Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME									
CENTRE NUMBER						CANDIDATE NUMBER				

6171385913

CHEMISTRY **9701/22**

Paper 2 AS Level Structured Questions **February/March 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 **16** pages. Any blank pages are indicated.

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[Turn over

1 The Pauling electronegativity values of elements can be used to predict the chemical properties of compounds.

Use the information in Table 1.1 to answer the following questions.

Table 1.1

element	H	Li	C	O	S
Pauling electronegativity value	2.1	1.0	2.5	3.5	2.6
first ionisation energy / kJ mol^{-1}	1310	519	1090	1310	1000
second ionisation energy / kJ mol^{-1}	—	7300	2350	3390	2260

(a) (i) Define electronegativity.

.....

..... [1]

(ii) O and S are in Group 16.

Explain the difference in the Pauling electronegativity values of O and S.

.....

.....

..... [2]

(b) (i) LiH is an ionic compound.

Draw a dot-and-cross diagram of LiH.

Include **all** electrons.

[2]

(ii) Suggest the shape of a molecule of H_2S.

..... [1]

(c) **(i)** Write an equation that represents the first ionisation energy of H.

..... [1]

(ii) Explain why there is no information given in Table 1.1 for the second ionisation energy of H.

..... [1]

(iii) Give the full electronic configuration of $S^{2+}(g)$.

..... [1]

(d) CO_2 and SO_2 are acidic gases.

(i) Write an equation for the reaction of SO_2 with H_2O.

..... [1]

(ii) Write an equation for the reaction of SO_2 with NaOH.

..... [1]

(iii) Construct an equation for the reaction of CO_2 with $Mg(OH)_2$.

..... [1]

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(e) (i) Complete Table 1.2 by placing a tick (✓) to show which of the compounds have molecules with an overall dipole moment.

Table 1.2

compound	O=C=O	O=S=O	S=C=S	S=C=O
overall dipole moment				

[2]

(ii) At 150 °C and 103 kPa, all of the compounds listed in Table 1.2 are gases.

Under these conditions, 0.284 g of one of the compounds occupies a volume of 127 cm^3.

Use this information to calculate the M_r of the compound. Hence, identify the compound from those given in Table 1.2.

Show your working.

M_r = ... identity of compound = ...

[3]

[Total: 17]

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2 The Group 2 elements Mg to Ba are all silvery-white reactive metals.

(a) **(i)** Draw a labelled diagram to show the bonding and structure of the Group 2 metals at room temperature.

[2]

(ii) Explain why Mg has a higher electrical conductivity than Na.

.....

..... [1]

(b) Write an equation for the reaction of magnesium with cold water.

..... [1]

(c) Identify a single reagent that can be used to distinguish separate samples of dilute $Mg(NO_3)_2(aq)$ and dilute $Ba(NO_3)_2(aq)$.

Explain your answer.

reagent .....

explanation .....

.....

[2]

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(d) (i) Describe what is observed when $SrI_2(aq)$ reacts with concentrated sulfuric acid.

.....

..... [2]

(ii) Compound **X**, an anhydrous Group 2 bromide, is dissolved in water and titrated against aqueous silver nitrate.

A solution containing 0.250 g of **X** requires 33.65 cm^3 of 0.0500 mol dm^{-3} $AgNO_3(aq)$ for complete reaction.

Identify **X**.

Show your working.

X = ... [3]

[Total: 11]

3 Alkenes undergo an addition reaction with a 1:1 mixture of CO and H_2 to form aldehydes.

Fig. 3.1 shows the reaction of propene with a 1:1 mixture of CO and H_2.

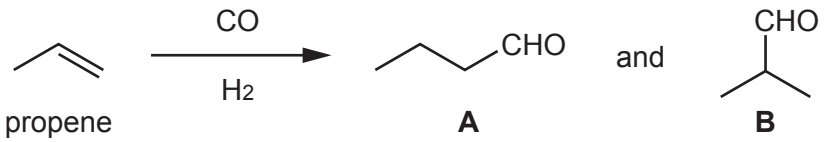

Fig. 3.1

(a) (i) Define addition reaction.

.....

..... [1]

(ii) Aldehydes **A** and **B** are structural isomers.

State the type of structural isomerism shown by **A** and **B**.

..... [1]

(iii) Name **A**.

..... [1]

(iv) The complete reaction of propene with a 1:1 mixture of CO and H_2 produces **A** and **B** only. The product mixture contains 96% **A** and 4% **B**.

Calculate the mass of **A** produced in this reaction when 5.00×10^3 kg of propene is used.

mass of **A** = ... kg [1]

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(b) **A** and **B** show reactions typical of aliphatic aldehydes.

(i) **A** undergoes a nucleophilic addition reaction with a mixture of HCN and KCN, forming compound **C**.

Complete the diagram to show the mechanism for this reaction.

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

Draw the structure of the organic intermediate.



[4]

(ii) Table 3.1 shows information about three experiments involving **B**.

Complete Table 3.1.

Table 3.1

experiment	reagents	observation with **B**
1		solution turns from orange to green
2		a silver mirror forms on the sides of the reaction vessel
3	$Br_2(aq)$	

[3]

(iii) **B**, C_4H_8O, is oxidised by acidified potassium manganate(VII).

Complete the equation for this reaction. Use [O] to represent one atom of oxygen from the oxidising agent.

C_4H_8O + ... [1]

(iv) **C** is a chiral molecule.

Circle any chiral centres in the structure of **C** shown in Fig. 3.2.

C

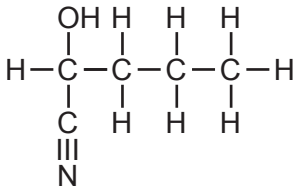

Fig. 3.2

[1]

(c) When propene reacts with CO and an excess of H_2, an alkane and a mixture of alcohols are formed instead. The alcohols are isomers of each other.

Suggest the molecular formulae of the alkane and the alcohols that are formed under these conditions.

molecular formula of alkane .....

molecular formula of alcohols .....

[2]

(d) The reaction of ethene, C_2H_4, with a 1:1 mixture of CO and H_2 is shown in equation 1.

equation 1 $C_2H_4(g) + CO(g) + H_2(g) \rightleftharpoons CH_3CH_2CHO(g)$

At atmospheric pressure a cobalt-based catalyst is used in this reaction.

(i) State and explain the effect of using a catalyst on this reaction.

.....

.....

.....

..... [2]

(ii) Explain why the yield of $CH_3CH_2CHO(g)$ increases when the overall pressure of the reaction mixture is increased.

.....

..... [1]

(iii) Use the information in Table 3.2 to calculate the enthalpy change, ΔH_r, of the reaction in equation 1.

equation 1 $C_2H_4(g) + CO(g) + H_2(g) \rightleftharpoons CH_3CH_2CHO(g)$

Table 3.2

compound	enthalpy change of formation, ΔH_f / kJ mol^{-1}
$C_2H_4(g)$	+52
CO(g)	–111
$CH_3CH_2CHO(g)$	–187

ΔH_r = ... kJ mol^{-1} [2]

(iv) The reaction mixture is cooled to collect CH_3CH_2CHO as a liquid.

Identify all types of van der Waals' forces that are present between molecules of CH_3CH_2CHO.

.....

..... [1]

[Total: 21]

4 Fig. 4.1 shows some reactions of compound **D**, 2-bromobutane.

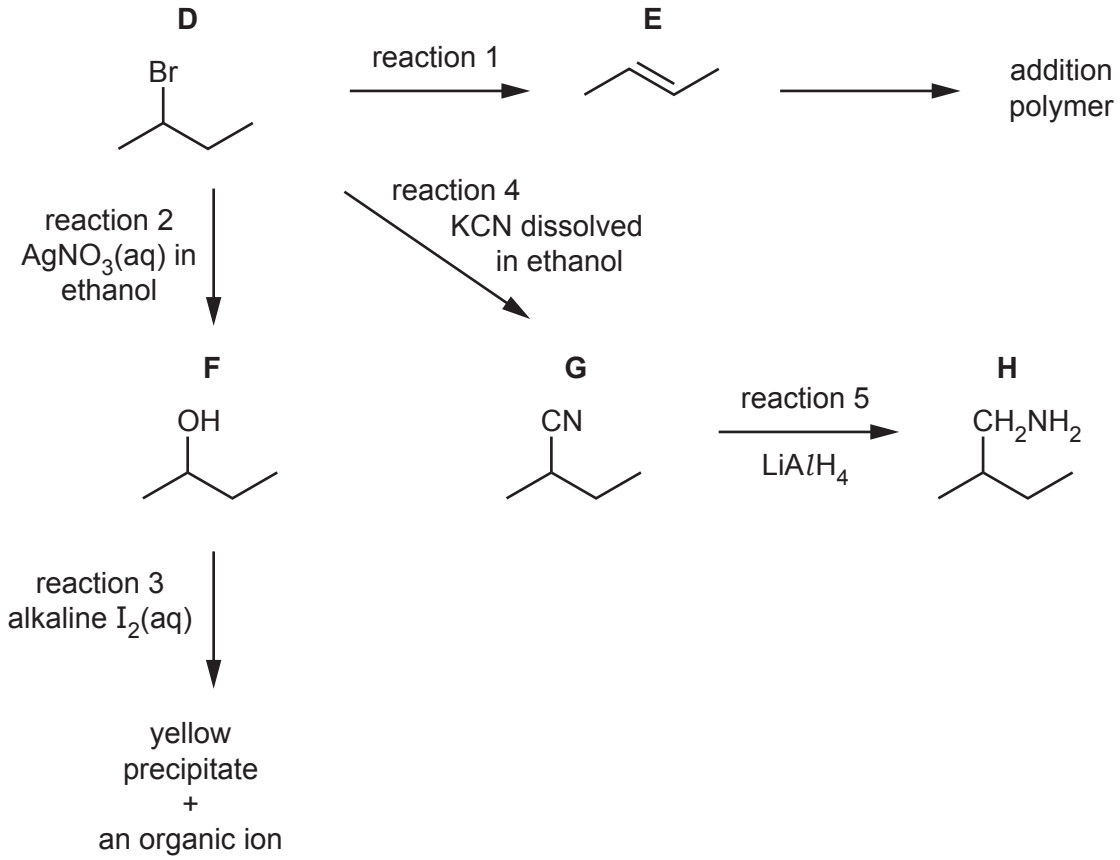

Fig. 4.1

(a) (i) State the reagent and conditions used to form **E** in reaction 1.

..... [1]

(ii) Draw the structure of **one** repeat unit of the addition polymer that forms from **E**.

[1]

(iii) **E** also forms when **F** is heated strongly in the presence of an Al_2O_3 catalyst.

Write an equation for this reaction.

..... [1]

(b) (i) Predict what is observed in reaction 2.

..... [1]

(ii) Identify the yellow precipitate and the organic ion formed in reaction 3.

yellow precipitate .....

organic ion .....

[2]

(c) (i) State the type of reaction that occurs in reaction 4.

..... [1]

(ii) Reaction 5 is similar to the reaction of $LiAlH_4$ with carboxylic acids to form alcohols.

Suggest the role of $LiAlH_4$ in reaction 5.

..... [1]

(d) (i) Fig. 4.2 shows the infrared spectrum of one of the compounds **D**, **E**, **F**, **G** or **H**.

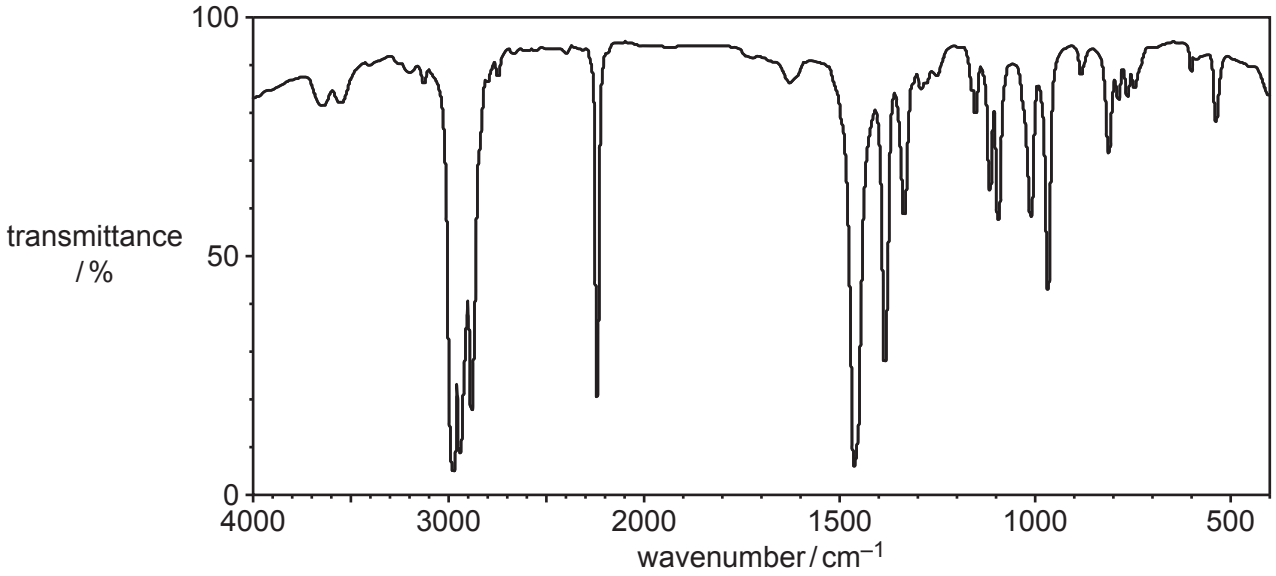

Fig. 4.2

Use information from Table 4.1 (on page 14) to identify which of the compounds **D**, **E**, **F**, **G** or **H** produces the infrared spectrum in Fig. 4.2.

Explain your answer.

.....

.....

..... [2]

Table 4.1

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 3200–3600

(ii) In the mass spectrum of **D**, the relative abundance of the molecular ion peak is 3.4.

Predict the relative abundance of the M+2 peak for **D**.

Explain your answer.

.....

.....

..... [1]

[Total: 11]

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

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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 –

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