Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME			
CENTRE NUMBER		CANDIDATE NUMBER	

6840752305

CHEMISTRY **9701/22**

Paper 2 AS Level Structured Questions **February/March 2024**

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 Bismuth is an element in Group 15 of the Periodic Table.

(a) Bismuth has metallic bonding.

Draw a labelled diagram to show the metallic bonding in bismuth.

[1]

(b) Bismuth reduces water to form bismuth oxide, Bi_2O_3. A colourless gas that ignites with a squeaky pop also forms.

(i) Construct an equation for the reduction of water by bismuth.

.... [1]

(ii) Bi_2O_3 is a yellow insoluble solid that melts at 1090 K. The molten compound conducts electricity.

Deduce the structure and bonding of Bi_2O_3. Explain your answer.

....

....

.... [2]

(c) Bi_2O_3 can be used to form $NaBiO_3$, as shown in equation 1.

equation 1 $Na_2O + Bi_2O_3 + O_2 \rightarrow 2NaBiO_3$

(i) Deduce the oxidation number of Bi in Bi_2O_3 and in $NaBiO_3$.

oxidation number of Bi:

in Bi_2O_3 .... in $NaBiO_3$ ....
[1]

(ii) Identify the reducing agent in equation 1.

.... [1]

(d) $NaBiO_3$ is an oxidising agent with similar properties to $KMnO_4$.

Fig. 1.1 shows an example of the use of $NaBiO_3$ as an oxidising agent.

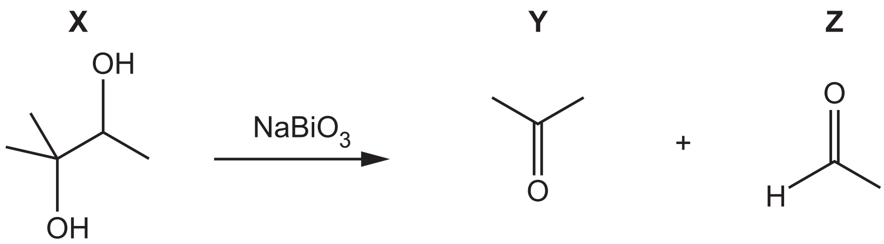


Fig. 1.1

(i) Explain the term oxidising agent.

....

.... [1]

(ii) Compound **X** forms when methylbut-2-ene reacts with $KMnO_4$.

State the essential conditions for this reaction.

.... [1]

(iii) Complete Table 1.1 to show what is observed when compounds **Y** and **Z** react separately with the named reagents.

Table 1.1

reagent	observation with **Y**	observation with **Z**
$Na_2CO_3(aq)$	no reaction	
alkaline $I_2(aq)$		
2,4-dinitrophenylhydrazine (2,4-DNPH)		
Tollens' reagent		

[4]

(iv) Construct an equation for the reaction of **Z** with $NaBH_4$.

Use [H] to represent an atom of hydrogen from the reducing agent.

.... [1]

(e) $NaBiO_3$ can be used to determine the concentration of Mn^{2+}(aq). The ionic equation for the reaction is shown in equation 2.

equation 2 $$2Mn^{2+} + 5BiO_3^{-} + 14H^{+} \rightarrow 2MnO_4^{-} + 5Bi^{3+} + 7H_2O$$

A student uses the following procedure in an experiment.

- Add 100.0 cm^3 of a saturated solution of Mn^{2+}(aq) to a volumetric flask.
- Add distilled water to the flask to make a 1.00 dm^3 diluted solution.
- Titrate a 25.00 cm^3 sample of the diluted solution with 0.100 mol dm^{-3} $NaBiO_3$(aq).

The 25.00 cm^3 sample of the diluted solution of Mn^{2+}(aq) reacts completely with exactly 21.50 cm^3 of 0.100 mol dm^{-3} $NaBiO_3$(aq).

Calculate the concentration, in mol dm^{-3}, of Mn^{2+}(aq) in the saturated solution.

Show your working.

concentration of Mn^{2+}(aq) in the saturated solution = ... mol dm^{-3} [3]

[Total: 16]

2 Chlorine, Cl_2, reacts with many elements and compounds to form chlorides.

Table 2.1 shows information about some chlorides of Period 3 elements.

Table 2.1

	Na	Mg	Si
formula of chloride			
structure of chloride	giant		
bonding of chloride			covalent
pH of solution formed on addition of chloride to water		6.2	

(a) Complete Table 2.1. [3]

(b) When Cl_2 reacts with **cold** NaOH(aq), Cl_2 is both oxidised and reduced. The products are NaCl, water and **G**.

(i) State the type of redox reaction in which the same species is both oxidised and reduced.

.... [1]

(ii) Identify **G**.

.... [1]

(iii) Write an equation for the reaction between Cl_2 and **hot** NaOH(aq).

.... [1]

(iv) Describe fully what is observed when $AgNO_3$(aq) is added to the aqueous solution of the chloride of sodium, followed by dilute NH_3(aq).

....

.... [2]

(c) An excess of Cl_2 reacts with phosphorus to form PCl_5.

(i) PCl_5 is a simple molecule in the gas phase.

It also exists in a solid form as two ions, PCl_4^+ and PCl_6^-.

Complete Table 2.2 to identify the shapes of each of these species.

Table 2.2

species	PCl_5	PCl_4^+	PCl_6^-
shape		tetrahedral	

[2]

(ii) PCl_5 reacts with **J** to form H_3PO_4.

Identify **J** and state the type of reaction.

J .... type of reaction ....

[2]

(d) Cl_2 reacts readily with propene to form **K**, 1,2-dichloropropane.

K can be used to form **L**.

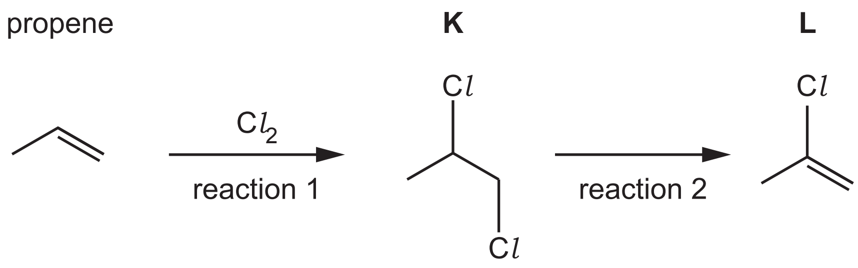


Fig. 2.1

(i) Complete Fig. 2.2 to show the mechanism for the reaction of Cl_2 with propene in reaction 1.

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

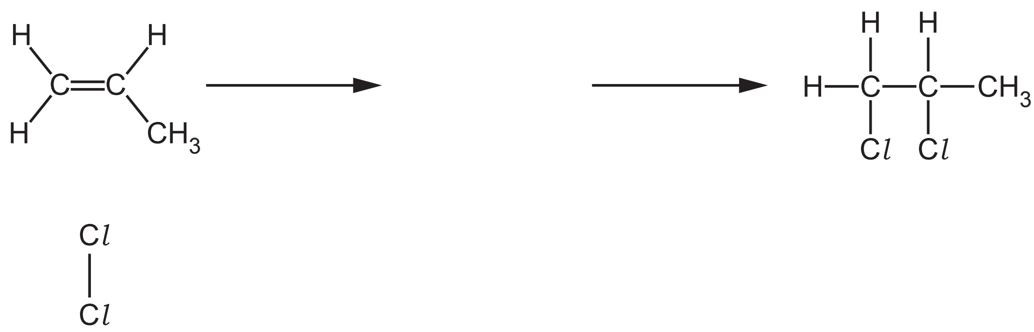


Fig. 2.2 [4]

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

.... [1]

(iii) Draw **one** repeat unit of the addition polymer that forms from **L**.

[1]

[Total: 18]

3 Nitrogen, N_2, is generally an unreactive molecule but it does react under certain conditions.

(a) Give **two** reasons to explain the lack of reactivity of nitrogen.

1 ....

2 ....
[2]

(b) N_2 can react with oxygen in an internal combustion engine to form a mixture of NO and NO_2. Fig. 3.1 shows a reaction scheme involving N_2.

reaction 1 $\quad N_2 \xrightarrow{O_2}$ NO and NO_2

reaction 2 $\quad NO_2 \xrightarrow{H_2O}$ products

reaction 3 $\quad NO_2 \xrightarrow{\text{unburned hydrocarbons}}$ peroxyacetyl nitrate (PAN)

Fig. 3.1

(i) Write an equation to show the formation of a mixture of NO and NO_2 in reaction 1.

.... [1]

(ii) Give the formulae of the products of reaction 2.

.... [1]

(iii) State **one** environmental consequence of reaction 3.

.... [1]

(c) The Haber process involves the reaction of N_2 and H_2 to form ammonia, NH_3.

A catalyst is used, which allows the process to be carried out at a lower temperature and pressure.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92\,kJ\,mol^{-1}$$

(i) Use the information in **(c)** to complete Table 3.1.

Table 3.1

compound	enthalpy change of formation, ΔH_f / kJ mol^{-1}
N_2	
H_2	
NH_3	

[2]

(ii) Explain how the presence of a catalyst affects the reaction.

....

....

.... [1]

(iii) State and explain the effect, if any, on the **rate** of the Haber process as the pressure is lowered.

....

....

....

.... [2]

(d) The N_2F_2 molecule has a double covalent bond between its nitrogen atoms. This consists of a σ and a π bond.

(i) Complete Fig. 3.2 to show the dot-and-cross diagram for N_2F_2.

Show outer electrons only.

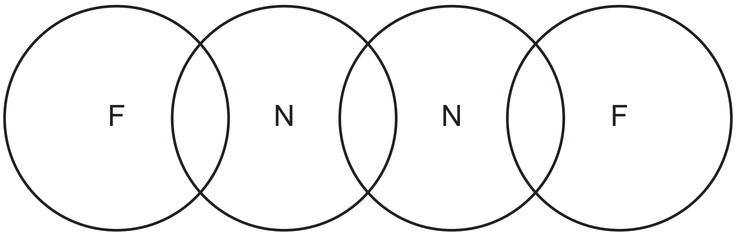


Fig. 3.2

[2]

(ii) Deduce the hybridisation of the N atoms in N_2F_2.

.... [1]

(iii) Draw a diagram of the π bond between the N atoms in N_2F_2 and describe how it forms.

....

....

[2]

[Total: 15]

4 Compound **S** is used in food flavourings. A possible synthesis of **S** is shown in Fig. 4.1.

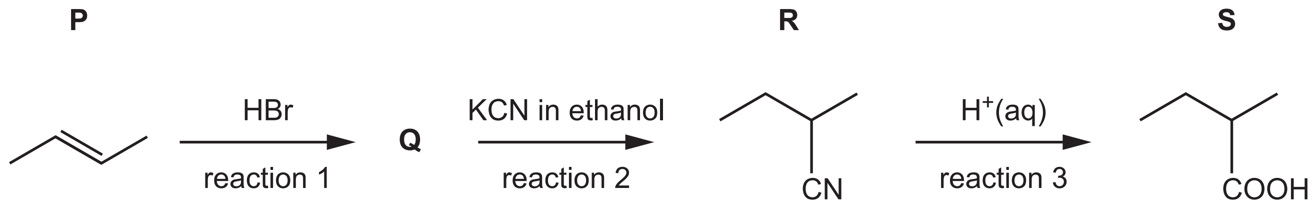


Fig. 4.1

(a) **P**, **Q**, **R** and **S** show stereoisomerism.

Complete Table 4.1 by identifying with a tick (✓) the type of stereoisomerism that each molecule shows.

The type of stereoisomerism shown by **Q** is given.

Table 4.1

	P	Q	R	S
geometrical isomerism				
optical isomerism		✓		

[2]

(b) **(i)** Give the structural formula of **Q**.

.... [1]

(ii) Name the mechanism in reaction 2.

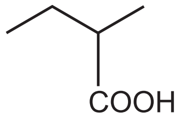
.... [1]

(iii) Complete the equation for reaction 3. **R** is represented as C_4H_9CN.

C_4H_9CN + ... [1]

(c) Compounds **S** and **T** react to form organic compound **U**, which has a single functional group.

S



+ **T** ⟶ **U** + H_2O

Table 4.2 shows some data from the mass spectrum of **U**.

Table 4.2

peak	relative abundance
M^+	7.2
$[M+1]^+$	0.55

(i) Use the data from Table 4.2 to show that **U** contains 7 carbon atoms.

Show your working.

[2]

(ii) Fig. 4.2 shows the infrared spectrum of **U**.

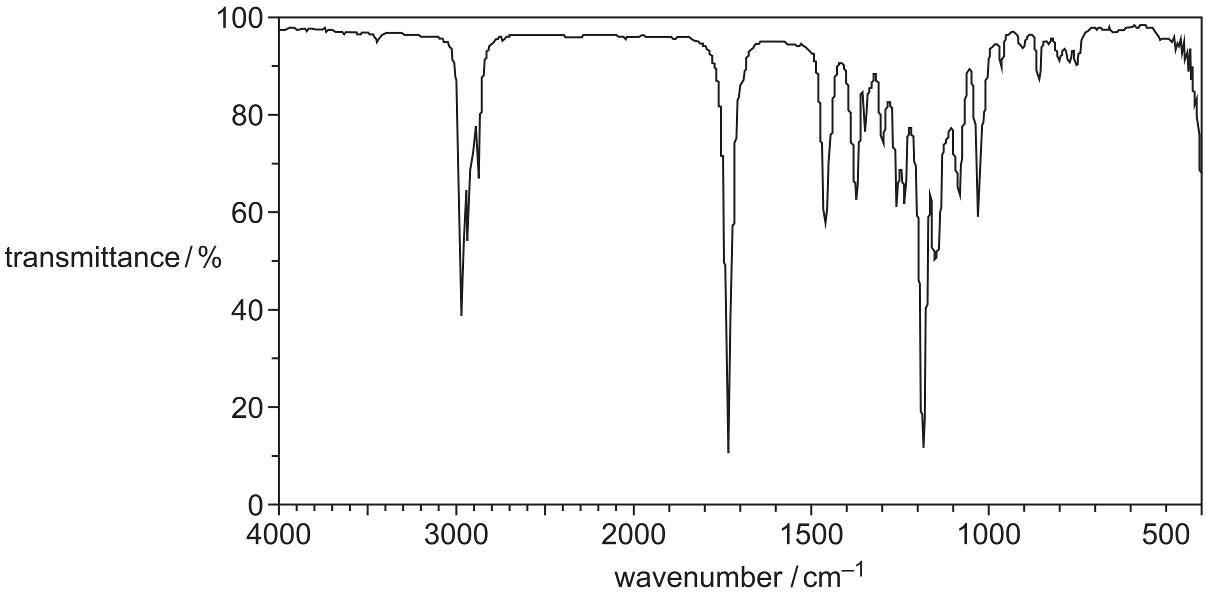


Fig. 4.2

Table 4.3

bond	functional groups 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	2850–2950
N–H	amine, amide	3300–3500
O–H	carboxyl hydroxy	2500–3000 3200–3650

Use Fig. 4.2 and Table 4.3 to identify the functional group present in **U**.

Explain your answer fully.

functional group ....

explanation ....

....

....

.... [2]

(iii) **T** also has a single functional group.

Use the information in **(c)(i)** and your answer to **(c)(ii)** to identify **T** and **U**.

Draw the structures of **T** and **U** in the boxes.

T	**U**

[2]

[Total: 11]

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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 144.2	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 –