



# Cambridge International AS & A Level

CANDIDATE NAME				
CENTRE NUMBER		CANDIDATE NUMBER		

CHEMISTRY

Paper 2 AS Level Structured Questions

October/November 2022

1 hour 15 minutes

9701/22

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.

1

Species	s such as NH	<sub>4</sub> +, CO <sub>3</sub> <sup>2-</sup> and P	O <sub>4</sub> 3- are examples	of molecular ions.						
(a) lon	lonic and covalent bonds both involve an electrostatic attraction between different species.									
Ide	Identify the species that are electrostatically attracted to one another in:									
•	an ionic bond									
•	a covalent l	oond.								
					[2]					
	mplete Table		e total numbers of	protons and electro	ons in the molecular ions					
			Table 1.1							
		molecular	total number	total number						
		ion	of protons	of electrons						
		NH <sub>4</sub> <sup>+</sup>								
		CO <sub>3</sub> <sup>2-</sup>								
		PO <sub>4</sub> <sup>3-</sup>								
				<u> </u>	[3]					
					1-1					
(c) NH	<sub>4</sub> + is a Brøns	ted-Lowry acid								
(i)	Define Brør	nsted–Lowry ac	id.							
					[1]					
(ii)	When NH <sub>4</sub> +	(aq) is heated v	vith NaOH(aq), a p	ungent gas is prod	uced.					
	Write an ior	nic 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<sub>x</sub> orbital on the axes in Fig. 1.1.

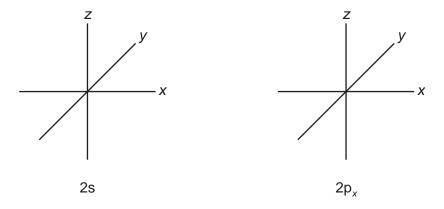


Fig. 1.1

[2]

- (d) There are many naturally occurring hydrated compounds that contain the anion PO<sub>4</sub><sup>3-</sup>.
  - (i) Name the anion PO<sub>4</sub><sup>3-</sup>.

[1
----

(ii) Struvite is a soft hydrated mineral with  $M_r$  = 245.3. The anhydrous form of the mineral has the formula NH<sub>4</sub>MgPO<sub>4</sub>.

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.

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

Define tertiary bromoalkane.	
	[1]

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

Draw the structure of M.



[1]

[3]

[Total: 17]

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

Table 2.1

Period 3 chloride	NaC1	AlCl <sub>3</sub>	SiCl <sub>4</sub>	PCl <sub>5</sub>	PCl <sub>3</sub>	SCl <sub>2</sub>
bonding					С	С
structure					S	S
oxidation state of Period 3 element						

- 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

**(b)** Write equations for the reactions of NaCl and PC $l_{\scriptscriptstyle 5}$  with water.

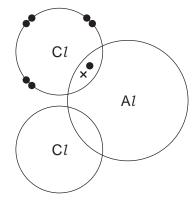
[4	

Include state symbols in both equations.
NaC1
PC <i>l</i> <sub>5</sub>

(c	) In the gas	s nhase	$\Delta ICI$ (a)	evicte at	equilibrium	with A	41 C.1 (a)	as showr
ν,	, iii iiic ga	o priasc,	$I \cup \iota_3(g)$	CAISIS at	Cquiiibiiuiii	VVILII /	16(9)	as shown

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

(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 Explain your answer.	1 <b>1</b> .
		[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 cm³ 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.

$$M_{\rm r} =$$
 ...... formula of Period 3 chloride = ..... [3]

(i)	An excess of $Cl^-(aq)$ is added to 1 cm <sup>3</sup> 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 quantum temperature.	gas
	Explain the difference in the physical state of ${\rm SC}l_2$ and ${\rm SBr}_2$ . Give your answer in terms intermolecular forces.	s of
		[2]
Bisr	muth 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 $\mathrm{BiC} l_3$ . $\mathrm{BiC} l_3$ is a solid at room temperature. It melts when heated gently. $\mathrm{BiC} l_3$ reacts vigorously with water at room temperature to form an acidic solution.	
	Suggest the type of bonding and structure shown by $\mathrm{BiC}l_3$ . Explain your answer.	
		[2]
	[Total:	21]
	(ii)	<ul> <li>(ii) SCl<sub>2</sub> has M<sub>i</sub> = 103.1 and is a liquid at room temperature. SBr<sub>2</sub> has M<sub>i</sub> = 191.9 and is a at room temperature.  Explain the difference in the physical state of SCl<sub>2</sub> and SBr<sub>2</sub>. Give your answer in terms intermolecular forces.  Bismuth is a dense metal in the same group as phosphorus.  (i) Draw a labelled diagram to show the bonding in bismuth metal.  (ii) Bismuth reacts with chlorine to form BiCl<sub>3</sub>.  BiCl<sub>3</sub> is a solid at room temperature. It melts when heated gently.  BiCl<sub>3</sub> reacts vigorously with water at room temperature to form an acidic solution.  Suggest the type of bonding and structure shown by BiCl<sub>3</sub>. Explain your answer. </li></ul>

- 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 co	ompounds	reagent	positive result of chemical test on identified compound
A1 O H	<b>A2</b> O		
B1	B2 O		
C1 O	C2 0 0		
D1  CH <sub>3</sub> OH	D2 OH		

- (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 <b>B2</b> .	
			[1]
	(iv)	Deduce the molecular formula of <b>D1</b> .	
			[1]
(b)	D2	forms polymer <b>Z</b> when heated gently.	
	(i)	Identify the type of polymer that forms from <b>D2</b> .	
			[1]
	(ii)	Draw one repeat unit of polymer <b>Z</b> .	

[2]

(c) Organic compound E contains three carbon atoms.

**E** reacts with cold dilute acidified KMnO<sub>4</sub>(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**.

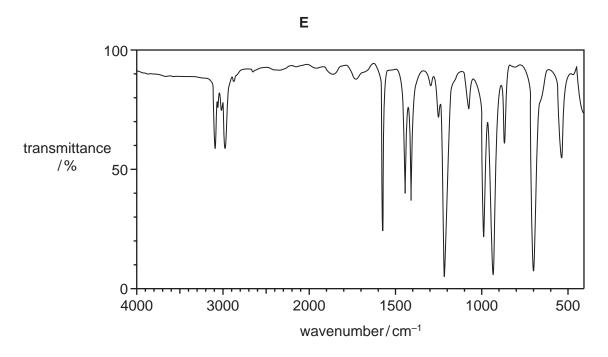


Fig. 3.1

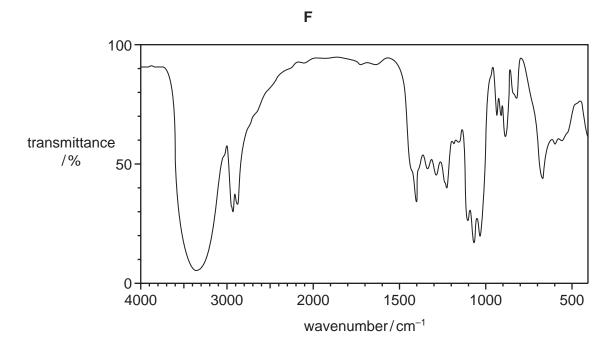


Fig. 3.2

Table 3.2

bond	functional group containing the bond	characteristic infrared absorption range (in wavenumbers)/cm <sup>-1</sup>
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<sup>-1</sup> 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 <b>E</b> .
	Explain your answer, referring only to absorptions at frequencies greater than 1500 cm <sup>-1</sup> .
	functional group
	explanation
	[1]
(ii)	Use the infrared spectrum of ${\bf F}$ to identify the functional group formed when ${\bf E}$ reacts with cold dilute acidified KMnO <sub>4</sub> (aq). Explain your answer, referring only to absorptions at frequencies greater than 1500 cm <sup>-1</sup> .
	functional group
	explanation
	[1]
(iii)	The mass spectrum of <b>E</b> 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, $M_{\rm r}$ , of <b>E</b> .
	$M_{\rm r} = \dots $ [1]

(	iv)	Use the	information	in	3(c)	to	suggest	а	structure	for	E,

		[1]
(v)	Complete the equation for the reaction of $\bf E$ with cold dilute acidified $KMnO_4(aq)$ to form In the equation, [O] represents cold dilute acidified $KMnO_4(aq)$ .	F.
	$H_2O + [O] + \dots \rightarrow \dots$	 [1]
		ניו

(d)  ${\bf C2}$  can be synthesised using  ${\bf A1}$  as a single organic reactant.



Devise a multi-step synthetic route to form <b>C2</b> from <b>A1</b> . Identify relevant reagents and conditions, and state the organic products of each step.
[3

[Total: 22]

13

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14

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## Important values, constants and standards

molar gas constant	$R = 8.31 \mathrm{J}\mathrm{K}^{-1}\mathrm{mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \mathrm{C}\mathrm{mol}^{-1}$
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	$V_{\rm m} = 22.4 {\rm dm^3  mol^{-1}}$ at s.t.p. (101 kPa and 273 K) $V_{\rm m} = 24.0 {\rm dm^3  mol^{-1}}$ at room conditions
ionic product of water	$K_{\rm w} = 1.00 \times 10^{-14} \rm mol^2  dm^{-6}  (at  298  K  (25  {}^{\circ}C))$
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

	18	0,	<u> </u>	helium 4.0	0	e	u c	γ α	· -	argon 39.9	9	ج	noto 1.8	4	( <b>a</b> )	1.3	9	<u> </u>	don -	18	g	esson	
	_		_	hel 4	-	<b>Z</b>	ē ĉ	2 -	_	arg 39	e			2	× —	13. xer	8	~	rad	7	0	ogane	_
	17				6	Щ	fluorine	13.0	C1	chlorine 35.5	35	Ŗ	bromine 79.9	53	Ι	iodine 126.9	82	At	astatine -	117	<u>Σ</u>	tennessine	ı
	16				80	0	oxygen	5.0	ഭഗ	suffur 32.1	34	Se	selenium 79.0	52	Те	tellurium 127.6	84	Ро	polonium –	116	_	livermorium	ı
	15				7	z	nitrogen	5. T	≘	phosphorus 31.0	33	As	arsenic 74.9	51	Sp	antimony 121.8	83	Ξ	bismuth 209.0	115	Mc	moscovium	
	14				9	ပ	carbon	0.51	:iS	silicon 28.1	32	Ge	germanium 72.6	20	Sn	tin 118.7	82	Pb	lead 207.2	114	lΉ	flerovium	
	13				2	В	boron	2.0	Ϋ́	aluminium 27.0	31	Ga	gallium 69.7	49	In	indium 114.8	18	11	thallium 204.4	113	Z	nihonium	
										12	30	Zu	zinc 65.4	48	g	cadmium 112.4	80	Нg	mercury 200.6	112	ပ်	copernicium	-
										7	29	C	copper 63.5	47	Ag	silver 107.9	62	Au	gold 197.0	111	Rg	roentgenium	
dn										10	28	Ē	nickel 58.7	46	Pq	palladium 106.4	78	₫	platinum 195.1	110	Ds	darmstadtium	-
Group										6	27	ပိ	cobalt 58.9	45	R	rhodium 102.9	77	Ľ	iridium 192.2	109	¥	meitnerium	-
			I	hydrogen 1.0						80	26	Pe	iron 55.8	44	Ru	ruthenium 101.1	92	SO	osmium 190.2	108	Ϋ́	hassium	-
					J					7	25	Mn	manganese 54.9	43	ည	technetium -	75	Re	rhenium 186.2	107	뮵	bohrium	-
						loc		8		9	24	ပ်	chromium 52.0	42	Mo	molybdenum 95.9	74	>	tungsten 183.8	106	Sg	seaborgium	
				Key	atomic number	atomic symbo	name	ive atomic ma		2	23	>	vanadium 50.9	41	g	niobium 92.9	73	Б	tantalum 180.9	105	8	dubnium	-
					ଅ	ator	100	- G		4	22	F	titanium 47.9	40	Zr	zirconium 91.2	72	Ξ	hafnium 178.5	104	¥	rutherfordium	
								_		က	21	Sc	scandium 45.0	39	>	yttrium 88.9	57-71	lanthanoids		89–103	actinoids		
	2				4	Be	beryllium	3.0	Ma	magnesium 24.3	20	Sa	calcium 40.1	38	ഗ്	strontium 87.6	56	Ba	barium 137.3	88	Ra	radium	
	-				3	:=	lithium	5.5	. Z	sodium 23.0	19	×	potassium 39.1	37	Rb	rubidium 85.5	55	S	caesium 132.9	87	ь́	francium	

71	ŋ	lutetium 175.0	103	۲	lawrencium	ı	
70	Yb	ytterbium 173.1	102	Š	nobelium	ı	
69	T	thulium 168.9	101	Md	mendelevium	ı	
89	ш	erbium 167.3	100	Fm	ferminm	I	
29	웃	holmium 164.9	66	Es	einsteinium	ı	
99	۵	dysprosium 162.5	86	₽	californium	I	
65	Д	terbium 158.9	26	益	berkelium	ı	
49	Вd	gadolinium 157.3	96	CB	curium	ı	
63	En	europium 152.0	92	Am	americium	ı	
62	Sm	samarium 150.4	94	Pu	plutonium	ı	
61	Pm	promethium —	93	g	neptunium	ı	
09	PN	neodymium 144.4	92	$\supset$	uranium	238.0	
59	Ā	praseodymium 140.9	91	Ра	protactinium	231.0	
58	Se	cerium 140.1	06	Ļ	thorium	232.0	
22	La	lanthanum 138.9	88	Ac	actinium	ı	

lanthanoids actinoids

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