Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER | | | | | |

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8748629381

CHEMISTRY **9701/22**

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

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Answer **all** the questions in the spaces provided.

1 Fig. 1.1 shows how **first** ionisation energies vary across Period 2.

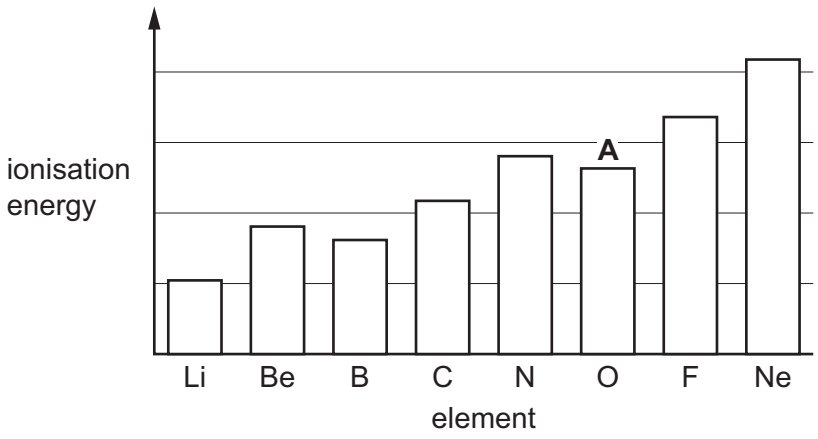

Fig. 1.1

(a) Construct an equation to represent the **first** ionisation energy of oxygen. Include state symbols.

..... [1]

(b) (i) State and explain the general trend in first ionisation energies across Period 2.

.....

.....

.....

.....

..... [3]

(ii) Explain why ionisation energy **A** in Fig. 1.1 does **not** follow the general trend in first ionisation energies across Period 2.

.....

.....

.....

..... [2]

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(c) Element **E** is in Period 3 of the Periodic Table.
The first eight ionisation energy values of **E** are shown in Table 1.1.

Table 1.1

ionisation	1st	2nd	3rd	4th	5th	6th	7th	8th
ionisation energy / kJ mol^{-1}	577	1820	2740	11 600	14 800	18 400	23 400	27 500

Deduce the full electronic configuration of **E**.
Explain your answer.

full electronic configuration of **E** = ...

explanation .....

.....

.....
[3]

[Total: 9]

2 Some oxides of elements in Period 3 are shown.

Na_2O Al_2O_3 P_4O_6 P_4O_{10} SO_2 SO_3

(a) Na reacts with O_2 to form Na_2O. Na is the reducing agent in this reaction.

(i) Define reducing agent.

.....

..... [1]

(ii) Write an equation for the reaction of Na_2O with water.

..... [1]

(b) Al_2O_3 is an amphoteric oxide found in bauxite.

(i) State what is meant by amphoteric.

.....

..... [1]

(ii) Al_2O_3 is purified from bauxite in several steps. The first step involves heating Al_2O_3 with an excess of NaOH(aq). A colourless solution forms.

Write an equation for this reaction.

..... [1]

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(iii) Al_2O_3 is used as a catalyst in the dehydration of alcohols.

State the effect of using Al_2O_3 as a catalyst in the dehydration of alcohols. Use the Boltzmann distribution in Fig. 2.1 to help explain your answer.

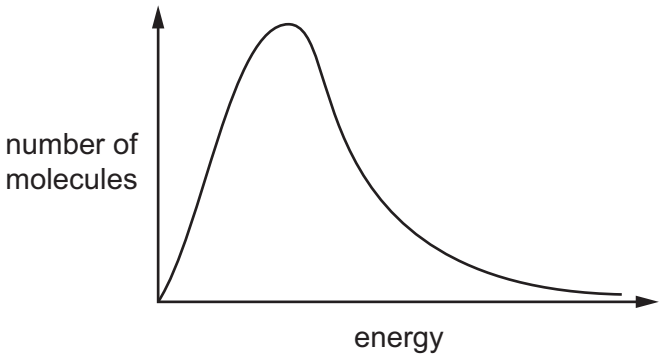

Fig. 2.1

.....

.....

..... [3]

(c) P_4O_6 is a white solid that has a melting point of 24 °C. Solid P_4O_6 reacts with water to form H_3PO_3.

(i) Deduce the type of structure and bonding shown by P_4O_6. Explain your answer.

.....

.....

..... [2]

(ii) Determine the oxidation number of P in H_3PO_3.

..... [1]

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(iii) When $P_4O_6(s)$ is heated with oxygen it forms $P_4O_{10}(s)$.

$$P_4O_6(s) + 2O_2(g) \rightarrow P_4O_{10}(s) \qquad \Delta H_r = -1372\,kJ\,mol^{-1}$$

The enthalpy change of formation, ΔH_f, of $P_4O_{10}(s)$ is $-3012\,kJ\,mol^{-1}$.

Calculate the enthalpy change of formation, ΔH_f, of $P_4O_6(s)$.

ΔH_f of $P_4O_6(s)$ = ... $kJ\,mol^{-1}$ [1]

(iv) Write an equation for the reaction of P_4O_{10} with water.

..... [1]

(d) SO_2 and SO_3 are found in the atmosphere.
The oxidation of SO_2 to SO_3 in the atmosphere is catalysed by NO_2.
The first step of the catalytic oxidation is shown in equation 1.

equation 1 $\quad SO_2(g) + NO_2(g) \rightleftharpoons SO_3(g) + NO(g)$

(i) Construct an equation to show how NO_2 is regenerated in the catalytic oxidation of SO_2.

..... [1]

(ii) NO_2 can also react with unburned hydrocarbons to form photochemical smog.

State the product of this reaction that contributes to photochemical smog.

..... [1]

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(iii) Fig. 2.2 shows how the temperature of the atmosphere varies with height from the ground.

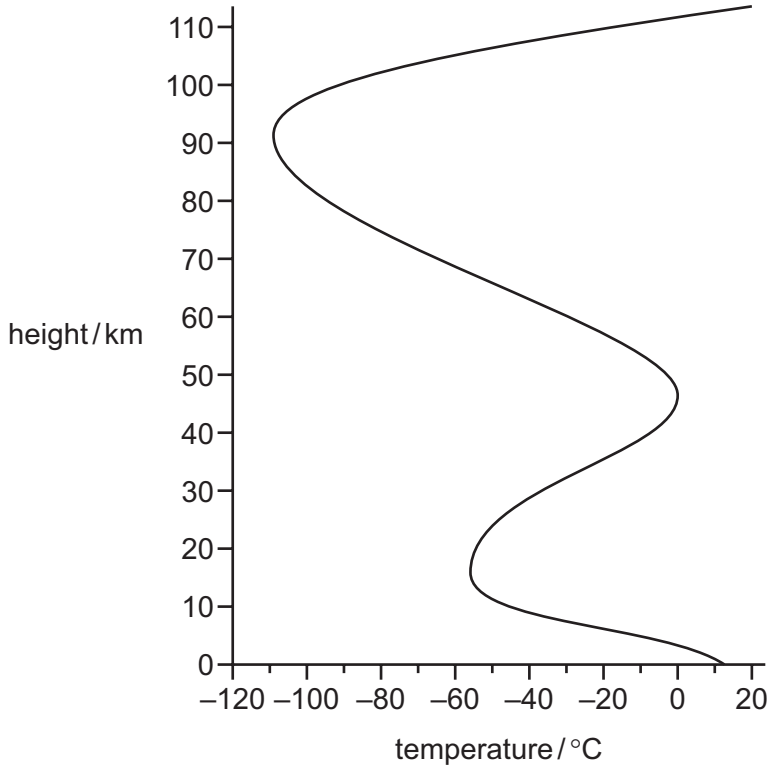

Fig. 2.2

The equilibrium reaction in equation 1 has $\Delta H_r = -168\,kJ\,mol^{-1}$.

Suggest how the position of this equilibrium differs at a height of 20 km compared with a height of 50 km from the ground.
Explain your answer.

.....

.....

..... [2]

[Total: 16]

3 The hydrogen halides HCl, HBr and HI are all colourless gases at room temperature.

(a) The hydrogen halides can be formed by reacting the halogens with hydrogen.

Describe and explain the relative reactivity of the halogens down the group when they react with hydrogen to form HCl, HBr and HI.

.....

.....

..... [2]

(b) HCl is a product of several different reactions. Some of these are shown in Fig. 3.1.

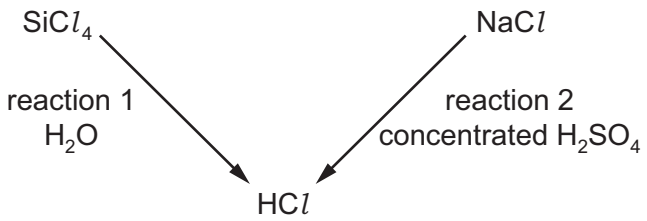

Fig. 3.1

(i) Write an equation for reaction 1.

..... [1]

(ii) In reaction 2, NaCl reacts with concentrated H_2SO_4 to form HCl and $NaHSO_4$.
When NaBr reacts with concentrated H_2SO_4, the products include Br_2 and SO_2.

Identify the type(s) of reaction that occur in each case by completing Table 3.1.
Explain the difference in these reactions.

Table 3.1

reactants	type(s) of reaction
NaCl and concentrated H_2SO_4	
NaBr and concentrated H_2SO_4	

explanation .....

.....

[3]

(c) When heated with a Bunsen burner, HCl does not decompose, whereas HI forms H_2 and I_2.

Explain the difference in the effect of heating on HCl and HI.

.....

..... [1]

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[Turn over

(d) The hydrogen halides dissolve in water to form strong Brønsted–Lowry acids.

The concentration of a strong acid can be determined by titration.

(i) State what is meant by strong Brønsted–Lowry acid.

.....

.....

..... [2]

(ii) On Fig. 3.2, sketch the pH titration curves produced when:

- 0.1 mol dm^{-3} NaOH(aq) is added to 25 cm^3 of 0.1 mol dm^{-3} HBr(aq), to excess
- 0.1 mol dm^{-3} NH_3(aq) is added to 25 cm^3 of 0.1 mol dm^{-3} HBr(aq), to excess.

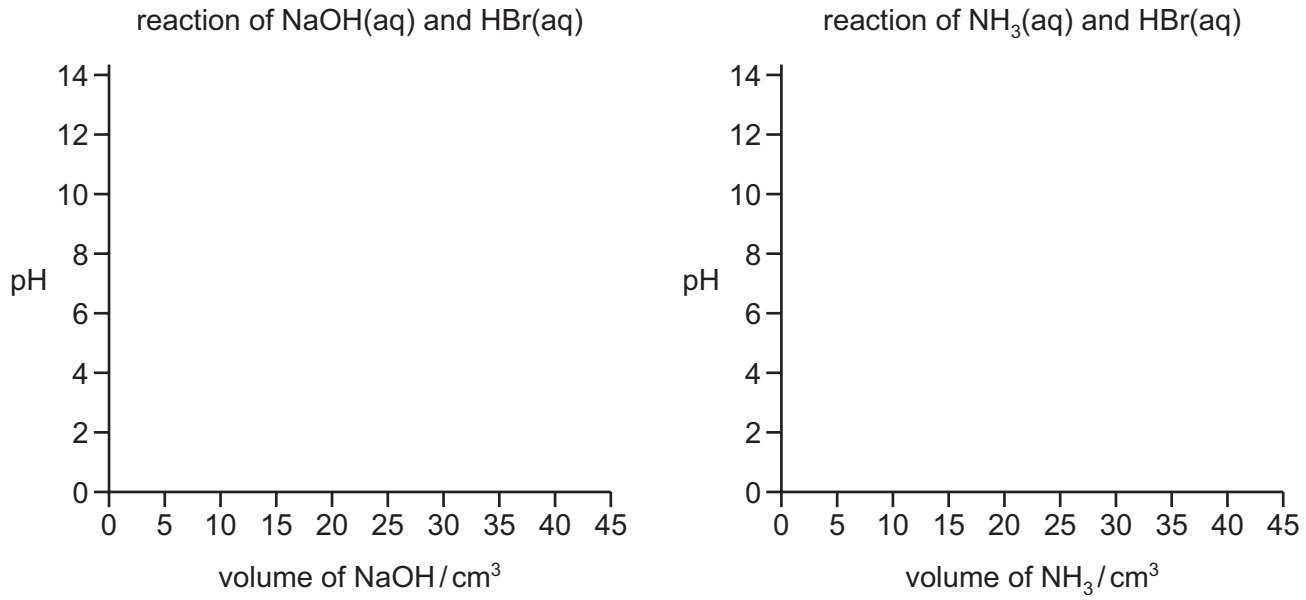
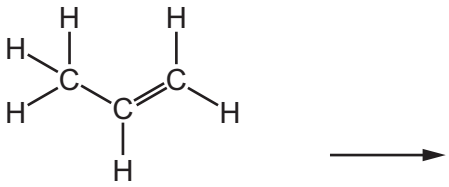


Fig. 3.2

[3]

(e) HBr reacts with propene to form two bromoalkanes, $CH_3CH_2CH_2Br$ and $(CH_3)_2CHBr$.

(i) Complete the diagram to show the mechanism of the reaction of HBr and propene to form the major organic product.
Include charges, dipoles, lone pairs of electrons and curly arrows, as appropriate.
Draw the structures of the intermediate and the major organic product.



H—Br

[4]

(ii) Explain why the two bromoalkanes are **not** produced in equal amounts by this reaction.

.....

.....

..... [2]

(iii) The reaction of $CH_3CH_2CH_2Br$ and NaOH is different depending on whether water or ethanol is used as a solvent.

Complete Table 3.2 to identify the organic and inorganic products of the reaction of $CH_3CH_2CH_2Br$ and NaOH in each solvent.

Table 3.2

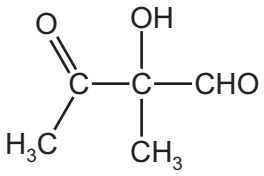
solvent	organic product(s)	inorganic product(s)
water		
ethanol		

[2]

[Total: 20]

4 Compounds **J** and **K** are found in plant oils.

J



K

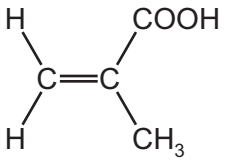


Fig. 4.1

(a) (i) Complete Table 4.1 to state what you would **observe** when **J** reacts with the reagents listed.

Table 4.1

reagent	observation with **J**
2,4-dinitrophenylhydrazine (2,4-DNPH)	
Tollens' reagent	
sodium metal	

[3]

(ii) **J** has **two** optical isomers.

Draw the three-dimensional structures of the **two** optical isomers of **J**.

[2]

(b) **K** is used to make the addition polymer Perspex®. A synthesis of Perspex® is shown in Fig. 4.2.

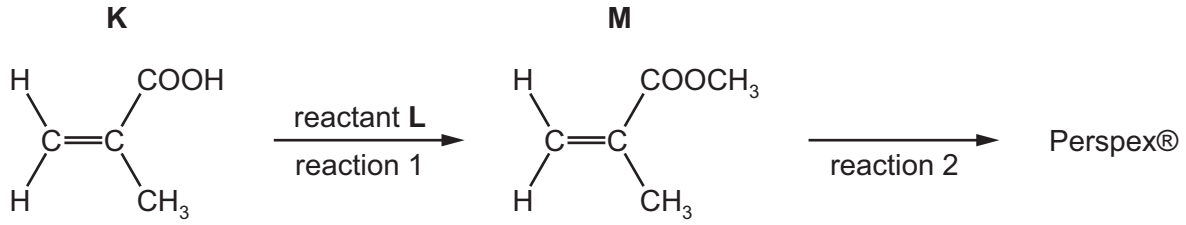


Fig. 4.2

(i) Identify **L**. State the conditions required for reaction 1.

L = ...

conditions = ...
[2]

(ii) Draw **one** repeat unit of the addition polymer Perspex®.

[2]

(iii) Use information from Table 4.2 to suggest how the infrared spectra of **M** and Perspex® would differ. Explain your answer.

.....

..... [1]

Table 4.2

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

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[Turn over

(iv) **K** can be made from propanone in the three-step synthesis shown in Fig. 4.3.

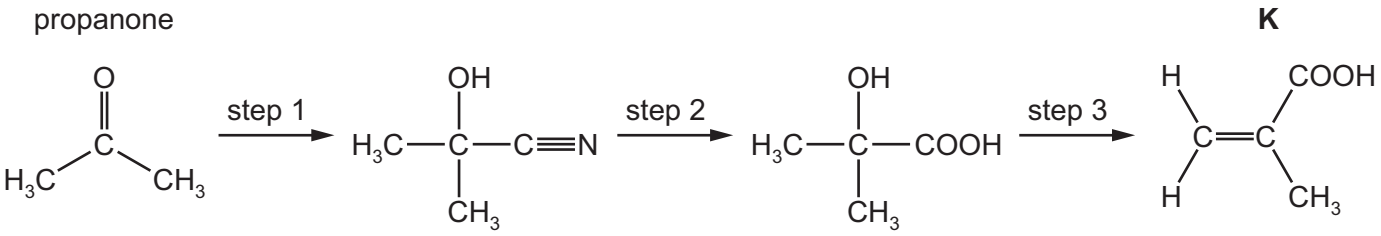

Fig. 4.3

Complete Table 4.3 to identify the reagent(s) used and the type of reaction in each step.

Table 4.3

step	reagent(s)	type of reaction
1		
2		
3	Al_2O_3	

[5]

[Total: 15]

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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