Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME	
CENTRE NUMBER	
CANDIDATE NUMBER	

3508507409

CHEMISTRY **9701/23**

Paper 2 AS Level Structured Questions **May/June 2023**

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 **20** pages. Any blank pages are indicated.

DC (LK/JG) 308408/5

1 Copper is used in electrical equipment. It has a melting point of 1085 °C.

(a) (i) Identify the lattice structure of copper.

.... [1]

(ii) Draw a labelled diagram to show the bonding present in copper.

[1]

(b) The relative isotopic masses and natural abundances of the two isotopes in a sample of copper are shown in Table 1.1.

Table 1.1

isotope	relative isotopic mass	% abundance
^{63}Cu	62.930	69.15
^{65}Cu	64.928	30.85

(i) Define the unified atomic mass unit.

....

.... [1]

(ii) Define relative atomic mass, A_r, in terms of the unified atomic mass unit.

....

.... [1]

(iii) Calculate the relative atomic mass, A_r, of copper in this sample using the data in Table 1.1.

Show your working.

A_r = ... [1]

(c) The mass spectrum of a sample of pure copper is shown in Fig. 1.1.

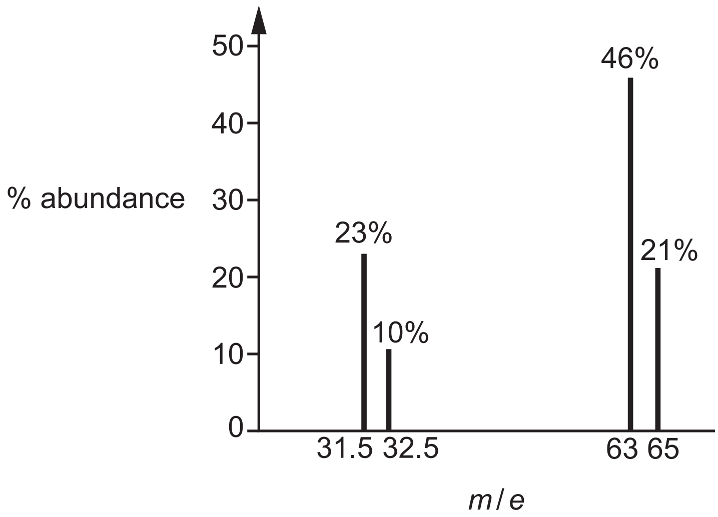

Fig. 1.1

Identify the ion with an abundance of 23% in the sample.

.... [1]

(d) When KI(aq) is added to $CuSO_4$(aq) the blue-coloured solution turns brown and a white precipitate of CuI(s) is seen.

The reaction between copper ions and iodide forms only two products.

(i) Complete the equation for this reaction.

...........Cu^{2+} + ...I^- $\rightarrow$ ....CuI + ...

[1]

(ii) Identify the oxidising agent in this reaction. Explain your answer in terms of electron transfer.

....

.... [1]

(iii) State the full electronic configuration of Cu^{2+}.

.... [1]

[Total: 9]

2 (a) The reaction of pure aluminium is only observed if the aluminium oxide layer is removed first. When pure aluminium is added to cold water, bubbles of gas are seen.

(i) State **one** property of aluminium oxide that explains why an aluminium object does **not** react with cold water until the aluminium oxide layer is removed.

.... [1]

(ii) Write an equation, with state symbols, for the reaction of aluminium oxide with an excess of NaOH(aq).

.... [2]

(iii) Name **one** other Period 3 element that also produces bubbles of gas when added to cold water.

.... [1]

(b) Aluminium nitrate is a white soluble salt. On heating aluminium nitrate, thermal decomposition occurs and a brown gas is seen.

State the formula of the salt of another element in Period 3 which also decomposes on heating to produce a brown gas.

.... [1]

(c) Aluminium chloride and phosphorus chloride are both white solids.

(i) State the maximum oxidation number of aluminium and of phosphorus in these solid chloride salts.

maximum oxidation number of aluminium ....

maximum oxidation number of phosphorus ....

[1]

(ii) State why the maximum oxidation number of aluminium is different from that of phosphorus.

....

.... [1]

(iii) Write an equation for the reaction of solid phosphorus chloride and excess water.

.... [1]

(iv) Name the type of reaction that occurs when aluminium chloride is added to water.

.... [1]

(v) Explain why the solution produced after aluminium chloride is added to water has a pH of 1–2.

....

.... [1]

[Total: 10]

3 A neutralisation reaction occurs when NaOH(aq) is added to H_2SO_4(aq).

equation 1 $2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$

(a) Define enthalpy change of neutralisation, ΔH_{neut}.

....

....

.... [2]

(b) In an experiment, $50.0\,cm^3$ of $2.00\,mol\,dm^{-3}$ NaOH(aq) is added to $60.0\,cm^3$ of $1.00\,mol\,dm^{-3}$ H_2SO_4(aq) in a polystyrene cup and stirred. Both solutions have a temperature of 21.4 °C before mixing. The maximum temperature of the mixture is measured.

(i) Use equation 1 to calculate the amount, in mol, of H_2SO_4(aq) that is neutralised in the experiment.

amount of H_2SO_4 neutralised = ... mol [1]

(ii) Calculate the theoretical maximum temperature of the mixture in this experiment.

Assume that:

- enthalpy change of neutralisation, ΔH_{neut}, of NaOH(aq) and H_2SO_4(aq) is $-57.1\,kJ\,mol^{-1}$
- full dissociation of H_2SO_4(aq) occurs
- the specific heat capacity of the final solution is $4.18\,J\,g^{-1}\,K^{-1}$
- $1.00\,cm^3$ of the final solution has a mass of 1.00 g
- there is no heat loss to the surroundings
- the experiment takes place at constant pressure.

Show your working.

theoretical maximum temperature = ... °C [3]

(c) The enthalpy change of neutralisation of $CH_3COOH(aq)$ and NaOH(aq) is –55.2 kJ mol^{-1}.

(i) Complete the equation for the reaction.

.........CH_3COOH + ...NaOH → .... [1]

(ii) Values for the enthalpy change of neutralisation, ΔH_{neut}, are shown in Table 3.1.

Table 3.1

reagents	ΔH_{neut} / kJ mol^{-1}
NaOH + HCl	–57.1
NaOH + CH_3COOH	–55.2

Suggest why the value for ΔH_{neut} of the weak acid, CH_3COOH, reacting with NaOH is different to the value obtained using the strong acid, HCl. Assume that the values are determined under the same conditions.

....

.... [1]

[Total: 8]

4 **(a)** Hydrogen chloride gas is made in the laboratory by adding concentrated sulfuric acid to potassium chloride.

(i) Construct an equation for this reaction.

.... [1]

(ii) Explain why hydrogen iodide is **not** prepared by adding concentrated sulfuric acid to sodium iodide.

....

.... [2]

(b) A sample of HI(g) is added to a $2.00\,dm^3$ sealed vessel at 764 K and allowed to reach equilibrium.

reaction 1 $\quad 2HI(g) \rightleftharpoons H_2(g) + I_2(g) \quad K_c = 0.0217$ at 764 K

At equilibrium the mixture contains 1.70 mol of HI(g).

(i) State **one** difference in the appearance of the initial reaction mixture compared to the mixture at equilibrium.

....

.... [1]

(ii) Deduce the expression for equilibrium constant K_c for reaction 1.

K_c =

[1]

(iii) Calculate the concentration of I_2 present in the reaction mixture at equilibrium.
Show your working.

concentration of I_2 = ... $mol\,dm^{-3}$ [3]

(c) The experiment is repeated at 500 K. The value of K_c under these conditions is 0.00625.

(i) Describe the difference in the composition of the equilibrium mixture at 500 K compared to 764 K.

....

.... [1]

(ii) Use Le Chatelier's principle to deduce whether the decomposition of HI(g) is endothermic or exothermic. Explain your answer.

....

....

.... [1]

[Total: 10]

5 **Y** is formed from **X** in a single-step reaction, as shown in Fig. 5.1.

Fig. 5.1

(a) Deduce the empirical formula of **Y**.

.... [1]

(b) The formation of **Y** from **X** requires the addition of a suitable reducing agent.

(i) Construct an equation using molecular formulae and [H] for the reaction in Fig. 5.1. Use [H] to represent one atom of hydrogen from the reducing agent.

.... [1]

(ii) Identify a suitable non-gaseous reducing agent for the formation of **Y** from **X**.

.... [1]

(c) Complete Table 5.1 to show the number of sp^2 and sp^3 hybridised carbon atoms in a molecule of **X**.

Table 5.1

type of hybridisation	sp^2	sp^3
number of carbon atoms in **X**		

[2]

(d) Complete Table 5.2 with the expected observations that occur when the reagents shown are added to separate solutions of **X** and **Y**. Do **not** refer to temperature changes in your answer.

Table 5.2

reagent	observation on addition to **X**	observation on addition to **Y**
aqueous sodium carbonate		
2,4-dinitrophenylhydrazine (2,4-DNPH reagent)		
alkaline aqueous iodine		

[3]

[Total: 8]

6 Compound **W**, CH_2=CHCN, is used to make an addition polymer which is present in carbon fibres.

(a) Draw **one** repeat unit of the addition polymer of **W**.

[1]

(b) CH_3CHO is used in a two-step synthetic route to form **W**, as shown in Fig. 6.1.
In step 1, CH_3CHO is heated with HCN in the presence of KCN.

$$CH_3CHO \xrightarrow{\text{step 1}} CH_3CH(OH)CN \xrightarrow{\text{step 2}} \overset{\textbf{W}}{CH_2{=}CHCN}$$

Fig. 6.1

(i) Name the mechanism for the reaction in step 1 in Fig. 6.1.

.... [1]

(ii) Complete Fig. 6.2 to show the mechanism for the reaction in step 1.
Include all products, charges, dipoles, lone pairs of electrons and curly arrows, as appropriate.

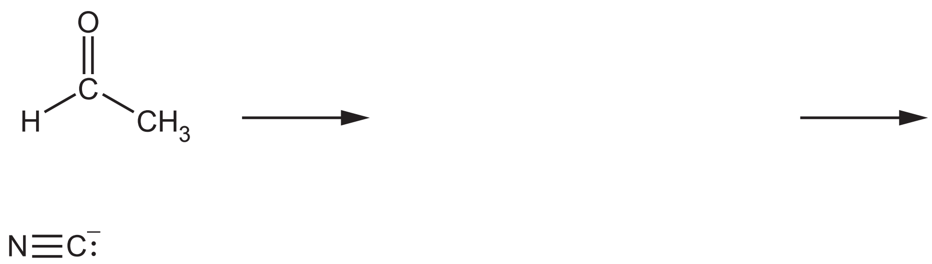

Fig. 6.2

[3]

(iii) Suggest a suitable reagent and conditions for step 2 in Fig. 6.1.

.... [1]

(iv) Fig. 6.3 shows the infrared spectrum of **W**, CH_2=CHCN.

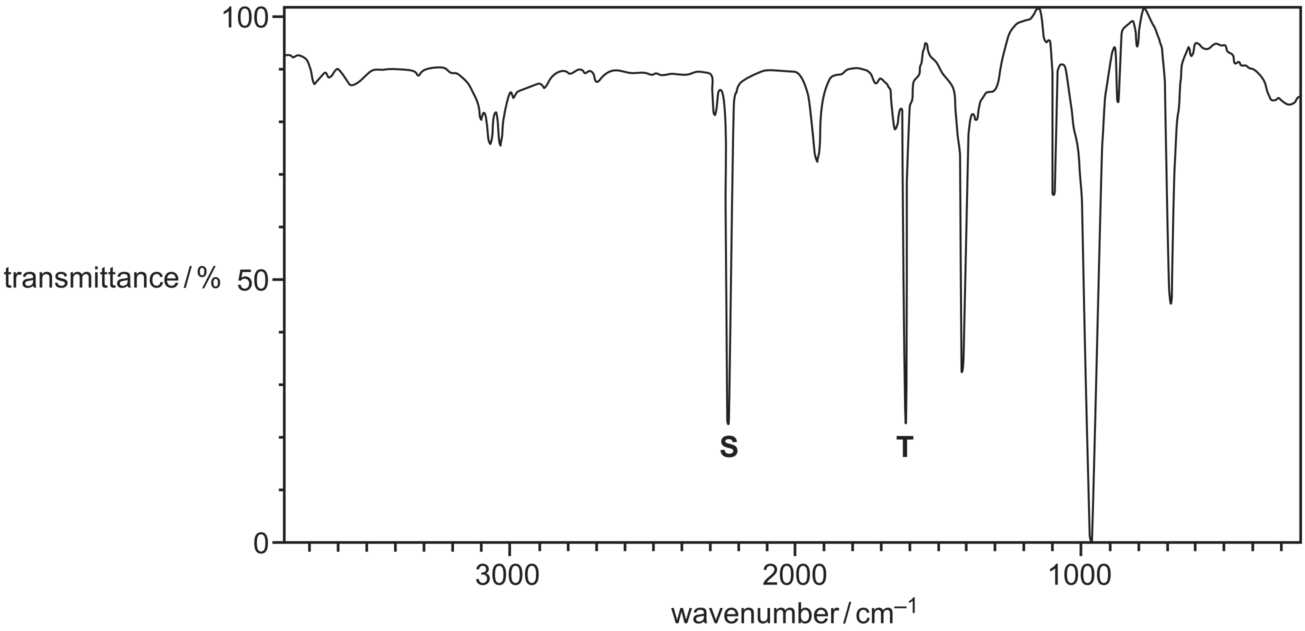

Fig. 6.3

Table 6.1

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 3200–3600

Use Table 6.1 to identify the bonds responsible for the absorptions marked **S** and **T** on Fig. 6.3.

S ....

T ....

[1]

(c) Molecules of **W**, CH_2=CHCN, do **not** show stereoisomerism.

(i) Describe stereoisomerism.

....

.... [1]

(ii) Describe the **two** essential features of an alkene molecule that cause it to show geometrical stereoisomerism.

....

.... [2]

(d) Molecules of CH_3CH(OH)CN exist as a pair of optical isomers.

Draw three-dimensional diagrams in the boxes to show the optical isomers of CH_3CH(OH)CN.

isomer 1	isomer 2

[1]

(e) Propanenitrile is heated with hydrogen gas and a platinum catalyst. The only product is propylamine.

Construct an equation for this reaction.

.... [1]

(f) Propylamine can also be formed in a two-step synthesis from propan-1-ol, as shown in Fig. 6.4.

$$CH_3CH_2CH_2OH \xrightarrow[SOCl_2]{\text{step 1}} CH_3CH_2CH_2Cl \xrightarrow{\text{step 2}} CH_3CH_2CH_2NH_2$$

Fig. 6.4

(i) Name the type of reaction in step 1 in Fig. 6.4.

.... [1]

(ii) Identify the reagent and conditions for step 2 in Fig. 6.4.

....

.... [2]

[Total: 15]

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Important values, constants and standards

molar gas constant	$R = 8.31\,J\,K^{-1}\,mol^{-1}$
Faraday constant	$F = 9.65 \times 10^{4}\,C\,mol^{-1}$
Avogadro constant	$L = 6.022 \times 10^{23}\,mol^{-1}$
electronic charge	$e = -1.60 \times 10^{-19}\,C$
molar volume of gas	$V_m = 22.4\,dm^3\,mol^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0\,dm^3\,mol^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14}\,mol^2\,dm^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18\,kJ\,kg^{-1}\,K^{-1}$ ($4.18\,J\,g^{-1}\,K^{-1}$)

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 144.4	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 –