GradeMax

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CAMBRIDGE
International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

4033427433

CHEMISTRY **9701/21**

Paper 2 AS Level Structured Questions **May/June 2026**

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. Do **not** use correction fluid or tape.
- 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.

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[Turn over

1 **(a)** **(i)** Complete the dot-and-cross diagram in Figure 1.1 to show the arrangement of outer shell electrons in a molecule of SF_6.

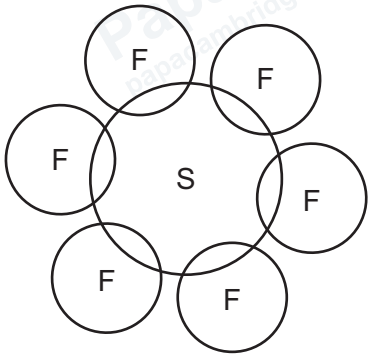

Figure 1.1

[1]

(ii) Name the shape of a molecule of SF_6.

..... [1]

(b) Table 1.1 shows information about sulfur and chlorine.

Table 1.1

element	electronic configuration	first ionisation energy / kJ mol^{-1}
sulfur	[Ne] $3s^2$ $3p^4$	1000
chlorine	[Ne] $3s^2$ $3p^5$	1260

(i) Name the orbital that contains the lowest energy electron in an atom of sulfur. Draw the shape of this orbital.

name .....

shape

[1]

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(ii) Construct an equation to represent the first ionisation energy of chlorine.

..... [1]

(iii) Explain the difference in the values of first ionisation energy of sulfur and chlorine in Table 1.1.

.....

.....

.....

.....

..... [3]

(c) A molecule of SCl_2 is polar.

(i) Predict bond angle *x* in Figure 1.2 using VSEPR theory. Explain your answer.



Figure 1.2

bond angle *x* = ...°

explanation .....

.....

.....

[3]

(ii) Show on Figure 1.3 all the dipoles present in the molecule of SCl_2.

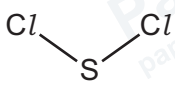

Figure 1.3

[1]

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(d) SCl_2 and H_2O both contain instantaneous dipole–induced dipole attractions and permanent dipole attractions.

(i) Complete Table 1.2.

Table 1.2

	SCl_2	H_2O
total number of electrons per molecule		10

[1]

(ii) Identify which molecule, SCl_2 or H_2O, has the stronger instantaneous dipole–induced dipole attractions. Explain your answer.

.....

..... [1]

(iii) H_2O has a greater dipole moment than SCl_2. Explain why.

.....

.....

..... [1]

(e) Compound **X** contains sulfur and chlorine only.

100.0 g of **X** contains 47.49 g of sulfur. The relative molecular mass, M_r, of **X** is 135.2.

Determine the molecular formula of **X**. Show your working.

molecular formula of **X** = ... [3]

[Total: 17]

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2 The Contact process uses sulfur to produce sulfuric acid.

stage 1 Sulfur is burned in excess air.

stage 2 $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ $\Delta H = -196\,kJ\,mol^{-1}$

stage 3 SO_3 reacts to produce H_2SO_4.

(a) Write an overall equation for stage 3.

..... [1]

(b) The reaction conditions for stage 2 include:

- using a ratio of 1 mol SO_2 to 1 mol O_2
- heat in the presence of V_2O_5.

(i) Stage 2 is repeated using a ratio of more than 1 mol SO_2 to 1 mol O_2.

Predict the effect on the percentage yield of SO_3 at equilibrium. Use Le Chatelier's Principle to explain your answer.

.....

.....

..... [1]

(ii) Explain how V_2O_5 affects the rate of reaction.

.....

.....

.....

..... [2]

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(c) $CaCO_3$ and O_2 are added to the waste gases from the Contact process before they escape. This prevents the release of SO_2 into the atmosphere.

equation 1 $2CaCO_3 + 2SO_2 + O_2 \rightarrow 2CaSO_4 + 2CO_2$

(i) State **one** environmental consequence of the release of $SO_2(g)$ into the atmosphere.

..... [1]

(ii) Use the ideal gas equation to calculate the volume of $O_2(g)$ that reacts with 0.500 mol of SO_2 at 400 °C and 101 kPa in equation 1.

Include units in your answer.

volume of $O_2(g)$ = ...

units .....

[4]

[Total: 9]

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3 Separate samples of NaCl, NaBr and NaI each react with concentrated H_2SO_4.
Table 3.1 shows the observations for each reaction.

Table 3.1

reaction	compound	observations
1	NaCl	• effervescence • steamy fumes that turn blue litmus paper red
2	NaBr	• effervescence • steamy fumes initially that turn blue litmus paper red • brown vapour • pungent smell of SO_2
3	NaI	• effervescence • steamy fumes initially that turn blue litmus paper red • purple vapour • pungent smell of SO_2 and then a rotten egg smell of H_2S

(a) (i) Write an equation for reaction 1.

..... [1]

(ii) Identify the reactant that behaves as a Brønsted–Lowry base in reaction 1.

..... [1]

(b) State the formulae of the species responsible for the brown vapour in reaction 2 and for the purple vapour in reaction 3.

brown vapour .....

purple vapour .....
[1]

(c) Explain why reaction 3 produces purple vapour.

.....

..... [1]

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(d) Complete Table 3.2.

Table 3.2

species	oxidation number of sulfur
H_2SO_4	
SO_2	
H_2S	

[2]

(e) Explain why reaction 3 produces H_2S but reaction 2 does **not** produce H_2S.

.....

..... [1]

(f) **(i)** Describe what is observed when $Ag^+(aq)$, followed by $NH_3(aq)$, are added to a sample of NaI(aq).

observation after addition of $Ag^+(aq)$ .....

observation after addition of $NH_3(aq)$ .....

[2]

(ii) Write an ionic equation for the reaction of $Ag^+(aq)$ with NaI(aq).

..... [1]

[Total: 10]

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4 **(a)** Compound **Z** is oxidised to produce organic compound **W**, $C_5H_6O_7$, by heating under reflux with an excess of acidified $Cr_2O_7^{2-}(aq)$.

Z

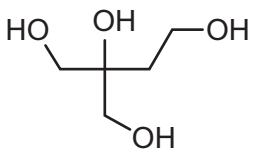

Figure 4.1

(i) Describe the colour change in this reaction.

colour of mixture at start of the reaction .....

colour of mixture after the reaction .....

[1]

(ii) The complete oxidation of 0.025 mol of **Z** requires 0.050 mol of $Cr_2O_7^{2-}(aq)$.
W is produced in this reaction.

Balance the equation for this reaction.

Z **W**

$$.....C_5H_{12}O_4 + ...Cr_2O_7^{2-} + ...H^+ \rightarrow .....C_5H_6O_7 + ...Cr^{3+} + ...H_2O$$

[1]

(b) Compound **A** is a structural isomer of **Z**.

A

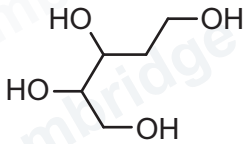

Figure 4.2

(i) Complete Table 4.1 to show what is observed when separate samples of **A** are added to each reagent. State 'none' if no reaction occurs.

Table 4.1

reagent	observation with A
Na(s)	
2,4-dinitrophenylhydrazine (2,4-DNPH)	
Fehling's reagent	none

[2]

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(ii) Suggest why Fehling's reagent does **not** react with **A** but does react with aldehyde functional groups.

.....

.....

..... [1]

(iii) Compound **A** is heated under reflux with an excess of acidified $Cr_2O_7^{2-}(aq)$ to produce organic compound **Y**.

Draw the structure of **Y**.

Y

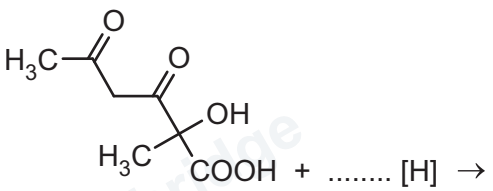
[2]

(c) Compound **B** reacts with an excess of $LiAlH_4$ to produce organic compound **C**.

Complete the equation in Figure 4.3 to show the reaction of **B** with an excess of $LiAlH_4$ to produce **C**.

[H] represents one atom of hydrogen from the reducing agent, $LiAlH_4$.

B



..... [H] →

C

+ .....

Figure 4.3

[2]

[Total: 9]

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5 Figure 5.1 describes a sequence of reactions starting with ethene to produce poly(chloroethene), PVC.

$$\text{ethene} \xrightarrow{\text{reaction 1}} \text{1,2-dichloroethane} \xrightarrow{\text{reaction 2}} \text{chloroethene} \xrightarrow{\text{reaction 3}} \text{poly(chloroethene)}$$

Figure 5.1

(a) Complete Table 5.1.

Table 5.1

compound	type of hybridisation of carbon atoms
1,2-dichloroethane	
chloroethene	

[2]

(b) In reaction 1, ethene reacts with Cl_2(g) at room temperature.
Name the mechanism for reaction 1.

..... [1]

(c) Describe what is meant by heterolytic fission of a covalent bond.

.....

..... [2]

(d) Complete Figure 5.2 to show the mechanism for the reaction of ethene with Cl_2 in reaction 1.
Include charges, dipoles, lone pairs of electrons and curly arrows, as appropriate.



Figure 5.2

[4]

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(e) When 1,2-dichloroethane is heated in reaction 2, thermal decomposition occurs. The reaction is endothermic.

State the type of reaction that occurs.

..... [1]

(f) Draw the repeat unit of poly(chloroethene).

[1]

(g) Figure 5.3 shows the mass spectrum of chloroethene.

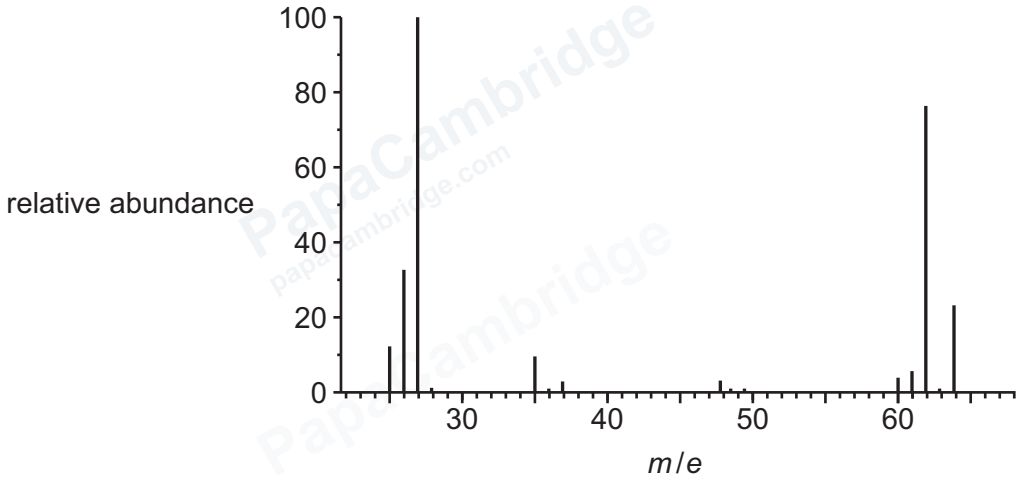

Figure 5.3

(i) Identify the species responsible for the peaks at $m/e = 64$ and $m/e = 27$.

peak at $m/e = 64$ .....

peak at $m/e = 27$ .....

[2]

(ii) Explain the difference in relative abundance of the peaks at $m/e = 62$ and $m/e = 64$.

.....

..... [2]

[Total: 15]

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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	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9	Group 10	Group 11	Group 12	Group 13	Group 14	Group 15	Group 16	Group 17	Group 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 144.2	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 –

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