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Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

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CHEMISTRY **9701/23**

Paper 2 AS Level Structured Questions **May/June 2025**

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.

DC (CJ/CT) 339916/3

1 The chemical properties of an element are related to the electronic configuration of its atoms.

(a) (i) Give the full electronic configuration of a fluorine atom.

.... [1]

(ii) Deduce the number of pairs of electrons in the second energy shell, $n = 2$, of an oxygen atom.

.... [1]

(iii) Draw the shape of the highest energy orbital that contains electrons in an atom of calcium.

[1]

(b) (i) Write an equation to represent the first ionisation energy of sulfur.

.... [1]

(ii) Explain why the first ionisation energy of sulfur is less than the first ionisation energy of phosphorus.

....

....

....

.... [2]

(iii) Arrange the three species F^-, Ne and Na^+ in order of increasing radius.

Explain your answer.

.... < .... < ....
smallest radius largest radius

....

....

....

....
[4]

[Total: 10]

2 The chemical properties of oxides are related to the chemical bonding present in these compounds.

(a) A Period 3 oxide produces a solution with a pH greater than 10 when it is added to water. State the formula of the oxide.

.... [1]

(b) P_4O_{10} is added to an excess of aqueous NaOH. Write an equation to describe the reaction.

.... [1]

(c) Table 2.1 shows the melting points of some oxides.

Table 2.1

oxide	melting point / °C
SO_2	–73
H_2O	0
SO_3	17
SiO_2	1610
Na_2O	1132
MgO	2852
Al_2O_3	2072

(i) Identify the oxide from Table 2.1 that contains the element with the highest oxidation number.

.... [1]

(ii) A student suggests the following hypothesis.

The melting point of an ionically bonded oxide is only determined by the charge on the cation.

Use Table 2.1 to deduce if this hypothesis is true or false or if there is **not** enough information to make a conclusion. Explain your answer.

....

....

.... [2]

(d) State why ZnO is described as a Brønsted–Lowry base when it is added to $H_2SO_4(aq)$.

.... [1]

(e) Al_2O_3 is a white amphoteric compound.

(i) State the formula of the aluminium-containing species produced when Al_2O_3 reacts with NaOH(aq).

.... [1]

(ii) State the formula of the aluminium-containing salt produced when Al_2O_3 reacts with $H_2SO_4(aq)$.

.... [1]

[Total: 8]

3 **(a)** Different hydrocarbon mixtures produced from fractional distillation of crude oil have different uses.

(i) State the compound that is heated with long-chain hydrocarbons to produce more useful smaller alkanes and alkenes.

.... [1]

(ii) Describe how photochemical smog is produced during the combustion of petrol in an internal combustion engine.

....

....

.... [2]

(b) C_4H_8 reacts with an excess of H_2 to produce C_4H_{10}.

reaction 1 $C_4H_8 + H_2 \rightarrow C_4H_{10}$

(i) Name a catalyst for reaction 1.

.... [1]

(ii) Define activation energy, E_A.

....

.... [1]

(iii) The Boltzmann distribution for the reaction mixture in reaction 1 is shown in Fig. 3.1.
Use the Boltzmann distribution to explain the effect of adding a catalyst on the rate of reaction.

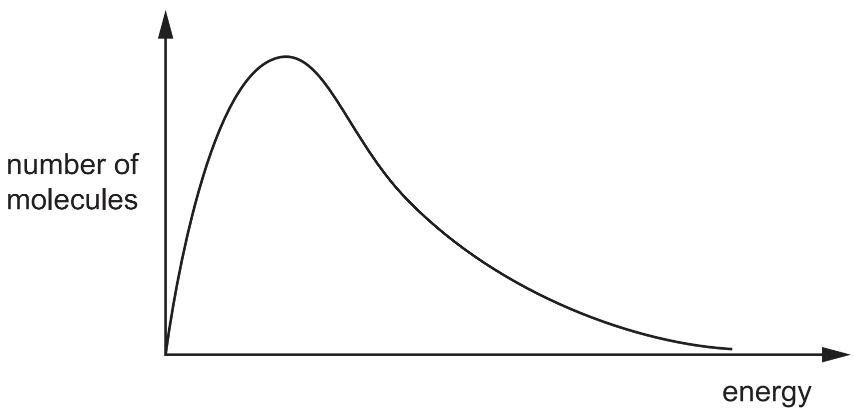

Fig. 3.1

....

....

....

.... [2]

[Total: 7]

4 The reaction between $Na_2S_2O_3$(aq) and HCl(aq) is monitored at constant temperature.

$$Na_2S_2O_3 + 2HCl \rightarrow 2NaCl + SO_2 + S + H_2O$$

Fig. 4.1 shows how the concentration of HCl(aq) varies with time.

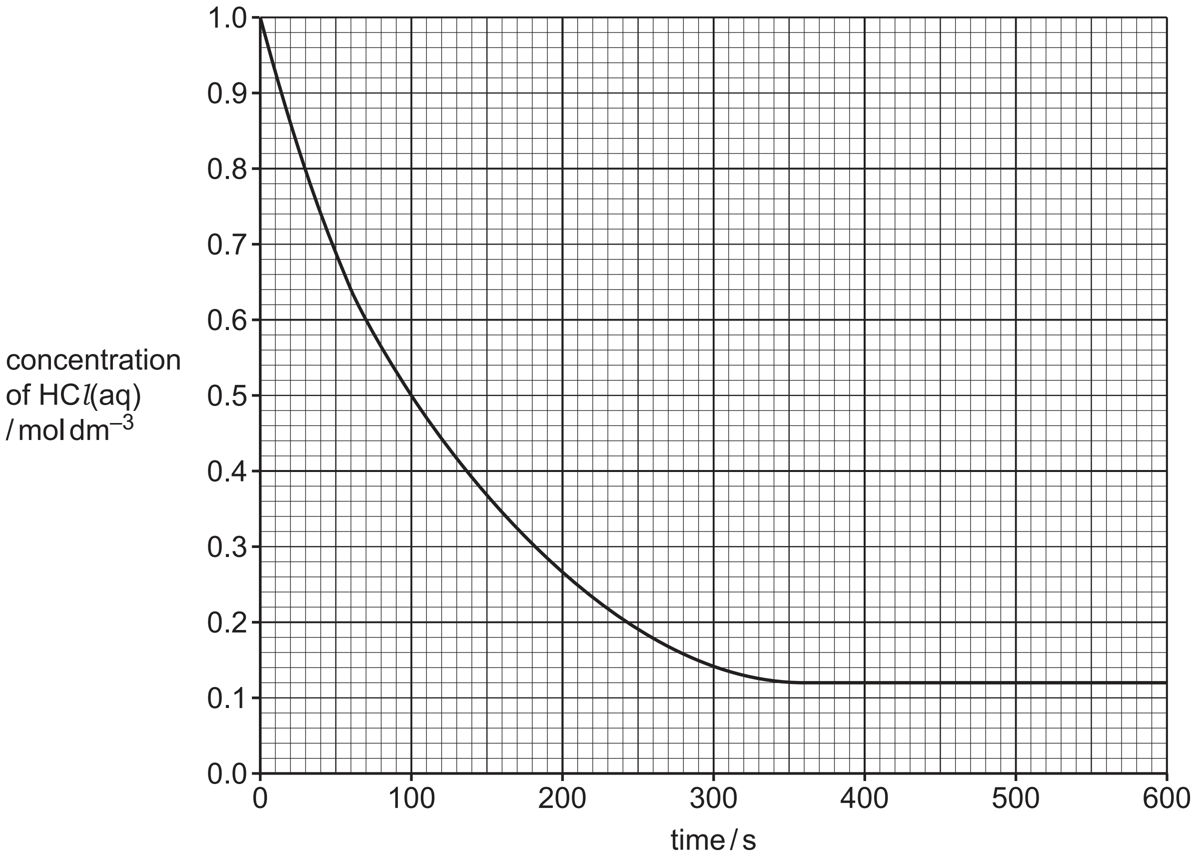

Fig. 4.1

(a) **(i)** Use Fig. 4.1 to find the average rate of change of concentration of HCl(aq) in this reaction between 0–100 seconds and between 400–500 seconds. Include units in your answers.

0–100 seconds .... units ....

400–500 seconds .... units ....

[2]

(ii) Use Fig. 4.1 to identify the limiting reagent. Explain your answer.

....

.... [1]

(iii) Explain why the rate of reaction changes with time.

....

....

.... [1]

(iv) The reaction between $Na_2S_2O_3$(aq) and HCl(aq) is repeated in a second experiment.

In this second experiment, 25.0 cm^3 of 0.050 mol dm^{-3} $Na_2S_2O_3$(aq) reacts with 0.0020 mol of HCl(aq). Calculate the number of sulfur atoms produced.

number of sulfur atoms produced = ... [2]

(v) Explain why the rate of reaction **cannot** be monitored accurately by measuring the volume of SO_2(g) produced in this reaction.

....

.... [1]

(b) Fig. 4.2 shows a possible arrangement of outer-shell electrons in one SO_2 molecule.

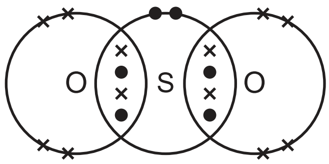

Fig. 4.2

(i) Use Fig. 4.2 to predict the shape and bond angle of a molecule of SO_2.

shape ....

bond angle ....°

[2]

(ii) Use Table 4.1 to predict the strength of the dipole moment of SO_2, if any, compared to that of H_2O. Explain your answer.

Table 4.1

	H	O	S
electronegativity	2.1	3.5	2.6

....

....

.... [2]

[Total: 11]

5 (a) **W** is a colourless liquid.

W

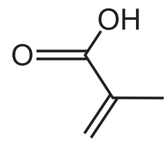

Fig. 5.1

(i) Deduce the empirical formula of **W**.

.... [1]

(ii) Two different reagents are each added to separate samples of **W** as shown in Table 5.1.

Complete Table 5.1.

Table 5.1

reagent and conditions	observation when reagent is added to **W**	structural formula of organic product when reagent is added to **W**
solid Na		
Br_2 in absence of ultraviolet light		

[4]

(b) Fig. 5.2 shows two reactions of **W** to produce organic compounds **Y** and **Z**.

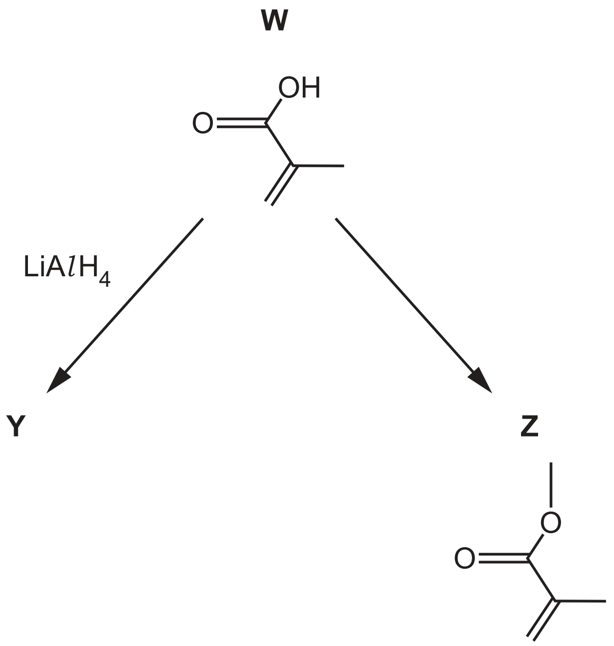

Fig. 5.2

(i) Deduce the number of sigma (σ) bonds and pi (π) bonds present in **Z**.

number of σ bonds ....

number of π bonds ....

[2]

(ii) **W** reacts with $LiAlH_4$ to produce **Y**.

Draw the structure of **Y**.

[1]

(iii) Identify the role of $LiAlH_4$ when it reacts with **W**.

.... [1]

(iv) Suggest the reagent and conditions required when **W** is converted into **Z**.

.... [1]

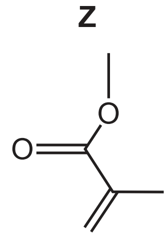

Fig. 5.3

(v) Fig. 5.3 shows the structure of **Z**.
Fig. 5.4 is the infrared spectrum of **Z**.

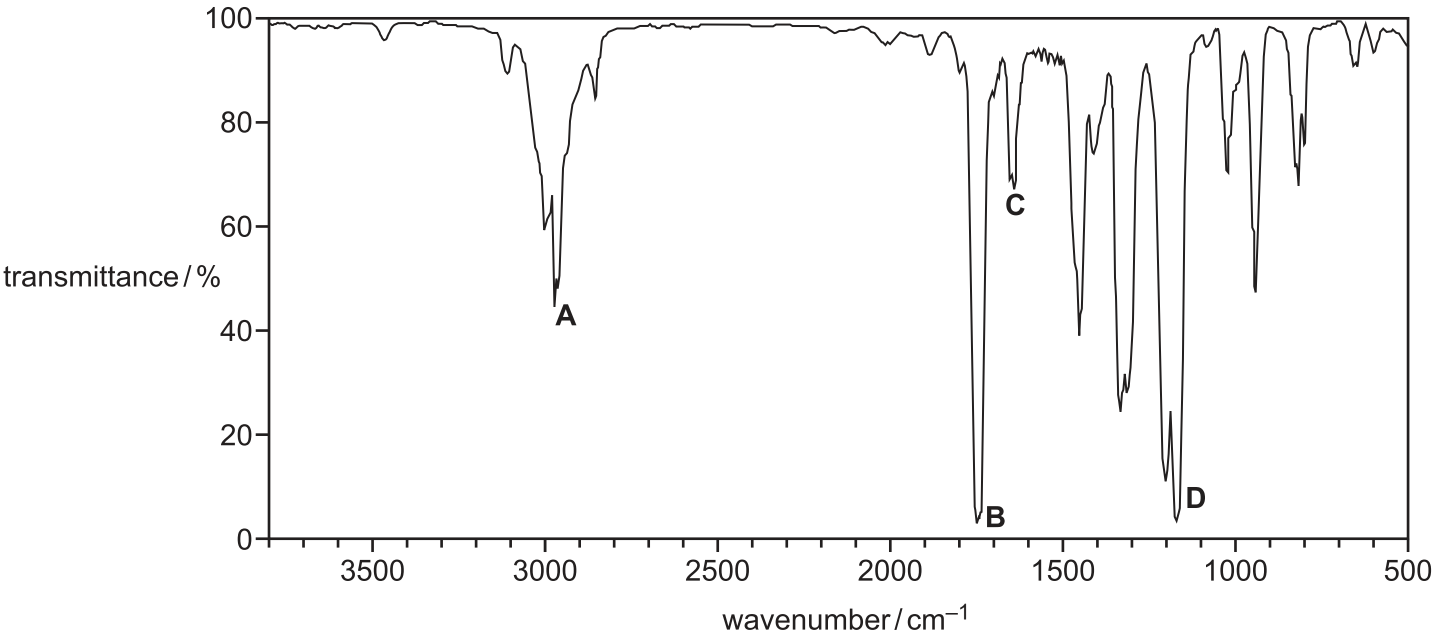

Fig. 5.4

Identify the bond and functional group responsible for each of the absorptions labelled **A**, **B**, **C** and **D** in Fig. 5.4.

A ....

B ....

C ....

D ....

[2]

Table 5.2

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 3200–3650

(vi) **Z** is used to produce addition polymer **Q**.

Draw the repeat unit of polymer **Q**.

[1]

(c) Poly(ethene) is an addition polymer made from ethene.

Explain why ethene reacts with electrophiles but poly(ethene) does **not**.

....

.... [1]

[Total: 14]

6 **(a)** HOC*l* reacts with $CH_2{=}CH_2$ to produce $HOCH_2CH_2Cl$ in an electrophilic addition reaction.

(i) Define addition reaction.

....

.... [1]

(ii) Describe how Cl_2 is used to produce HOC*l*.

....

.... [1]

(iii) State **one** use for HOC*l*.

....

.... [1]

(b) Complete Fig. 6.1 to show the mechanism for the reaction between HOC*l* and $CH_2{=}CH_2$ to produce $HOCH_2CH_2Cl$.

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

Fig. 6.1

[4]

(c) $HOCH_2CH_2Cl$ reacts in a two-step synthesis to produce $HOCH_2CH_2COOH$, as shown in Fig. 6.2.

$$HOCH_2CH_2Cl \xrightarrow{\text{step 1}} HOCH_2CH_2CN \xrightarrow[\text{}]{\substack{\text{step 2} \\ HCl(aq)}} HOCH_2CH_2COOH$$

Fig. 6.2

(i) State the reagent and conditions for step 1.

.... [1]

(ii) Identify the type of reaction that occurs in step 2.

.... [1]

(iii) Complete the equation to show the reaction in step 2.

$HOCH_2CH_2CN$ + ... [1]

[Total: 10]

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Important values, constants and standards

molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
Faraday constant	$F = 9.65 \times 10^{4}\,\mathrm{C\,mol^{-1}}$
Avogadro constant	$L = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
electronic charge	$e = -1.60 \times 10^{-19}\,\mathrm{C}$
molar volume of gas	$V_m = 22.4\,\mathrm{dm^3\,mol^{-1}}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0\,\mathrm{dm^3\,mol^{-1}}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14}\,\mathrm{mol^2\,dm^{-6}}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18\,\mathrm{kJ\,kg^{-1}\,K^{-1}}$ ($4.18\,\mathrm{J\,g^{-1}\,K^{-1}}$)

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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 144.2	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 –