GradeMax

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Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

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CHEMISTRY **9701/22**

Paper 2 AS Level Structured Questions **October/November 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.

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1 Manganese, Mn, and its compounds are widely used in many chemical reactions.

(a) Mn is usually found as a single isotope, manganese-55.

(i) Determine the number of protons, neutrons and electrons in an atom of manganese-55.

number of protons ..... neutrons ..... electrons .....
[1]

(ii) Define isotopes.

.....

..... [1]

(iii) A sample of manganese from the Moon is found to contain manganese-53 in addition to manganese-55.

State the two pieces of information needed to determine the relative atomic mass, A_r, of manganese in this sample.

1 .....

2 .....
[2]

(b) The shorthand electronic configuration of manganese is [Ar] $3d^5\ 4s^2$.

(i) Complete the full electronic configuration of manganese.

..... $3d^5\ 4s^2$ [1]

(ii) Deduce the total number of unpaired electrons in an atom of manganese.

..... [1]

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(c) Manganese(IV) oxide reacts with methanal, CH_2O, in acidic conditions to produce carbon dioxide. The movement of electrons to or from relevant species is shown in the following half-equations.

half-equation 1 $CH_2O + H_2O \rightarrow CO_2 + 4H^+ + 4e^-$

half-equation 2 $MnO_2 + 4H^+ + 2e^- \rightarrow Mn^{2+} + 2H_2O$

(i) Identify the species that is reduced in half-equation 2. Explain your answer.

.....

..... [1]

(ii) The oxidation state of carbon in methanal is 0.

Calculate the oxidation state of carbon in carbon dioxide.

..... [1]

(iii) Construct the ionic equation for the reaction of manganese(IV) oxide with methanal in acidic conditions.

..... [2]

[Total: 10]

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2 The Period 3 elements show trends in physical and chemical properties across the period.

(a) **(i)** Explain why the elements Na to A*l* are good electrical conductors.

.....

..... [1]

(ii) Explain why the elements P, S and C*l* do not conduct electricity.

.....

..... [1]

(b) Fig. 2.1 shows the variation in melting point of the Period 3 elements Si to C*l*.

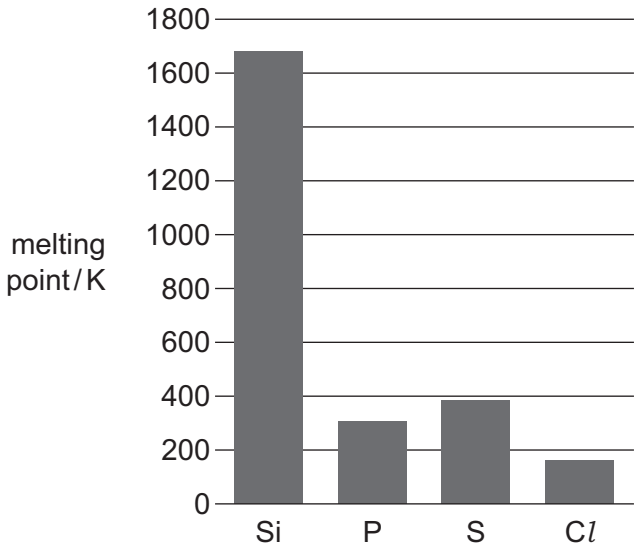


Fig. 2.1

The Period 3 elements Si to C*l* are all non-metals.

Explain why there is a large difference between the melting point of Si and the melting points of P, S and C*l*.

.....

.....

.....

..... [2]

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(c) Table 2.1 gives some information about some Period 3 chlorides.

Row B refers to the pH of the solution that forms when the Period 3 chloride is added to water.

Table 2.1

	formula of Period 3 chloride	$NaCl$	$MgCl_2$	$AlCl_3$	$SiCl_4$	PCl_5
A	oxidation number of element bonded to Cl					
B	pH of solution		6.5			
C	bonding			ionic		
D	structure			giant		

Complete Table 2.1.

You may use the following abbreviations.

I = ionic, C = covalent, M = metallic
G = giant, S = simple

[4]

(d) **(i)** Write an equation for the formation of $AlCl_3$ from its elements.

.....

..... [1]

(ii) Write an equation for the formation of H_3PO_4 from PCl_5.

..... [1]

(e) S_2Cl_2(l) reacts with Cl_2(g) in a reversible reaction to form SCl_2(l). Under certain conditions, a dynamic equilibrium is established.

$$S_2Cl_2(l) + Cl_2(g) \rightleftharpoons 2SCl_2(l) \qquad \Delta H = -41\,kJ\,mol^{-1}$$

(i) State what is meant by dynamic equilibrium.

.....

..... [1]

(ii) Identify the condition necessary to establish dynamic equilibrium.

..... [1]

(iii) $S_2Cl_2(l)$ is yellow and $SCl_2(l)$ is red.

$$S_2Cl_2(l) + Cl_2(g) \rightleftharpoons 2SCl_2(l) \qquad \Delta H = -41\,kJ\,mol^{-1}$$

State what is observed when the following changes are made to an equilibrium mixture of $S_2Cl_2(l)$ and $SCl_2(l)$.

Explain your answers.

- The equilibrium mixture is warmed gently.

  observation .....

  explanation .....

  .....

  .....

- The overall pressure of the equilibrium mixture is increased.

  observation .....

  explanation .....

  .....

  .....

[4]

(f) Aqueous $MgCl_2$ reacts with aqueous Na_2CO_3 to form a white precipitate. Upon heating, the white precipitate undergoes thermal decomposition.

(i) Construct an equation to show the reaction of aqueous $MgCl_2$ with aqueous Na_2CO_3. Use state symbols in your equation.

..... [2]

(ii) Identify the products of the thermal decomposition of the white precipitate.

..... [1]

(iii) State the trend in thermal stability of the Group 2 carbonates down the group.

..... [1]

[Total: 20]

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3 The alkanes are a homologous series of organic molecules. Alkanes are generally unreactive and are commonly used as fuels.

(a) Define homologous series.

.....

..... [2]

(b) Give two reasons to explain the general unreactivity of alkanes.

1 .....

2 .....
[2]

(c) Alkanes with low relative molecular mass, M_r, are more useful than those found in heavier crude oil fractions.

Name the process that is used to obtain alkanes with low M_r from heavier crude oil fractions.

..... [1]

(d) Hexane, C_6H_{14}, has four structural isomers.

Fig. 3.1 shows hexane and two of its structural isomers.

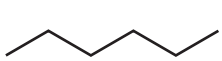
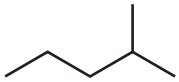
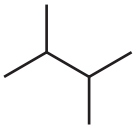
hexane	A	B	C	D
				

Fig. 3.1

(i) Complete Fig. 3.1 by drawing structures for **C** and **D**, the other two structural isomers of hexane. [2]

(ii) **A**, **B** and hexane have different boiling points.

Arrange **A**, **B** and hexane in order of increasing boiling point.

Explain your answer.

lowest ..... < ..... < ..... highest

.....

.....

.....
[3]

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(e) Hexane can be converted into compounds **E** and **F** at high temperature and pressure. Fig. 3.2 shows the reaction scheme involving hexane, **E** and **F**.

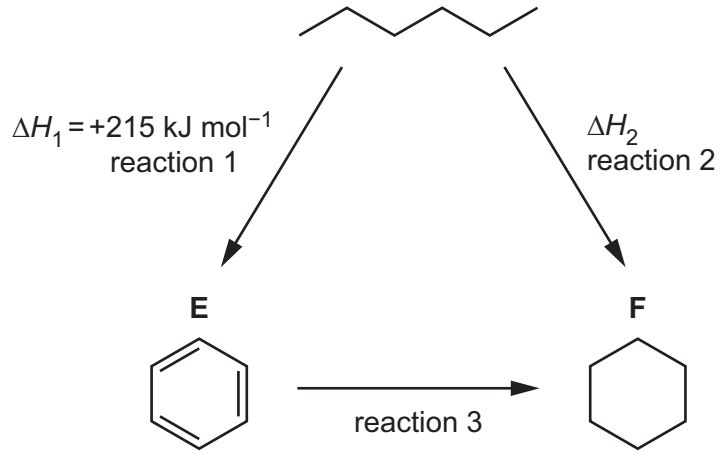


Fig. 3.2

(i) Identify a suitable reagent for reaction 3.

..... [1]

(ii) Use the data in Fig. 3.2 and in Table 3.1 to calculate the enthalpy change of reaction 2, ΔH_2.

Table 3.1

compound	enthalpy change of formation, ΔH_f / kJ mol^{-1}
	−156
	+48

ΔH_2 = ... kJ mol^{-1} [2]

(iii) Write an equation for the complete combustion of hexane.

..... [1]

[Total: 14]

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4 Fig. 4.1 shows how propane, C_3H_8, can be converted to propanoic acid, CH_3CH_2COOH.

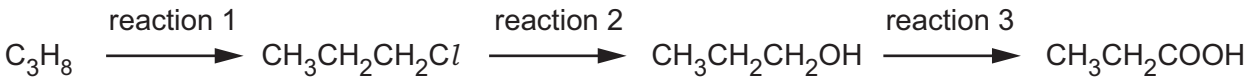


Fig. 4.1

(a) Reaction 1 in Fig. 4.1 takes place in the presence of sunlight.

$$C_3H_8 + Cl_2 \rightarrow CH_3CH_2CH_2Cl + HCl$$

The reaction takes place via initiation, propagation and termination steps.

(i) Name the mechanism shown by reaction 1.

..... [1]

(ii) Complete the mechanism for reaction 1.

Construct equations to describe the steps of the mechanism.

initiation $Cl_2 \rightarrow 2Cl\bullet$

propagation 1 .....

propagation 2 .....

termination ..... $\rightarrow CH_3CH_2CH_2Cl$

[3]

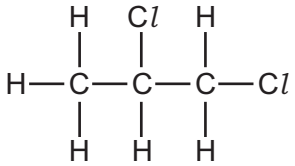
(iii) Reaction 1 is initiated by the bond fission of Cl_2.

State the type of bond fission shown in the initiation step.

..... [1]

(iv) Compound **Q** is a by-product of reaction 1.

Q



Name **Q**.

..... [1]

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(v) The molecular formula of **Q** is $C_3H_6Cl_2$.

Identify the types of structural isomerism and stereoisomerism that a molecule with molecular formula $C_3H_6Cl_2$ can show.

type of structural isomerism .....

type of stereoisomerism .....

[2]

(b) State the reagent and solvent required for reaction 2.

..... [1]

(c) Reaction 3 takes place when $CH_3CH_2CH_2OH$ is heated under reflux with acidified potassium dichromate(VI) solution.

(i) State the colour change that takes place in the reaction mixture.

..... [1]

(ii) Construct an equation to represent reaction 3. Use [O] to represent an atom of oxygen from the oxidising agent.

..... [1]

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(d) CH_3CH_2COOH reacts with an unsaturated alcohol **R** to form unsaturated ester **S**.

(i) State the **type** of reaction that forms **S**.

..... [1]

(ii) The infrared spectrum of **S** is shown in Fig. 4.2.

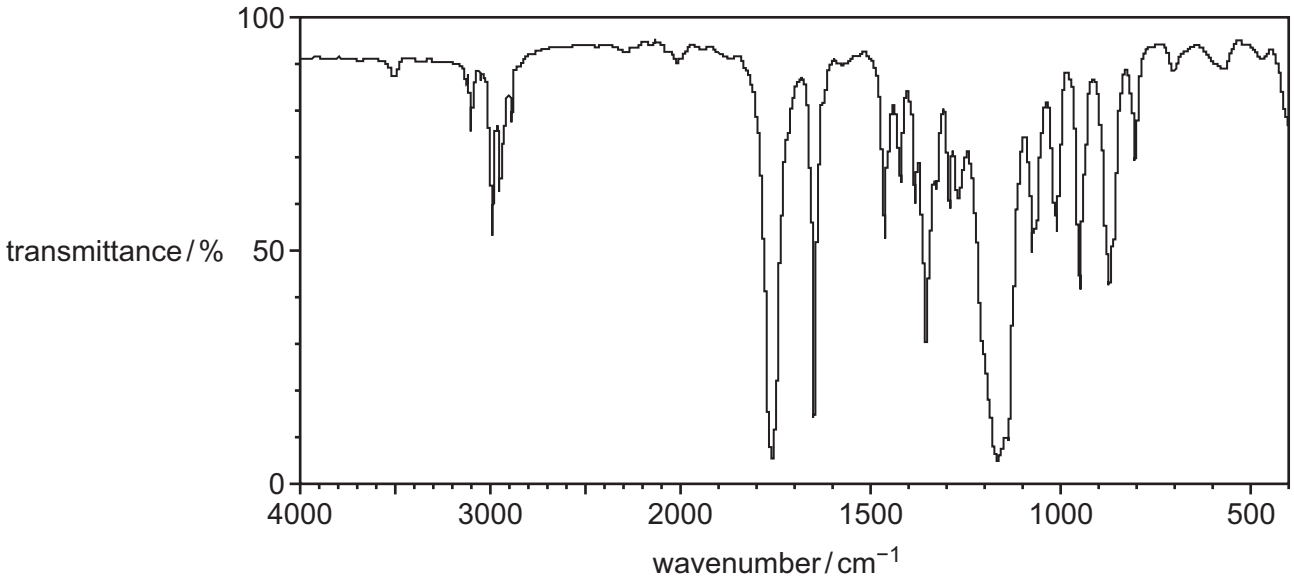


Fig. 4.2

Three absorptions in the infrared spectrum in Fig. 4.2 confirm that **S** is an ester and is unsaturated.

- Write **1**, **2** or **3** on Fig. 4.2 against each of these three absorptions.
- Complete Table 4.1 to show which bond is responsible for each absorption that you have identified in Fig. 4.2.

Table 4.1

absorption	**1**	**2**	**3**
bond responsible			

[3]

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Table 4.2

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

(iii) The mass spectrum of **S** shows the following peaks.

Table 4.3

peak	relative abundance
M^+	4.7
$[M+1]^+$	0.31

Use Table 4.3 to calculate the number of carbon atoms in **S**.

number of carbon atoms in **S** = ... [1]

[Total: 16]

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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	$L = 6.02 \times 10^{23}\,\text{mol}^{-1}$
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	$c = 4.18\,\text{kJ kg}^{-1}\,\text{K}^{-1}$ ($4.18\,\text{J g}^{-1}\,\text{K}^{-1}$)

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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	3	4	5	6	7	8	9	10	11	12	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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