Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME			
CENTRE NUMBER		CANDIDATE NUMBER	

1663220061

CHEMISTRY **9701/22**

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. Any blank pages are indicated.

IB22 11_9701_22/3RP

1 Species such as NH_4^+, CO_3^{2-} and PO_4^{3-} are examples of molecular ions.

(a) Ionic and covalent bonds both involve an electrostatic attraction between different species.

Identify the species that are electrostatically attracted to one another in:

- an ionic bond

....

- a covalent bond.

....
[2]

(b) Complete Table 1.1 to show the total numbers of protons and electrons in the molecular ions NH_4^+, CO_3^{2-} and PO_4^{3-}.

Table 1.1

molecular ion	total number of protons	total number of electrons
NH_4^+		
CO_3^{2-}		
PO_4^{3-}		

[3]

(c) NH_4^+ is a Brønsted–Lowry acid.

(i) Define Brønsted–Lowry acid.

....

.... [1]

(ii) When $NH_4^+(aq)$ is heated with NaOH(aq), a pungent gas is produced.

Write an ionic equation for this reaction.

.... [1]

(iii) The nitrogen atom in NH_4^+ is sp^3 hybridised. sp^3 orbitals form from the mixing of one 2s and three 2p orbitals.

Sketch the shapes of a 2s and a $2p_x$ orbital on the axes in Fig. 1.1.

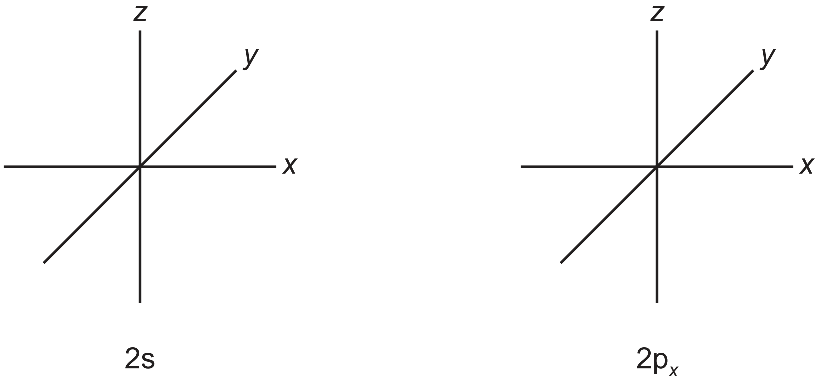


Fig. 1.1

[2]

(d) There are many naturally occurring hydrated compounds that contain the anion PO_4^{3-}.

(i) Name the anion PO_4^{3-}.

.... [1]

(ii) Struvite is a soft hydrated mineral with M_r = 245.3. The anhydrous form of the mineral has the formula NH_4MgPO_4.

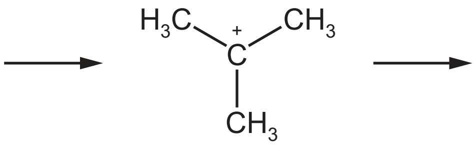
Calculate the number of molecules of water of crystallisation in struvite.

Give your answer to the nearest integer. Show your working.

number of molecules of water of crystallisation = ... [2]

(e) OH^-(aq) reacts with 2-bromo-2-methylpropane in an S_N1 reaction.
The molecular ion $(CH_3)_3C^+$ forms as the intermediate in this reaction.

(i) Draw the mechanism for the S_N1 reaction of OH^- with 2-bromo-2-methylpropane.
Include charges, dipoles, lone pairs of electrons and curly arrows as appropriate.
Draw the structures of the organic reactant and organic product.



[3]

(ii) 2-bromo-2-methylpropane is a tertiary bromoalkane.

Define tertiary bromoalkane.

....

.... [1]

(iii) Organic compound **M** forms when 2-bromo-2-methylpropane is heated with **ethanolic** OH^-.

Draw the structure of **M**.

[1]

[Total: 17]

2 The chlorides of some of the Period 3 elements are shown in Table 2.1.

Table 2.1

Period 3 chloride	$NaCl$	$AlCl_3$	$SiCl_4$	PCl_5	PCl_3	SCl_2
bonding					C	C
structure					S	S
oxidation state of Period 3 element						

(a) Complete Table 2.1.

- Identify the bonding shown by each chloride under standard conditions.
  Use C = covalent, I = ionic, M = metallic.
- Identify the structure shown by each chloride under standard conditions.
  Use G = giant, S = simple.
- Deduce the oxidation state of the Period 3 element in each chloride.

[4]

(b) Write equations for the reactions of $NaCl$ and PCl_5 with water.
Include state symbols in both equations.

$NaCl$ ....

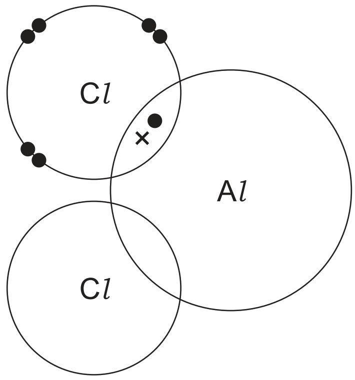
PCl_5 ....

[3]

(c) In the gas phase, $AlCl_3$(g) exists at equilibrium with Al_2Cl_6(g) as shown.

equation **1** $2AlCl_3(g) \rightleftharpoons Al_2Cl_6(g)$ $\Delta H_r = -63\,kJ\,mol^{-1}$

(i) Complete the dot-and-cross diagram to show the bonding in Al_2Cl_6.



[2]

(ii) State the effect of an increase in temperature on the equilibrium mixture in equation **1**. Explain your answer.

....

.... [1]

(d) A 3.30 g sample of a Period 3 chloride is heated to 500 K in a sealed flask. At this temperature, the chloride is a gas of volume 250 cm^3 and the pressure in the flask is 323 kPa.

Use the ideal gas equation $pV = nRT$ to calculate the M_r of the Period 3 chloride. Deduce its formula.

M_r = ...

formula of Period 3 chloride = ...
[3]

(e) **(i)** An excess of Cl^-(aq) is added to 1 cm^3 of Br_2(aq).

Describe what is observed. Explain your answer.

....

....

.... [2]

(ii) SCl_2 has M_r = 103.1 and is a liquid at room temperature. SBr_2 has M_r = 191.9 and is a gas at room temperature.

Explain the difference in the physical state of SCl_2 and SBr_2. Give your answer in terms of intermolecular forces.

....

....

....

.... [2]

(f) Bismuth is a dense metal in the same group as phosphorus.

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

[2]

(ii) Bismuth reacts with chlorine to form $BiCl_3$.
$BiCl_3$ is a solid at room temperature. It melts when heated gently.
$BiCl_3$ reacts vigorously with water at room temperature to form an acidic solution.

Suggest the type of bonding and structure shown by $BiCl_3$. Explain your answer.

....

....

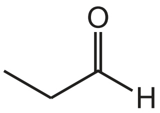
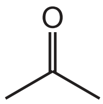
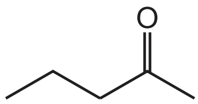
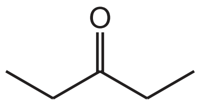
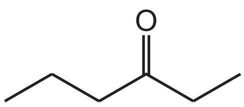
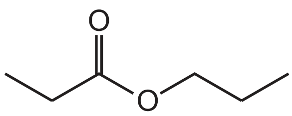
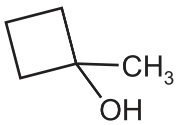
.... [2]

[Total: 21]

3 Organic compounds can be distinguished using chemical tests and analytical techniques.

(a) Table 3.1 shows four pairs of organic compounds.

Table 3.1

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

(i) Complete Table 3.1 to:

- identify a reagent which can 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]

(ii) **A1** and **A2** are structural isomers.

Define structural isomers.

....

.... [1]

(iii) Give the systematic name of **B2**.

.... [1]

(iv) Deduce the molecular formula of **D1**.

.... [1]

(b) **D2** forms polymer **Z** when heated gently.

(i) Identify the type of polymer that forms from **D2**.

.... [1]

(ii) Draw one repeat unit of polymer **Z**.

[2]

(c) Organic compound **E** contains three carbon atoms.
E reacts with cold dilute acidified $KMnO_4(aq)$ to form a single compound **F** with M_r = 154.9.
Fig. 3.1 shows the infrared spectrum of **E**.
Fig. 3.2 shows the infrared spectrum of **F**.

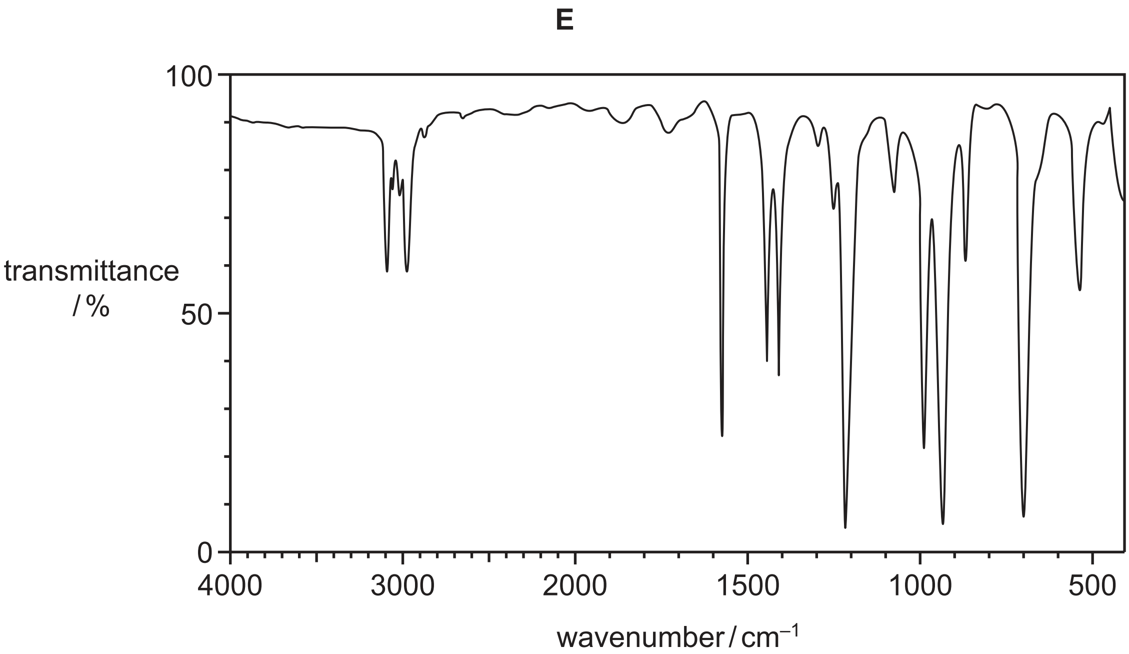


Fig. 3.1

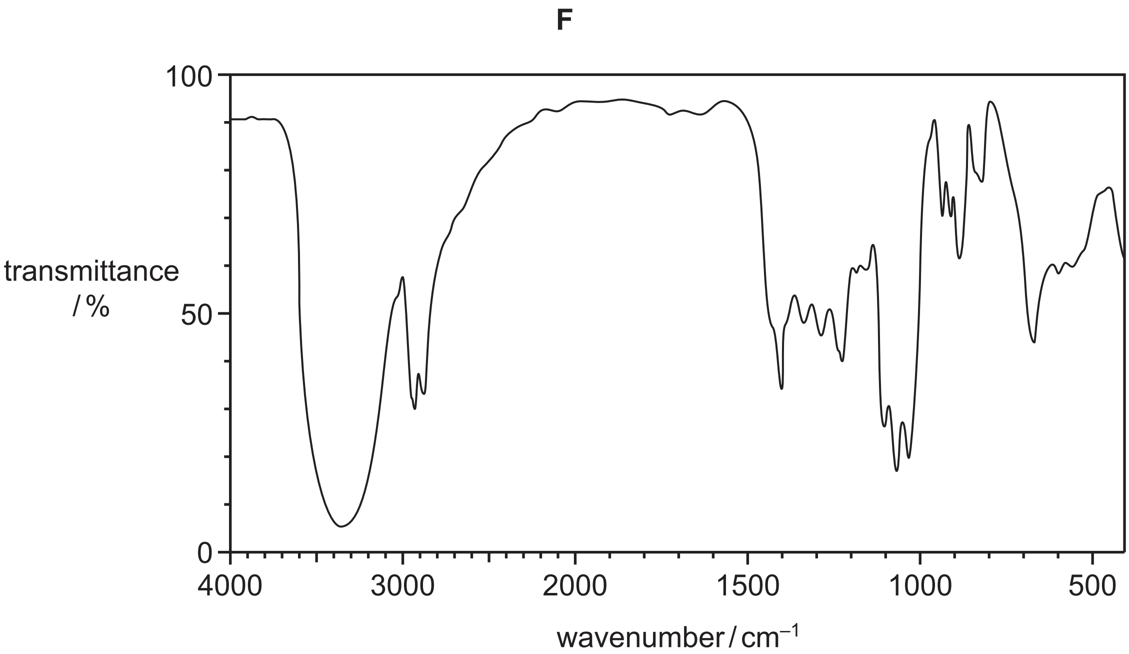


Fig. 3.2

Table 3.2

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

Both spectra show absorptions between 2850 and 2950 cm^{-1} owing to C–H bonds in each molecule.

(i) Use the two infrared spectra and Table 3.2 to identify the functional group present only in **E**.
Explain your answer, referring only to absorptions at frequencies greater than 1500 cm^{-1}.

functional group ....

explanation ....

....
[1]

(ii) Use the infrared spectrum of **F** to identify the functional group formed when **E** reacts with cold dilute acidified $KMnO_4(aq)$.
Explain your answer, referring only to absorptions at frequencies greater than 1500 cm^{-1}.

functional group ....

explanation ....

....
[1]

(iii) The mass spectrum of **E** shows a molecular ion peak and an M+2 peak of approximately equal abundance at m/e = 120 and 122.

Deduce the relative molecular mass, M_r, of **E**.

M_r = ... [1]

(iv) Use the information in **3(c)** to suggest a structure for **E**.

[1]

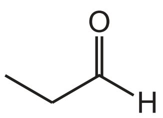
(v) Complete the equation for the reaction of **E** with cold dilute acidified $KMnO_4$(aq) to form **F**.
In the equation, [O] represents cold dilute acidified $KMnO_4$(aq).

H_2O + [O] + ... $\rightarrow$ ....

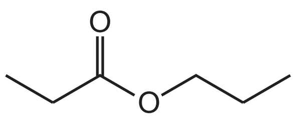
[1]

(d) **C2** can be synthesised using **A1** as a single organic reactant.

A1



C2



Devise a multi-step synthetic route to form **C2** from **A1**.
Identify relevant reagents and conditions, and state the organic products of each step.

....

....

....

....

....

.... [3]

[Total: 22]

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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 –