [1]

(ii) Construct an equation for the complete thermal decomposition of barytocalcite.

The formula of barytocalcite is $BaCa(CO_3)_2$.

$BaCa(CO_3)_2$ .... [1]

(c) $Ba(OH)_2$ is used to hydrolyse organic compounds.

Fig. 2.2 shows the reaction of **B** with $Ba(OH)_2$, followed by acidification.

Draw the structures of the organic products of the process shown in Fig. 2.2.

B

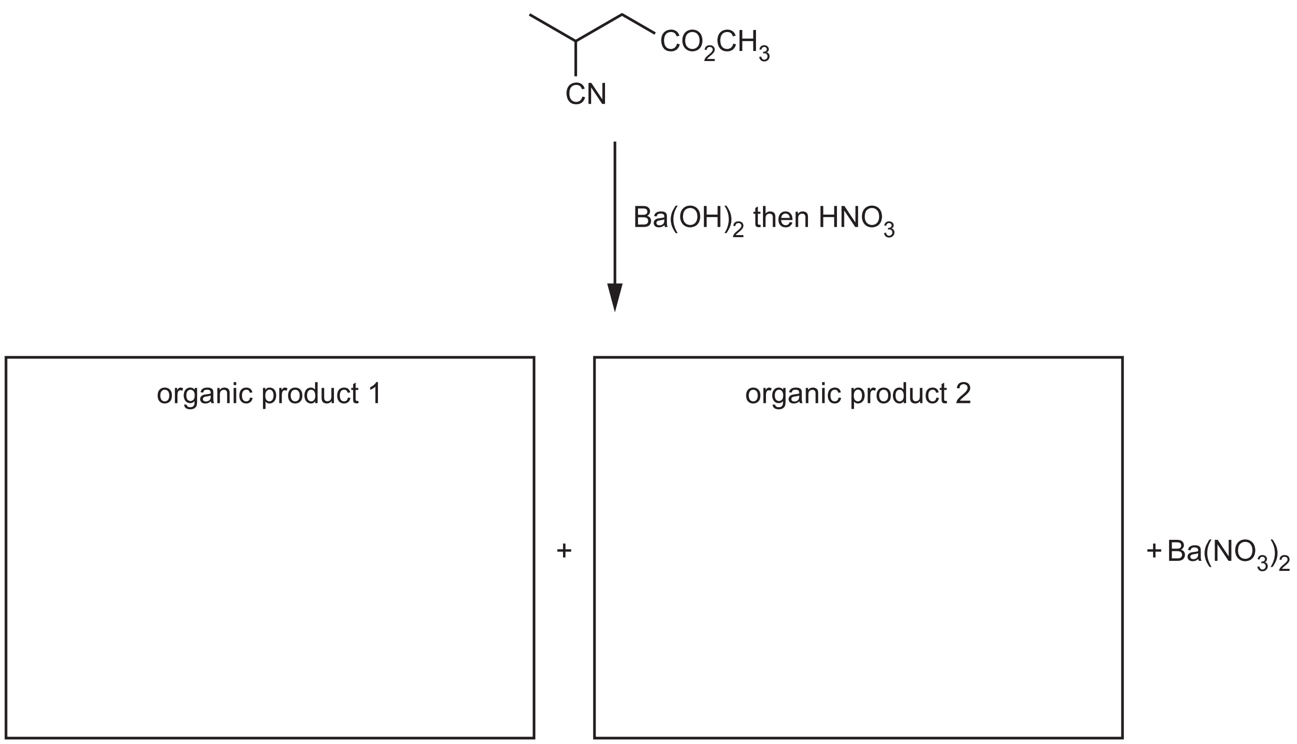

Fig. 2.2

[3]

[Total: 10]

3 Potassium chlorate, $KClO_3$, is widely used as an oxidising agent and to make $O_2(g)$.

(a) Define oxidising agent.

....

.... [1]

(b) $KClO_3(s)$ decomposes when heated.

$MnO_2(s)$ catalyses the exothermic decomposition reaction.

Complete and label the diagram in Fig. 3.1 to show the effect of $MnO_2(s)$ on the decomposition of $KClO_3(s)$.

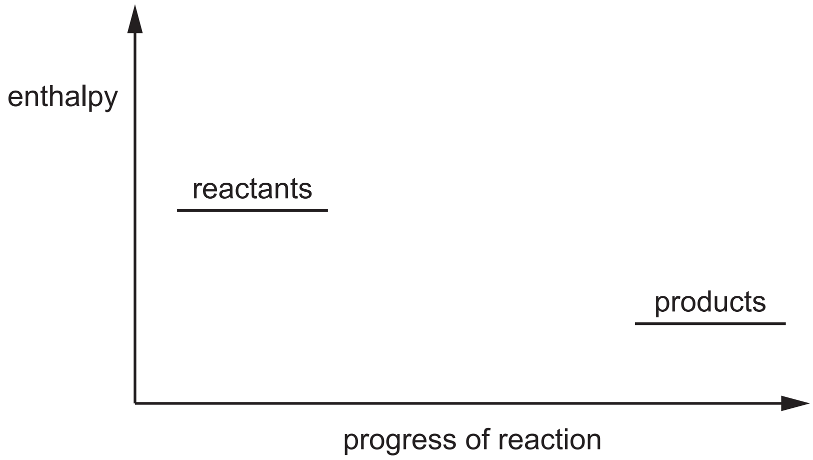

Fig. 3.1

[2]

(c) When $KClO_3$ is heated without a catalyst, $KClO_4$ and KCl form.

$$4KClO_3 \rightarrow 3KClO_4 + KCl$$

Explain why this reaction is described as a disproportionation reaction.

....

.... [1]

(d) Molten $KClO_3$ reacts with glucose, $C_6H_{12}O_6$.

$$4KClO_3 + C_6H_{12}O_6 \rightarrow 6CO_2 + 6H_2O + 4KCl$$

$KClO_3$ melts at 630 K. At this temperature, both CO_2 and H_2O are gases.

(i) Use the ideal gas equation to calculate the volume, in m^3, of one mole of gas at 630 K and 1.00×10^5 Pa.

Show your working. Give your answer to 3 significant figures.

volume of 1 mol of gas = ... m^3 [1]

(ii) 5.00 g of $C_6H_{12}O_6$ reacts completely with molten $KClO_3$.

Use your answer to **(d)(i)** to calculate the total volume of gas released at 630 K and 1.00×10^5 Pa in this reaction.

(If you were unable to answer **(d)(i)**, use 0.0463 m^3 in this question. This is **not** the correct answer to **(d)(i)**.)

total volume of gas released = ... m^3 [2]

(e) The structure of glucose, $C_6H_{12}O_6$, is shown in Fig. 3.2.

glucose

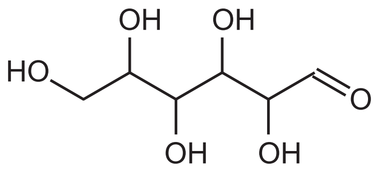

Fig. 3.2

(i) Complete Table 3.1 to identify the number of primary, secondary and tertiary alcohol groups present in the structure shown in Fig. 3.2.

Table 3.1

type of alcohol group	primary	secondary	tertiary
number of groups			

[1]

(ii) Separate samples of aqueous glucose are tested with the reagents shown in Table 3.2.

Complete Table 3.2 with the observation for each reaction.

Write "no reaction" if applicable.

Table 3.2

reagent and conditions	observation with glucose
acidified $KMnO_4$(aq) and warm	
Fehling's reagent and warm	
alkaline I_2(aq) and warm	

[3]

(iii) There are many structural isomers of $C_6H_{12}O_6$.

Define structural isomers.

....

.... [1]

[Total: 12]

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  [Turn over

4 Compounds **C** and **D** are alkenes with the same molecular formula, C_5H_{10}.

C **D**

Fig. 4.1

(a) **(i)** Give the systematic name of **D**.

.... [1]

(ii) Explain why **C** and **D** do not show geometrical (*cis/trans*) isomerism.

....

.... [1]

(iii) Draw the structure of a molecule that is a positional isomer of **C** and **D**.

[1]

(iv) Give the structural formula of the compound formed when **D** reacts with H_2(g) in the presence of a Pt catalyst.

.... [1]

(v) **C** can form an addition polymer.

Draw the structure of **one** repeat unit of this addition polymer.

[1]

(b) The mass spectrum of **C** shows a molecular ion peak at *m*/*e* = 70. This peak has a relative intensity of 48.7.

The relative intensity of the [M+1] peak is 2.7.

Show that this information is consistent with the molecular formula of **C**.

[2]

(c) **C** and **D** both react with HBr.

(i) **C** reacts with HBr to form **E**.

Complete the diagram in Fig. 4.2 to show the mechanism for this reaction.

Draw the structure of the organic intermediate.

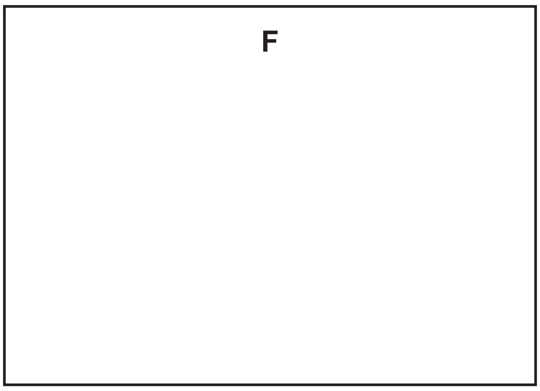
Include charges, dipoles, lone pairs of electrons and curly arrows, as appropriate.

Fig. 4.2

[3]

(ii) **D** reacts with HBr to produce **F**, a chiral bromoalkane.

Draw the structure of **F**.



[1]

(iii) Explain why the reaction of HBr with **C** and **D** produces different major products.

C **D**

Fig. 4.3

....

....

....

.... [2]

(d) **C** can be used to form **H**.

H

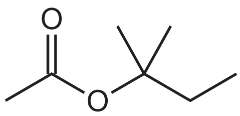


Fig. 4.4

One possible synthesis of **H** is shown in Fig. 4.5. Different portions of **C** are used in reactions 1 and 3. Some of the products are then combined to produce **H**.

Fig. 4.5 does not show any of the inorganic products of the reactions.

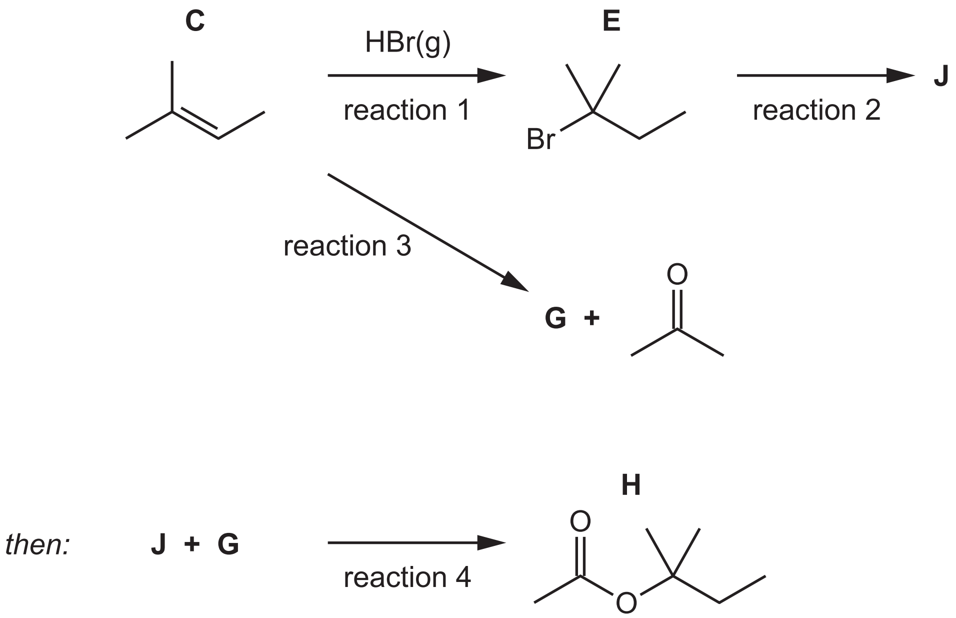
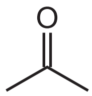


Fig. 4.5

Complete Table 4.1 with the reagents and conditions required for each of the reactions shown in Fig. 4.5.

Table 4.1

	reagent and conditions
reaction 1 **C** → **E**	HBr(g)
reaction 2 **E** → **J**	
reaction 3 **C** → **G** + 	
reaction 4 **J** + **G** → **H**	

[3]

[Total: 16]

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

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 –