Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

CHEMISTRY **9701/24**

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 (PQ) 357310

[Turn over

1 Elements in Period 3 of the Periodic Table show trends in their properties.

(a) Complete Table 1.1 by identifying the lattice structures of the crystalline solids of Mg, Si and P.

Table 1.1

element	Mg	Si	P
lattice structure in crystalline solid			

[3]

(b) The relative electrical conductivities of the Period 3 elements are shown in Fig. 1.1.

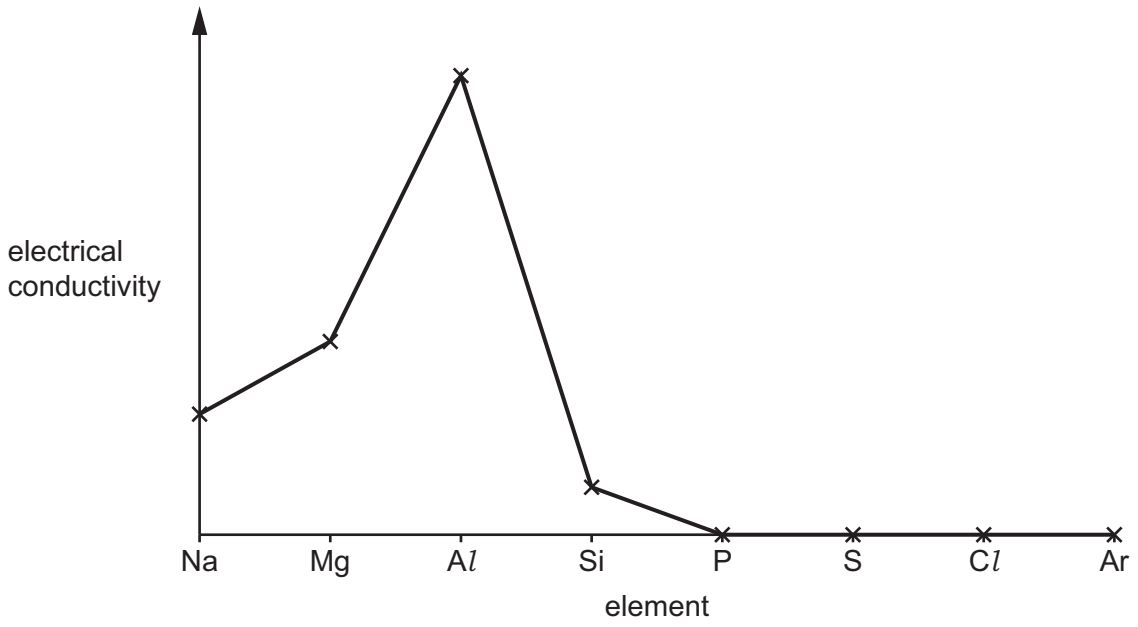

Fig. 1.1

Explain why there is an increase in conductivity from Na to Al and why P, S and Cl are non-conductors of electricity.

.....

.....

.....

.....

..... [2]

(c) The **third** ionisation energies of the Period 3 elements are shown in Fig. 1.2.

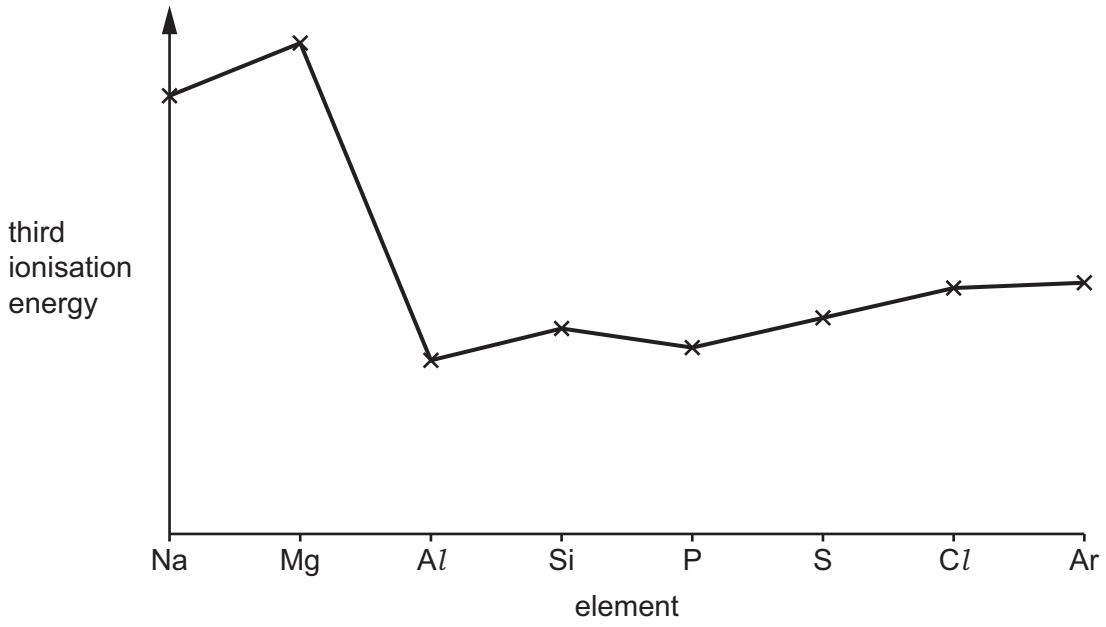

Fig. 1.2

(i) Write an equation, including state symbols, to represent the **third** ionisation energy of argon.

..... [2]

(ii) The differences in the values for third ionisation energy shown in Fig. 1.2 are due to differences in the strength of attraction between the nucleus and the outer electron of each ion.

State **two** factors that affect the strength of attraction between the nucleus and the outer electron.

1 .....

2 .....

[2]

(iii) Use Fig. 1.2 to suggest the most significant factor that determines the size of attraction between the nucleus and the outer electron. Explain your answer.

.....

.....

..... [2]

(iv) In the third ionisation energy of argon, the ion produced has the electronic configuration $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$.

Complete Fig. 1.3 to show the arrangement of electrons in the orbitals of this ion.

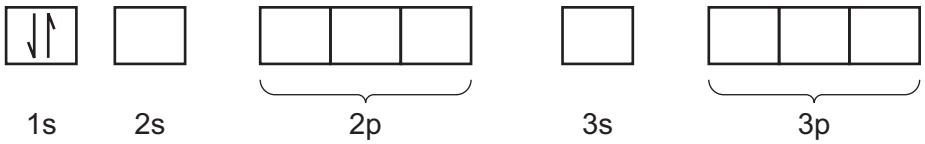

Fig. 1.3

[1]

(d) Most Period 3 elements react with oxygen to form oxides.

(i) Write an equation for the reaction of phosphorus with oxygen.

..... [1]

(ii) Write an equation for the reaction of aluminium oxide with an excess of aqueous sodium hydroxide.

..... [1]

[Total: 14]

2 **(a)** Fig. 2.1 shows the covalent bonds and lone pairs of electrons in a molecule of SCl_2.

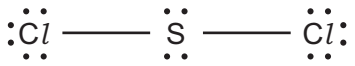

Fig. 2.1

(i) Use VSEPR theory to predict the shape of a molecule of SCl_2.

..... [1]

(ii) Predict the bond angle in a molecule of SCl_2.

..... ° [1]

(b) SCl_2 is a red liquid that reacts with water.

$$2SCl_2(l) + 3H_2O(l) \rightarrow H_2SO_3(aq) + S(s) + 4HCl(aq)$$

(i) Describe **two** observations, other than temperature change, that are made when an excess of water is added to SCl_2.

.....

..... [2]

(ii) When SCl_2 reacts with water, the SCl_2 is broken down and a disproportionation reaction occurs.

State the oxidation numbers of sulfur in SCl_2 and H_2SO_3.

oxidation number of S in SCl_2 .....

oxidation number of S in H_2SO_3 .....
[2]

(iii) State the general name to describe the type of reaction that occurs when a substance is broken down by water.

..... [1]

[Total: 7]

3 $H_2(g)$ and $I_2(g)$ react to form HI(g) in a reversible reaction, as shown in equation 1.

equation 1 $\quad H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

In three separate experiments, a student combines different amounts of two or more of the gases from equation 1. In each experiment, the gases are left to reach equilibrium at a given temperature.

(a) In experiment 1, $H_2(g)$ and $I_2(g)$ are combined.

Water is then added to the equilibrium mixture to produce 1.00 dm^3 of solution **A**.

The amount of $I_2(aq)$ present in 1.00 dm^3 of solution **A** is found by titration with $Na_2S_2O_3(aq)$.

Exactly 32.90 cm^3 of 0.200 mol dm^{-3} $Na_2S_2O_3$ reacts with all of the I_2 in a 25.0 cm^3 sample of solution **A**.

$$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$

(i) Calculate the amount, in mol, of $S_2O_3^{2-}$ that reacts in the titration.

amount of $S_2O_3^{2-}$ = ... mol [1]

(ii) Use your answer to **(a)(i)** to calculate the amount, in mol, of I_2 present in 1.00 dm^3 of solution **A**.

(If you were unable to obtain an answer in **(a)(i)**, then use 9.42×10^{-3} mol. This is **not** the correct answer.)

amount of I_2 in 1.00 dm^3 of solution **A** = ... mol [2]

(b) In experiment 2, 0.100 mol of $H_2(g)$, 0.200 mol of $I_2(g)$ and 0.300 mol of HI(g) are combined.

At equilibrium 0.154 mol of I_2 is present.

Calculate the amounts, in mol, of H_2 and HI in the equilibrium mixture produced in experiment 2.

amount of H_2 in equilibrium mixture = ... mol

amount of HI in equilibrium mixture = ... mol [3]

(c) In experiment 3, 0.0772 mol of H_2 and 0.0986 mol of I_2 are present in an equilibrium mixture at 298 K.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad K_c = 7.94 \times 10^2$$

Use the equilibrium constant, K_c, to calculate the amount, in mol, of HI present in the equilibrium mixture in experiment 3.

amount of HI in equilibrium mixture = ... mol [1]

(d) The value of K_c for the dissociation of HC*l* at 298 K is 5.50×10^{-34}.

$$2HCl(g) \rightleftharpoons H_2(g) + Cl_2(g) \qquad K_c = 5.50 \times 10^{-34}$$

(i) Define covalent bond.

.....

..... [1]

(ii) Describe and explain the relative thermal stabilities of the hydrogen halides HC*l* and HI.

.....

.....

..... [2]

(iii) Use the data given in **(c)** and **(d)** to suggest a value for the equilibrium constant for the **dissociation** of HBr(g) at 298 K.

..... [1]

[Total: 11]

4 The skeletal formula of **E** is shown in Fig. 4.1.

E

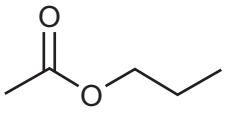

Fig. 4.1

(a) State the molecular formula of **E**.

..... [1]

(b) Name **E**.

..... [1]

(c) **E** is made when a carboxylic acid and an alcohol react together.

(i) Name the type of reaction that takes place during this esterification reaction.

..... [1]

(ii) Write an equation for the formation of **E** from a carboxylic acid and an alcohol. Use structural formulae to represent the organic species.

..... [1]

(iii) State the systematic name of the alcohol used to make **E**.

..... [1]

(d) **F** is an isomer of **E**.
F reacts with HCl(aq) to produce **G** and **H**.
G is a secondary alcohol.
H is also produced when HCl(aq) is added to CH_3CN.

(i) Construct an equation for the acid hydrolysis of CH_3CN with HCl(aq).

..... [1]

(ii) Draw the displayed formula of **G**.

[2]

(iii) CH_3OH is used to make CH_3CN in a two-step process, as shown in Fig. 4.2.

$$CH_3OH \xrightarrow{\text{step 1}} CH_3Cl \xrightarrow{\text{step 2}} CH_3CN$$

Fig. 4.2

State the reagents and conditions required for steps 1 and 2.

step 1 .....

step 2 .....

[3]

[Total: 11]

5 The skeletal formula of **W** is shown in Fig. 5.1.

W

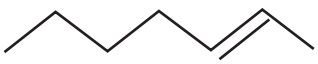

Fig. 5.1

(a) **W** has two positional isomers. Only one shows stereoisomerism.

Draw the structures of the **two** positional isomers of **W** in the boxes.

[2]

(b) **(i)** Describe the origin of stereoisomerism in **W**.

.....

..... [1]

(ii) State why **W** shows stereoisomerism but one of the positional isomers in **(a)** does **not**.

.....

.....

..... [1]

(c) Draw the skeletal structure of the stereoisomer of **W**.

[1]

(d) **W** reacts with reagent **X** to produce ethanoic acid and pentanoic acid.

(i) State the role of **X** in this reaction.

..... [1]

(ii) Identify **X** and state the conditions used for this reaction.

.....

..... [1]

[Total: 7]

6 **P**, **Q** and **R** are three different hydrocarbon molecules.

(a) **(i)** Define empirical formula.

.....

..... [1]

(ii) Hydrocarbon **P** contains 85.7% by mass of carbon.

Calculate the empirical formula of **P**.

Show your working.

empirical formula of **P** = ... [2]

(iii) Molecules of **P** have straight chains.

Name the homologous series to which **P** belongs.

..... [1]

(b) **Q** is a volatile hydrocarbon.
0.194 g of gaseous **Q** occupies a volume of 71.5 cm^3 at 100 °C and 100 kPa.

Use the ideal gas equation to calculate the M_r of **Q**.

M_r of **Q** = ... [2]

(c) The mass spectrum of hydrocarbon **R** is recorded.
Information about the two peaks with m/e greater than 135 is shown in Fig. 6.1.

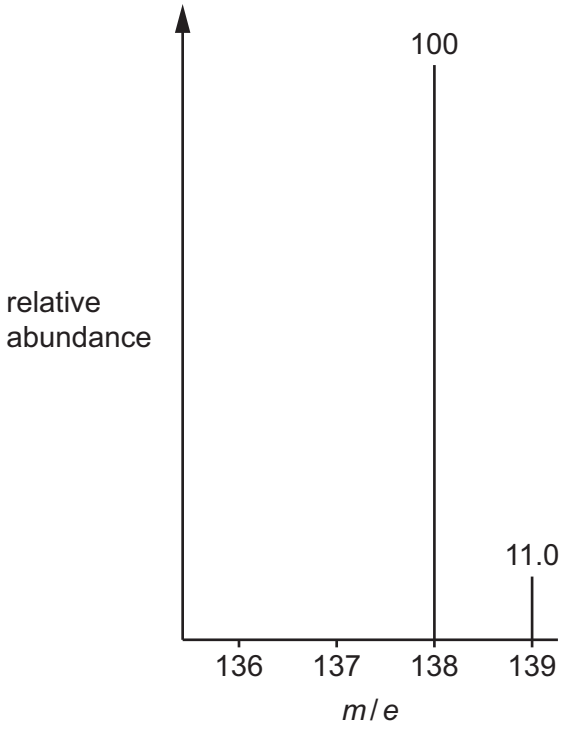

Fig. 6.1

(i) Use Fig. 6.1 to deduce the number of carbon atoms in a molecule of **R**.

Show your working.

number of carbon atoms = ... [2]

(ii) Use Fig. 6.1 and your answer to **(c)(i)** to deduce the molecular formula of **R**.

..... [1]

(iii) Suggest the molecular formula of the fragment of **R** with m/e = 57.

..... [1]

[Total: 10]

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

The Periodic Table of Elements

Key

atomic number
atomic symbol
name
relative atomic mass

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 –

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 –