* 0000800000001 *

Cambridge Assessment
International Education

Cambridge International AS & A Level

CANDIDATE NAME			
CENTRE NUMBER		CANDIDATE NUMBER	

8361971631

CHEMISTRY **9701/22**

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 (WW/SW) 339915/3

[Turn over

1 **(a)** Diamond and graphite are both crystalline solids made from carbon atoms. Graphite conducts electricity. Diamond does **not** conduct electricity.

(i) Name the type of lattice structure present in the crystalline solids diamond and graphite.

.... [1]

(ii) Explain how graphite conducts electricity.

....

.... [1]

(iii) Explain why diamond does **not** conduct electricity.

....

.... [1]

(b) Separate samples of phosphorus(V) chloride and silicon(IV) chloride are each added to an excess of cold water.

(i) Write an equation for each reaction.

....

.... [2]

(ii) Describe the appearance of phosphorus(V) chloride and silicon(IV) chloride at room temperature.

phosphorus(V) chloride ....

silicon(IV) chloride ....
[2]

(iii) Compare the appearance of the mixtures produced when each reaction is complete.

....

.... [2]

(c) Some oxides are amphoteric.

(i) Describe what is meant by amphoteric.

....

.... [1]

(ii) Identify the formula of a Period 3 oxide that is amphoteric.

.... [1]

(d) The melting points of different oxides are shown in Table 1.1.

Table 1.1

oxide	melting point / °C	force of attraction broken during melting
SO_2	–73	
H_2O	0	
SiO_2	1610	
Na_2O	1132	
MgO	2852	

(i) Complete Table 1.1 by identifying the strongest force of attraction in each oxide that is broken during melting. Use the abbreviations below.

i.d. = instantaneous dipole–induced dipole
p.d. = permanent dipole–permanent dipole
H = hydrogen bond
C = covalent bond
I = ionic bond

[3]

(ii) A student suggests the following hypothesis.

The stronger the covalent bond between atoms in non-metal oxides, the higher the melting point.

Use Table 1.1 to deduce if this hypothesis is true or false or if there is **not** enough information to make a conclusion. Explain your answer.

....

....

.... [2]

[Total: 16]

2 A sample of iron contains three different isotopes and has a relative atomic mass, A_r, of 55.8.

(a) **(i)** Define relative atomic mass.

....

....

.... [2]

(ii) Table 2.1 shows the abundances of two of the isotopes present in the sample of iron.

Table 2.1

isotope	relative isotopic mass	abundance / %
^{54}Fe	53.9	6.0
^{56}Fe	55.9	91.9

Use Table 2.1 to calculate the relative isotopic mass of the third isotope of iron in the sample. Show your working.

relative isotopic mass = ... [2]

(b) Deduce the number of pairs of electrons in the 3d sub-shell in an iron(II) ion.

.... [1]

(c) Sketch the shape of the lowest energy orbital in the shell with principal quantum number $n = 2$.

[1]

(d) Complete Table 2.2 to show information about particles in one ion of $^{56}Fe^{3+}$.

Table 2.2

particle	number of particles present in one ion of $^{56}Fe^{3+}$
electrons	
	30

[2]

(e) The atomic radius of iron is 1.26×10^{-10} m.

Suggest the change to the radius, if any, after an iron atom reacts to produce an Fe^{3+} ion. Explain your answer.

....

....

....

.... [2]

[Total: 10]

3 **(a)** C_3H_6 reacts with HBr(g) in an addition reaction.

(i) Define addition reaction.

....

.... [1]

(ii) Complete Fig. 3.1 to show the mechanism for the addition reaction between C_3H_6 and HBr to produce 2-bromopropane. Include charges, dipoles, lone pairs of electrons and curly arrows, as appropriate.

Fig. 3.1

[4]

(iii) Explain why the major product of this reaction is 2-bromopropane rather than 1-bromopropane.

....

....

.... [2]

(b) $H_2(g)$ and nickel are added to alkene **X**. Fig. 3.2 shows how the concentration of **X** changes with time.

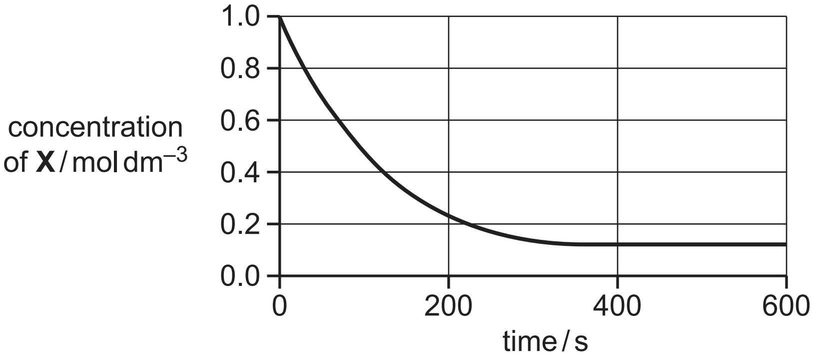

Fig. 3.2

(i) Use Fig. 3.2 to identify the limiting reagent in this reaction. Explain your answer.

....

.... [1]

(ii) Use Fig. 3.2 to describe how the gradient changes as the reaction proceeds. State what this shows about the rate during this reaction.

....

....

.... [1]

(c) Hydrocarbon **Y** contains two C=C groups. There are no other functional groups present.

Y reacts with an excess of $H_2(g)$ to produce hexane, C_6H_{14}.

Table 3.1

bond	energy / $kJ\,mol^{-1}$
C−C	350
C=C	610
C≡C	840
H−H	436
C−H	410

Use Table 3.1 to calculate the enthalpy change per mole of C_6H_{14} produced in this reaction.

enthalpy change = ... $kJ\,mol^{-1}$ [2]

(d) Hydrocarbon **Y** reacts with H_2(g).

Fig. 3.3 shows the distribution of energies of H_2(g) at temperature T.

Area **A** represents the number of molecules with energy greater than or equal to the activation energy, E_A, at temperature T.

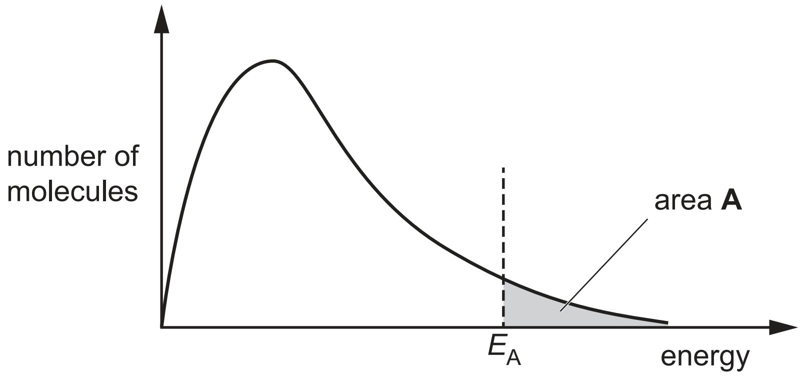

Fig. 3.3

(i) Annotate Fig. 3.3 to show the effect of adding nickel to **Y** and H_2(g) at temperature T. [1]

(ii) Area **B** (**not** labelled on Fig. 3.3) represents the number of molecules with energy greater than or equal to the activation energy when nickel is added at temperature T.

State the difference, if any, between areas **A** and **B**. Explain the significance of your answer on the rate of hydrogenation of **Y**. Give your answer in terms of collisions.

....

....

.... [2]

(e) Alkene **Z** contains two C=C bonds. **Z** reacts with an excess of hot concentrated acidified $KMnO_4$ to produce **only** CH_3COCH_3, $HOOCCH_2COOH$, CO_2 and H_2O.

Suggest the structure of **Z**.

[2]

[Total: 16]

4 **(a)** Propanoic acid, CH_3CH_2COOH, reacts with reducing agent **Q** to produce propan-1-ol, $CH_3CH_2CH_2OH$.

(i) Suggest the formula of reducing agent **Q**.

.... [1]

(ii) Complete the equation to show the reduction of propanoic acid to propan-1-ol.
Use [H] to represent one atom of hydrogen from **Q**.

......CH_3CH_2COOH + ...[H] → .... [1]

(b) Propan-1-ol is converted to compound **T** in a three-step synthesis.

In step 1, $SOCl_2$ is added to propan-1-ol to produce compound **E**.

In step 2, **E** reacts with a suitable reagent to produce butanenitrile.

In step 3, butanenitrile is heated with NaOH(aq).

(i) Name the type of reaction that occurs in step 1.

.... [1]

(ii) Identify the reagent and conditions required in step 2.

.... [1]

(iii) Construct an equation to describe the reaction of butanenitrile with NaOH(aq) in step 3.

.... [2]

(iv) Name the type of reaction that occurs in step 3.

.... [1]

(c) Compounds **A**, **B** and **C** belong to the alcohol homologous series. Each molecule of **A**, **B** and **C** contains four saturated carbon atoms.

(i) Identify the type of hybridisation shown in the saturated carbon atoms of all alcohols.

.... [1]

(ii) Identify the gas produced when Na(s) is added to separate samples of each alcohol.

.... [1]

(iii) Describe the role of Na(s) when it reacts with alcohols.

.... [1]

(d) Table 4.1 shows the results of two tests on separate samples of **A**, **B** and **C**.

Table 4.1

compound	heat under reflux with acidified $K_2Cr_2O_7$	warm with alkaline $I_2(aq)$
A	remains orange	no visible change
B	orange to green	no visible change
C	orange to green	pale yellow precipitate

(i) Deduce the structure of **A**.

[1]

(ii) Deduce a possible name for **B**.

.... [1]

(iii) Deduce the identity of **C**.

.... [1]

[Total: 13]

5 The structure of vitamin C is shown in Fig. 5.1.

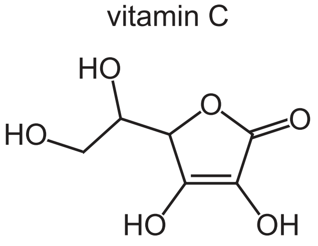

Fig. 5.1

(a) Deduce the empirical formula of vitamin C.

.... [1]

(b) The mass of vitamin C present in 150.0 g of lemon is found in an experiment.

stage 1 All the vitamin C in 150.0 g of lemon is extracted and dissolved in water to make 100.0 cm^3 of solution **L**.

stage 2 A 25.0 cm^3 sample of solution **L** is titrated with 5.00×10^{-3} mol dm^{-3} $I_2(aq)$.

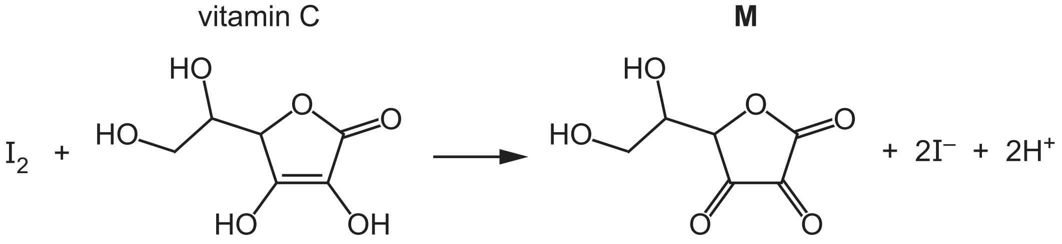

Fig. 5.2

Exactly 36.65 cm^3 of $I_2(aq)$ reacts with the 25.0 cm^3 sample of solution **L**.

[M_r: vitamin C, 176]

(i) Calculate the amount, in mol, of $I_2(aq)$ added in the titration.

amount of $I_2(aq)$ = ... mol [1]

(ii) Use your answer to **(b)(i)** to calculate the percentage by mass of vitamin C present in 150.0 g of lemon.

(If you were unable to calculate a value for the amount of I_2(aq) in **(b)(i)**, use the value 7.65×10^{-4} mol. This is **not** the correct value.)

percentage by mass = ...% [2]

(iii) The progress of the reaction of vitamin C with I_2(aq) to produce **M** is monitored using infrared spectroscopy.

Table 5.1 indicates the presence of some absorptions in the infrared spectrum of vitamin C. Complete Table 5.1 to predict which of these absorptions, if any, are present in the infrared spectrum of **M**.

Table 5.1

absorption / cm^{-1}	present in spectrum of vitamin C	present in spectrum of **M**
1500–1680	✓	
2850–2950	✓	
3200–3650	✓	

[1]

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

[Total: 5]

BLANK PAGE

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	$c = 4.18\,\text{kJ kg}^{-1}\,\text{K}^{-1}$ ($4.18\,\text{J g}^{-1}\,\text{K}^{-1}$)

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 –