Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME			
CENTRE NUMBER		CANDIDATE NUMBER	

9101965159

CHEMISTRY **9701/22**

Paper 2 AS Level Structured Questions **May/June 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.

1 The melting points of some solids are shown in Table 1.1.

Table 1.1

solid	melting point / K
magnesium	923
phosphorus	317
sodium chloride	1074
sulfur	392

(a) (i) State the type of bonding present in magnesium and in sodium chloride.

bonding in magnesium ....

bonding in sodium chloride .... [1]

(ii) Explain the difference in the melting points of magnesium and sodium chloride.

....

.... [1]

(iii) Explain the difference in the melting points of phosphorus and sulfur in terms of structure and bonding.

....

....

.... [2]

(b) (i) Define electronegativity.

....

.... [1]

(ii) Explain why electronegativity increases across a period.

....

....

.... [2]

(iii) Name the strongest intermolecular force that exists between NH_3(l) molecules.

.... [1]

(iv) Draw a diagram to show the formation of the strongest intermolecular force between **two** molecules of NH_3(l).

Include any relevant lone pairs of electrons and dipoles.

[2]

(v) The melting points of ice and ammonia are shown in Table 1.2.

Table 1.2

solid	melting point / K
ice	273
ammonia	195

Suggest **two** reasons for the difference in the melting points of ice and ammonia.

....

....

.... [2]

[Total: 12]

2 Chlorine is a reactive element. It forms many compounds.

(a) (i) Complete Table 2.1 to show the maximum oxidation number of the elements Na to P in their chlorides.

Table 2.1

element	Na	Mg	A*l*	Si	P
maximum oxidation number					

[1]

(ii) State what determines the maximum oxidation number of elements in Period 3.

....

.... [1]

(b) An excess of cold water is added to the chloride of silicon.

(i) Write an equation for the reaction between an excess of cold water and the chloride of silicon.

.... [1]

(ii) Suggest the pH of the solution produced in **(b)(i)**.

.... [1]

(c) An excess of cold water is added to the chloride of phosphorus.

(i) Write an equation for the reaction between an excess of cold water and the chloride of phosphorus.

.... [1]

(ii) Suggest the pH of the solution produced in **(c)(i)**.

.... [1]

(d) (i) Write an equation for the reaction of chlorine with water.

.... [1]

(ii) Write an equation for the reaction of chlorine with hot NaOH(aq).

.... [1]

(e) Bleach is used as a cleaning product to kill bacteria. It is made by adding compounds like sodium chlorate(I), NaClO, to water.

(i) Identify the formula of the ion present in bleach that kills bacteria.

.... [1]

(ii) Sodium chlorate(I), NaClO, reacts with hydrogen peroxide to produce sodium chloride, water and oxygen gas.

Construct an equation for this reaction.

.... [1]

(iii) A sample of bleach **W** contains an unknown concentration of sodium chlorate(I).

10.0 cm^3 of **W** is diluted with distilled water to make a total volume of 100 cm^3 of bleach solution. 25.0 cm^3 of this diluted bleach solution is added to an excess of hydrogen peroxide and the volume of gas produced measured under room conditions. The experiment is repeated and on average 25.0 cm^3 of diluted bleach solution produces 42.0 cm^3 of gas.

Calculate the concentration, in $g\,dm^{-3}$, of sodium chlorate(I) in **W**.

concentration of NaClO in **W** = ... $g\,dm^{-3}$ [3]

[Total: 13]

3 Fig. 3.1 describes a sequence of reactions that can be used to produce a food additive, compound **Y**, from CH_3CH_2Cl.

$$CH_3CH_2Cl \xrightarrow{\text{step 1}} \underset{\textbf{X}}{CH_3CH_2CN} \xrightarrow[\text{dilute acid}]{\text{step 2}} CH_3CH_2COOH \xrightarrow[\text{Ca(s)}]{\text{step 3}} \textbf{Y}$$

Fig. 3.1

(a) **(i)** State the reagent and conditions for step 1 in Fig. 3.1.

.... [1]

(ii) Give the systematic name of **X**.

.... [1]

(iii) Identify the type of reaction that occurs when dilute acid is added to **X** in step 2.

.... [1]

(iv) In step 3, **Y** and a gas are produced.
Construct an equation for step 3.

.... [2]

(b) CH_3CH_2COOH can also be formed from propan-1-ol and potassium dichromate(VI).
State the conditions required.

.... [1]

(c) Complete Table 3.1 to show the number of sigma bonds (σ) and pi bonds (π) present in a molecule of **X**.

Table 3.1

type of bond	number of bonds in **X**
sigma (σ)	
pi (π)	

[2]

[Total: 8]

4 In industry, ethanol is made by reacting ethene with steam in the presence of H_3PO_4.

reaction 1 $C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g)$

(a) Use the bond energy values in Table 4.1 to calculate the enthalpy change, ΔH_r, for reaction 1.

Table 4.1

bond	bond energy / $kJ\,mol^{-1}$
C–C	350
C=C	610
C≡C	840
C–H	410
C–O	360
C=O	740
O–H	460

ΔH_r = ... $kJ\,mol^{-1}$ [2]

(b) Reaction 1 reaches equilibrium at constant temperature and pressure.

Deduce what effect increasing the pressure will have on the amount of ethanol in the new equilibrium mixture. Use Le Chatelier's principle to explain your answer.

effect of increasing pressure ....

explanation ....

....
[2]

(c) The mechanism for reaction 1 can be described in three steps. Steps 1 and 2 for reaction 1 are shown in Fig. 4.1.

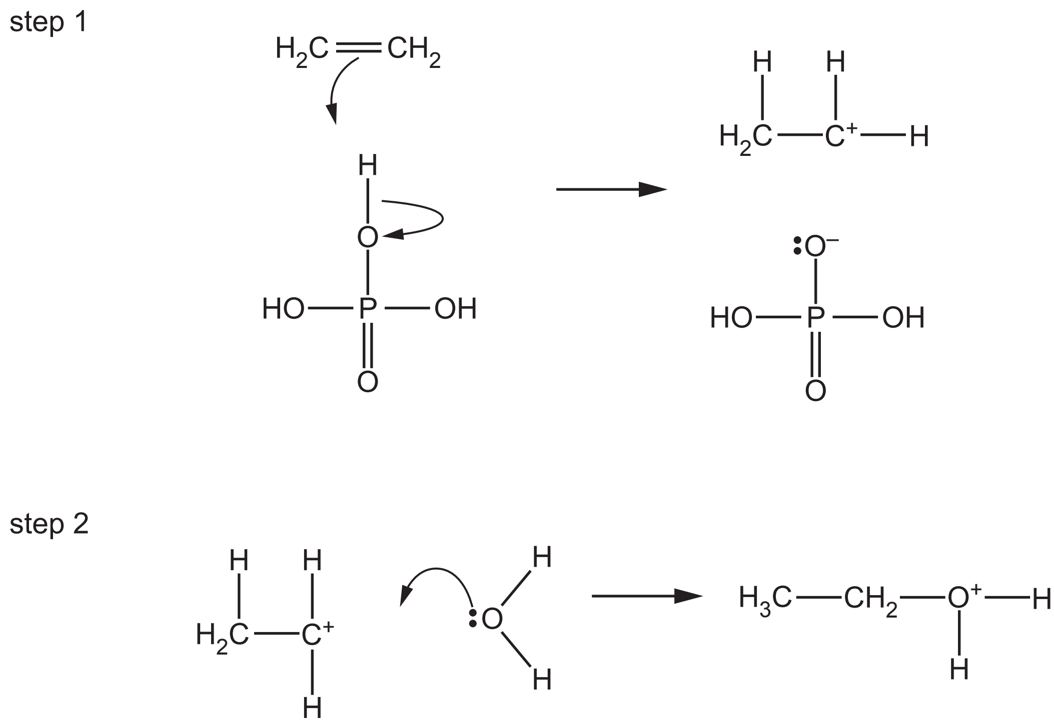

Fig. 4.1

(i) Describe the behaviour of H_3PO_4 in step 1 in Fig. 4.1. Explain your answer.

....

.... [1]

(ii) Identify the species that behaves as an electrophile in step 2 in Fig. 4.1. Explain your answer.

....

.... [1]

(iii) Complete Fig. 4.2 to show the mechanism for step 3 of reaction 1. Include charges, dipoles, lone pairs of electrons and curly arrows, as appropriate.

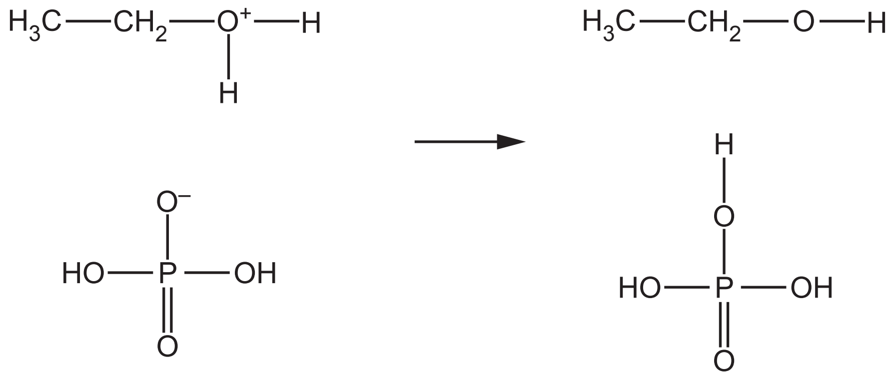

Fig. 4.2

[2]

(iv) Describe how a catalyst affects a reaction. Explain your answer.

....

.... [2]

(v) Use Fig. 4.1 and Fig. 4.2 to justify why H_3PO_4 is described as a catalyst in reaction 1.

....

.... [1]

(vi) Propene also reacts with steam. A mixture of organic products is produced.

Explain why propan-2-ol is produced in the higher yield.

....

....

.... [2]

(d) Describe the covalent bonds present between the carbon atoms in an ethene molecule by completing Table 4.2.

Table 4.2

	sigma (σ)	pi (π)
type of orbitals involved in bond		
how the orbitals overlap		

[2]

[Total: 15]

5 **(a)** Describe structural isomerism.

....

.... [1]

(b) **A** and **B** are structural isomers with molecular formula $C_5H_{10}O$.

They are both straight-chained molecules with only one functional group.

Table 5.1 describes observations when separate samples of **A** and **B** are added to different reagents.

Table 5.1

reagent	**A**	**B**
2,4-dinitrophenylhydrazine (2,4-DNPH reagent)	orange precipitate appears	orange precipitate appears
Tollens' reagent	silver mirror appears	no reaction
alkaline I_2(aq)	no reaction	no reaction

(i) Name the functional group present in both **A** and **B**.

.... [1]

(ii) Draw the structures of **A** and **B** in the boxes.

A	**B**

[2]

(c) **C** is a structural isomer of **A** and **B**.

C is straight chained and has two functional groups.

C shows only one type of stereoisomerism.

Table 5.2 describes observations when separate samples of **C** are added to different reagents.

Table 5.2

reagent	**C**
2,4-dinitrophenylhydrazine (2,4-DNPH reagent)	no reaction
Br_2(aq)	orange to colourless
alkaline I_2(aq)	yellow precipitate appears

(i) Draw the structure of **C** in the box.

C

[2]

(ii) Name the type of stereoisomerism shown by molecules of **C**.

.... [1]

(d) **D** reacts in the presence of a sulfuric acid catalyst to form **E** and water.

The structure of **E** is shown in Fig. 5.1.

E

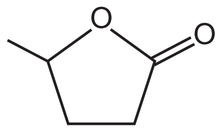

Fig. 5.1

(i) Name the functional group present in **E**.

.... [1]

(ii) Identify the type of reaction that occurs when **D** reacts to form **E**.

.... [1]

(iii) Draw the structure of **D** in the box.

D

[1]

(iv) The infrared spectrum of **E** is shown in Fig. 5.2.

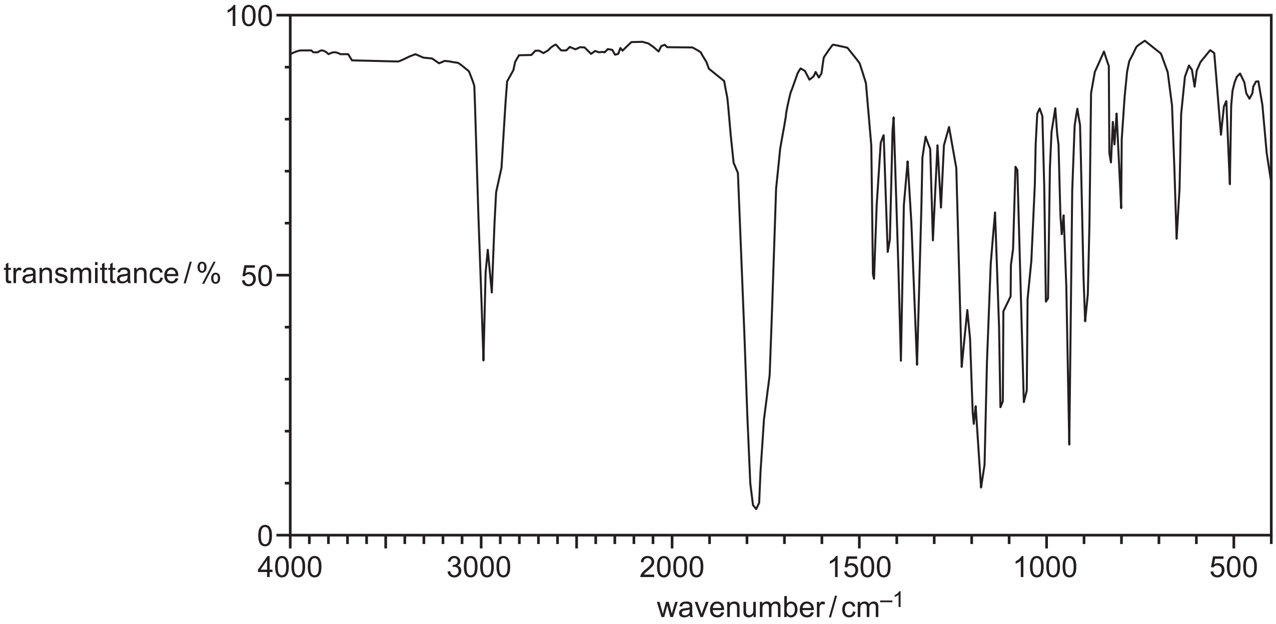

Fig. 5.2

Table 5.3

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 3200–3600

Use Fig. 5.2 and Table 5.3 to predict **two** differences in the absorptions above 1500 cm^{-1} of the infrared spectrum of **D** compared to **E**. Explain your answer.

....

....

.... [2]

[Total: 12]

BLANK PAGE

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

Group																	
1	2											13	14	15	16	17	18
				Key			1 H hydrogen 1.0										2 He helium 4.0
3 Li lithium 6.9	4 Be beryllium 9.0			atomic number atomic symbol name relative atomic mass								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	3	4	5	6	7	8	9	10	11	12	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 –