



Cambridge International AS & A Level

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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.



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/ $^{\circ}\text{C}$
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 $\text{H}_2\text{SO}_4(\text{aq})$.

..... [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 $\text{NaOH}(\text{aq})$.

..... [1]

(ii) State the formula of the aluminium-containing salt produced when Al_2O_3 reacts with $\text{H}_2\text{SO}_4(\text{aq})$.

..... [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} .



(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]



- 4 The reaction between $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$ and $\text{HCl}(\text{aq})$ is monitored at constant temperature.

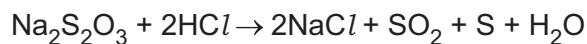


Fig. 4.1 shows how the concentration of $\text{HCl}(\text{aq})$ varies with time.

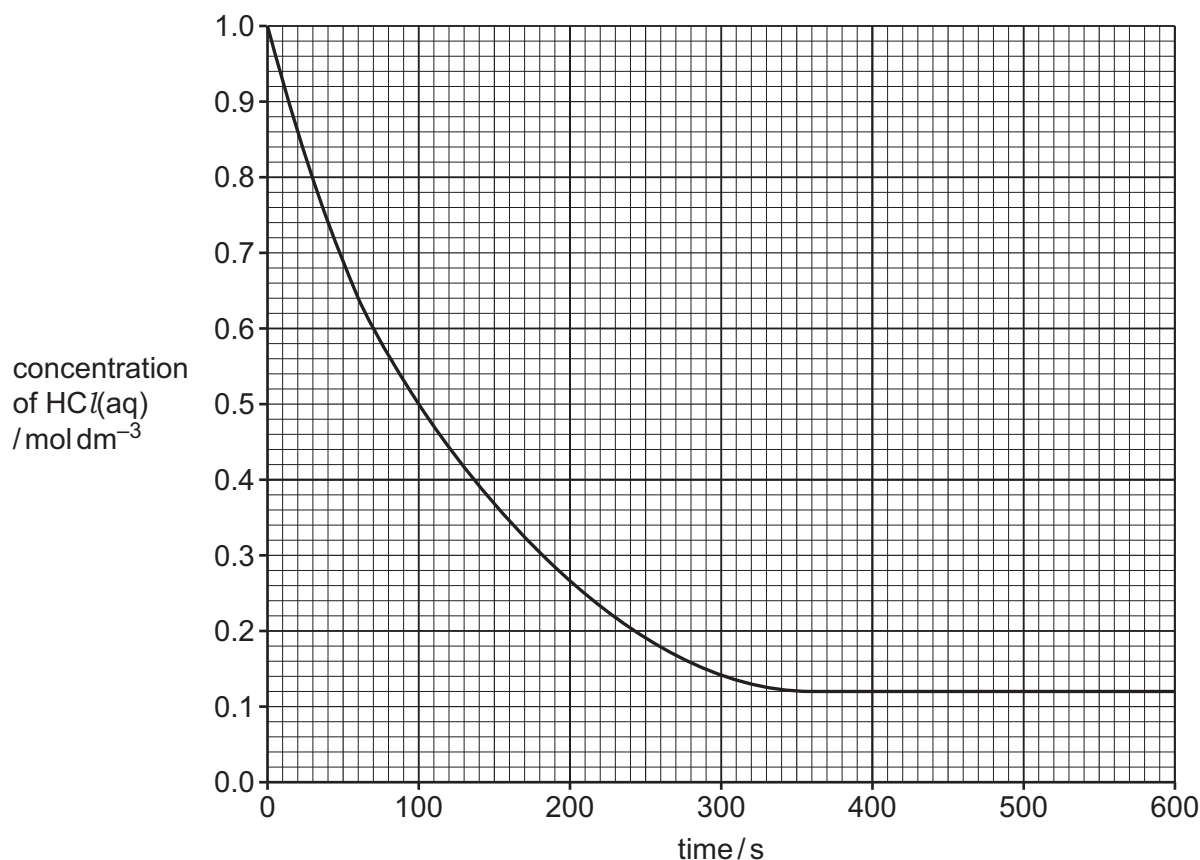


Fig. 4.1

- (a) (i) Use Fig. 4.1 to find the average rate of change of concentration of $\text{HCl}(\text{aq})$ 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 $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$ and $\text{HCl}(\text{aq})$ is repeated in a second experiment.

In this second experiment, 25.0 cm^3 of $0.050 \text{ mol dm}^{-3}$ $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$ reacts with 0.0020 mol of $\text{HCl}(\text{aq})$. 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 $\text{SO}_2(\text{g})$ produced in this reaction.

.....
 [1]

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

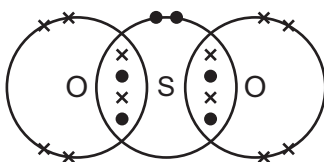


Fig. 4.2

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

shape

bond angle $^{\circ}$

[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

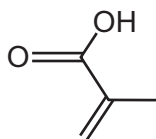


Fig. 5.1

(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**.

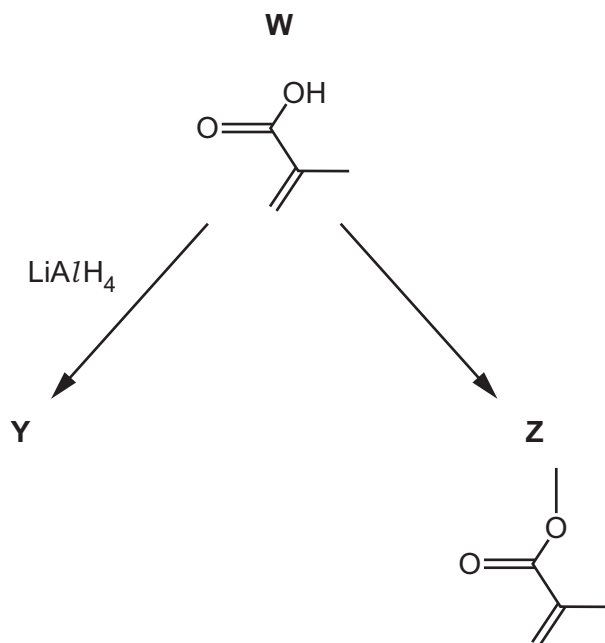


Fig. 5.2

- (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]





10

Z

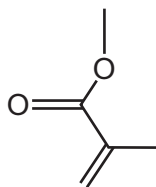


Fig. 5.3

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

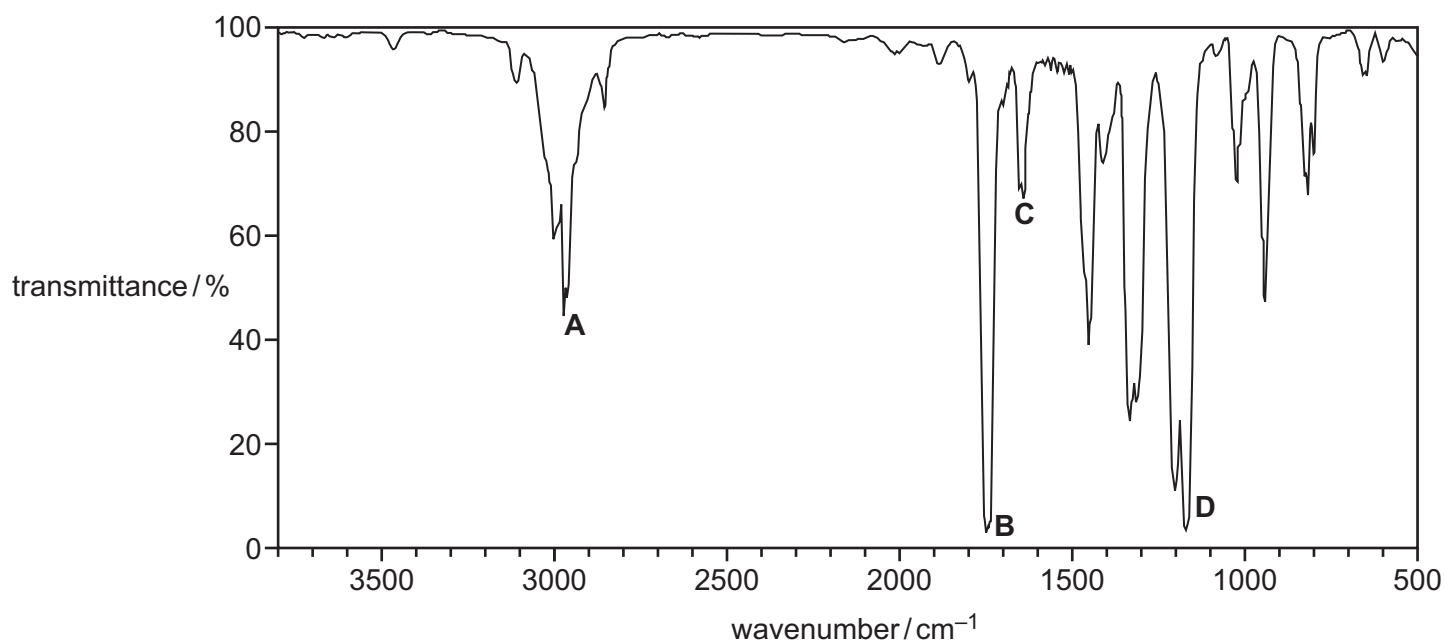


Fig. 5.4

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) HOCl reacts with $\text{CH}_2=\text{CH}_2$ to produce $\text{HOCH}_2\text{CH}_2\text{Cl}$ in an electrophilic addition reaction.

(i) Define addition reaction.

.....
 [1]

(ii) Describe how Cl_2 is used to produce HOCl .

.....
 [1]

(iii) State **one** use for HOCl .

.....
 [1]

(b) Complete Fig. 6.1 to show the mechanism for the reaction between HOCl and $\text{CH}_2=\text{CH}_2$ to produce $\text{HOCH}_2\text{CH}_2\text{Cl}$.

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

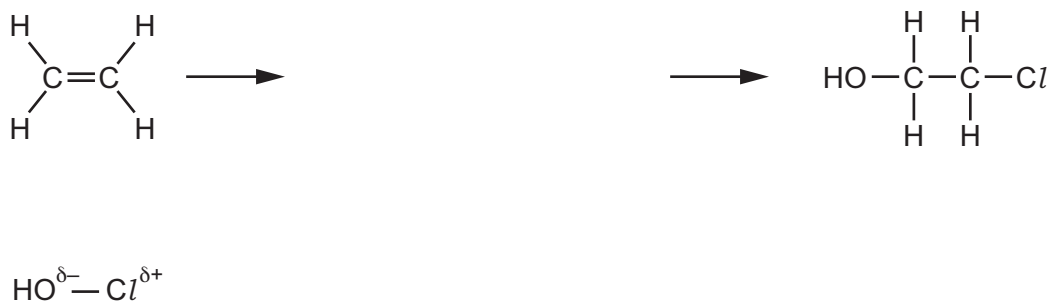


Fig. 6.1

[4]



- (c) $\text{HOCH}_2\text{CH}_2\text{Cl}$ reacts in a two-step synthesis to produce $\text{HOCH}_2\text{CH}_2\text{COOH}$, as shown in Fig. 6.2.

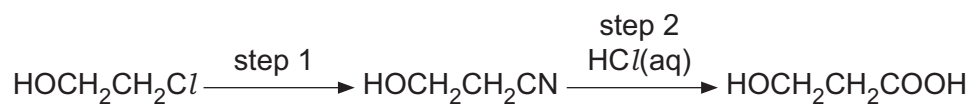


Fig. 6.2

- (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.

$\text{HOCH}_2\text{CH}_2\text{CN} + \dots\dots\dots$ [1]

[Total: 10]





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	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
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 J g ⁻¹ K ⁻¹)





The Periodic Table of Elements

Group																									
1	2													13	14	15	16	17	18						
														1 H hydrogen 1.0								2 He helium 4.0			

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	144.2	61	Pm	promethium	—	62	Sm	samarium	150.4	63	Eu	euporium	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	—

