Please check the examination details below before entering your candidate information

Candidate surname	Other names
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Centre Number | Candidate Number

Pearson Edexcel Level 3 GCE

Tuesday 13 May 2025

Morning (Time: 1 hour 30 minutes)

Paper reference **8CH0/01**

Chemistry

Advanced Subsidiary

PAPER 1: Core Inorganic and Physical Chemistry

You must have:
Scientific calculator, Data Booklet

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B).
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided
  – *there may be more space than you need.*

Information

- The total mark for this paper is 80.
- The marks for **each** question are shown in brackets
  – *use this as a guide as to how much time to spend on each question.*
- For the question marked with an **asterisk (*)**, marks will be awarded for your ability to structure your answer logically, showing how the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Show all your working in calculations and include units where appropriate.
- Check your answers if you have time at the end.

Turn over ▶

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Answer ALL questions.

Some questions must be answered with a cross in a box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 Chlorine, Cl_2, and silicon tetrachloride, $SiCl_4$, are covalently bonded molecules with low boiling temperatures.

(a) The definition of electronegativity is the ability of an atom to attract

(1)

☐ **A** a single bonding electron from a covalent bond

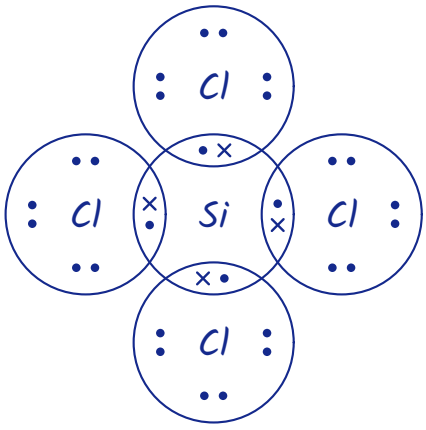
☒ **B** a pair of electrons from a covalent bond

☐ **C** electron density from a neighbouring atom

☐ **D** two electrons from a positive ion

(b) Draw a dot-and-cross diagram of silicon tetrachloride, showing outer shells of electrons only.
Use crosses (×) for silicon electrons and dots (•) for chlorine electrons.

(2)



key: × = Si electron
• = Cl electron

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(c) Explain, using electronegativity values, why both chlorine and silicon tetrachloride are non-polar molecules.

(3)

Chlorine: both atoms are the same, so there is no electronegativity difference between them (both 3.0). The Cl-Cl bond is non-polar, so the molecule has no dipole.

Silicon tetrachloride: chlorine (3.0) is more electronegative than silicon (1.9), so each Si-Cl bond is polar and has a permanent dipole.

However, $SiCl_4$ is tetrahedral and symmetrical, so the four bond dipoles cancel out and the molecule is non-polar overall.

(d) Explain why the boiling temperature of chlorine (–34 °C) is lower than that of silicon tetrachloride (57 °C).

(2)

Both chlorine and silicon tetrachloride are non-polar, so the only intermolecular forces between their molecules are London forces.

A Cl_2 molecule has fewer electrons (34) than a $SiCl_4$ molecule (82), so the London forces between chlorine molecules are weaker and need less energy to overcome.

(Total for Question 1 = 8 marks)

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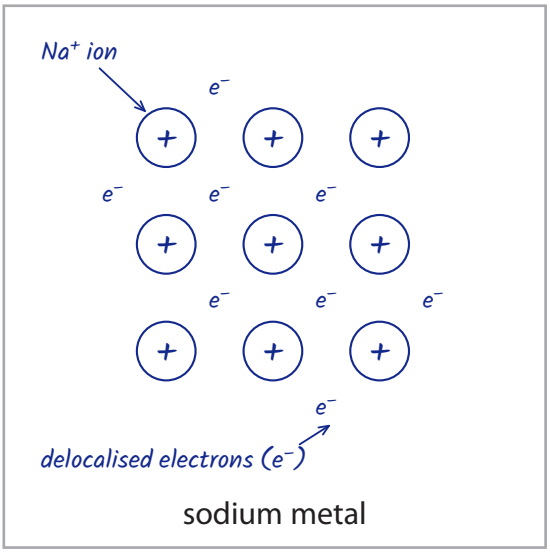
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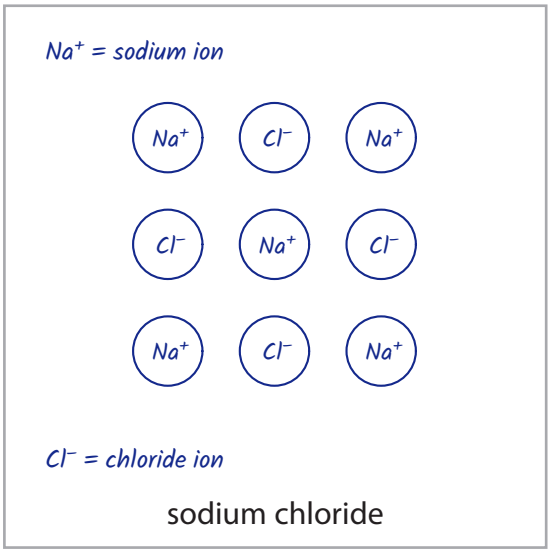
2 At room temperature, both sodium metal and sodium chloride are solids containing ions.

(a) (i) Draw labelled 2-dimensional diagrams showing the structures of both sodium metal and sodium chloride including **nine** ions in each diagram.

(3)



sodium metal



sodium chloride

(ii) Describe what holds the ions together in sodium metal and in sodium chloride.

(2)

Sodium metal

Strong electrostatic attraction between the positive sodium ions (Na^+) and the sea of delocalised electrons (metallic bonding).

Sodium chloride

Strong electrostatic attraction between the oppositely charged ions, Na^+ and Cl^-, in the lattice (ionic bonding).

(iii) The melting temperature of sodium chloride is much higher than that of sodium metal.

State what this information shows about the bonding in these two substances.

(1)

The ionic bonding in sodium chloride is much stronger than the metallic bonding in sodium, so more energy is needed to overcome it.

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(iv) Compare and contrast the electrical conductivity of sodium metal with that of sodium chloride, including how the charge is carried.

(3)

Similarity: both sodium and sodium chloride conduct electricity when molten.

Difference: only sodium conducts electricity as a solid. Solid sodium chloride does not conduct because its ions are fixed in the lattice; it only conducts when molten (or aqueous).

In sodium the charge is carried by delocalised electrons, which are free to move. In sodium chloride the charge is carried by ions (Na^+ and Cl^-), which can only move when molten.

(b) Sodium hydride, which contains the hydride ion, H^-, has the same type of structure as sodium chloride.

(i) Sodium hydride can be made by reacting sodium metal with hydrogen.

Write the equation for this reaction. State symbols are not required.

(1)

$2Na + H_2 \rightarrow 2NaH$

(ii) Sodium hydride reacts with aluminium chloride to produce sodium tetrahydridoaluminate(III), $NaAlH_4$.

Complete a balanced equation for this reaction.

(1)

4 NaH + ... $AlCl_3$ → ..... $NaAlH_4$ + 3 NaCl

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(iii) $H \rightarrow Al$ represents one of the bonds in AlH_4^-.

State the name of this type of bond and how the bond forms in this ion.

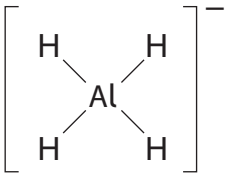
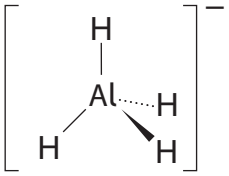
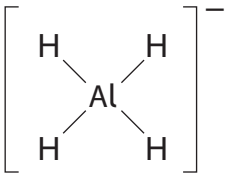
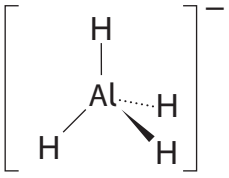
(2)

It is a dative (covalent) bond, also called a coordinate bond.

A lone pair of electrons on the hydride ion (H^-) is donated to the aluminium atom and shared between them.

(iv) What are the shapes of the aluminium chloride molecule and the tetrahydridoaluminate(III) ion?

(1)

		Name of shape of $AlCl_3$	Diagram of shape of AlH_4^-
☒	**A**	triangular-based pyramid	
☒	**B**	triangular-based pyramid	
☒	**C**	trigonal planar	
☒	**D**	trigonal planar	

(Total for Question 2 = 14 marks)

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3 This question is about intermolecular forces.

(a) What are the intermolecular forces between water molecules?

(1)

- ☐ **A** hydrogen bonds only
- ☐ **B** London forces and permanent dipoles only
- ☒ **C** London forces, permanent dipoles and hydrogen bonds
- ☐ **D** permanent dipoles and hydrogen bonds only

(b) Ethanol, CH_3CH_2OH, is soluble in water but ethanethiol, CH_3CH_2SH, is almost insoluble.

The **best** explanation for the difference in solubility is that

(1)

- ☐ **A** ethanethiol molecules form stronger London forces with water than ethanol
- ☐ **B** sulfur is less electronegative than oxygen
- ☒ **C** ethanol forms hydrogen bonds with water but ethanethiol does not
- ☐ **D** ethanol has a larger dipole than ethanethiol

(Total for Question 3 = 2 marks)

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4 This question is about magnesium nitrate, $Mg(NO_3)_2$.

Magnesium nitrate can be made by the reaction of magnesium metal with nitric acid.
A piece of magnesium metal was added to each of two conical flasks containing the same volume of nitric acid.
One flask contains dilute nitric acid and the other flask contains concentrated nitric acid.
In both flasks the acid was in excess.

(a) In the flask containing dilute nitric acid, the magnesium reacted, producing bubbles of a colourless gas.

(i) Give the name of the gas and the test for the gas, with the positive result.

(2)

Hydrogen (H_2).

Test: hold a lighted splint at the mouth of the flask; the gas burns with a squeaky pop.

(ii) Write an equation for the reaction that occurs with magnesium and dilute nitric acid.
Include state symbols.

(2)

$Mg(s) + 2HNO_3(aq) \rightarrow Mg(NO_3)_2(aq) + H_2(g)$

(iii) The flask containing concentrated nitric acid also produced bubbles, but this time the gas was nitrogen dioxide.
Water was also formed.

Write an equation for the reaction that occurs with concentrated nitric acid.
State symbols are not required.

(1)

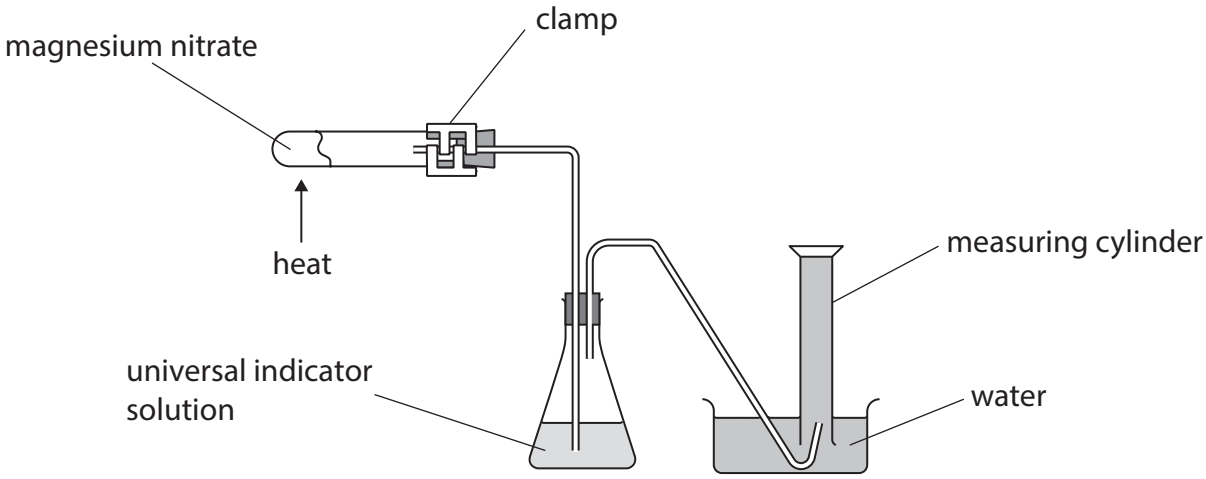
$Mg + 4HNO_3 \rightarrow Mg(NO_3)_2 + 2NO_2 + 2H_2O$

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(b) Magnesium nitrate thermally decomposes, as shown by the equation.

$$2Mg(NO_3)_2(s) \rightarrow 2MgO(s) + 4NO_2(g) + O_2(g)$$

A sample of magnesium nitrate was heated using the apparatus shown.
The resultant mixture of gases was passed through water containing universal indicator, removing one of the products. This green solution turned red.
The remaining gas was collected by displacement of water.



(i) State the appearance of the mixture of gases **before** bubbling through the universal indicator solution, and the appearance of the gas **after** being collected.

(1)

Before: the mixture of gases is brown. After: the gas collected is colourless.

(ii) Explain the change in appearance of the mixture of gases, and of the universal indicator solution.

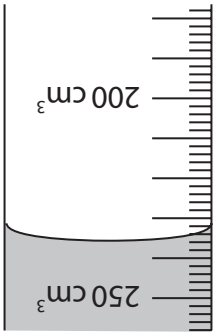
(2)

The brown nitrogen dioxide (NO_2) dissolves in the water and is removed, so only colourless oxygen is collected.

The universal indicator turns from green to red because nitrogen dioxide is an acidic gas: it reacts with the water to form nitric acid.

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(iii) The measuring cylinder was full of water before a sample of magnesium nitrate was thermally decomposed.
Part of the measuring cylinder after the reaction had finished is shown.



The volume of gas collected was

(1)

☒ **A** 218 cm^3

☒ **B** 236 cm^3

☒ **C** 257 cm^3

☒ **D** 264 cm^3

(iv) The sample of magnesium nitrate had a mass of 2.966 g.

Calculate the molar volume of the gas collected, giving your answer to 3 significant figures. Include units in your answer.

You should assume that the decomposition was complete.
The volume of gas was measured at standard temperature and pressure.
Use of $pV = nRT$ is not required.

[M_r of magnesium nitrate = 148.3]

(4)

$n(Mg(NO_3)_2) = 2.966 \div 148.3 = 0.0200$ mol

$n(O_2) = 0.0200 \div 2 = 0.0100$ mol

(only O_2 is collected, NO_2 is removed)

molar volume = $236 \div 0.0100 = 23\,600$ cm^3 mol^{-1}

molar volume = 23.6 dm^3 mol^{-1} (3 s.f.)

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(v) Explain why **three** significant figures is appropriate for the answer in this calculation.

(2)

The volume of gas (236 cm^3) can only be read from the measuring cylinder to the nearest 1 cm^3, so it is known to only 3 significant figures, whereas the mass (2.966 g) and M_r (148.3) are given to 4 significant figures.

The answer should be given to the same number of significant figures as the least precise data used in the calculation, which is 3.

(Total for Question 4 = 15 marks)

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5 The metal zinc (a d-block element) is chemically similar to magnesium (a Group 2 element). One reason for this is because both elements form ionic compounds containing stable 2+ ions.

(a) (i) Complete the electronic structure of the Zn atom and of the Mg^{2+} ion.

(2)

Zn $1s^2$ *$2s^2$ $2p^6$ $3s^2$ $3p^6$ $3d^{10}$ $4s^2$*

Mg^{2+} $1s^2$ *$2s^2$ $2p^6$*

(ii) Explain, in terms of ionisation energies, why zinc and magnesium both form stable 2+ ions.

(2)

For both zinc and magnesium the first and second ionisation energies are relatively low, but there is a large jump between the second and third ionisation energies. This is because the third electron would be removed from a new inner (sub-)shell (2p for Mg, 3d for Zn), closer to the nucleus and less shielded, so a 3+ ion needs too much energy to form.

(b) Naturally occurring samples of zinc have five isotopes, the most abundant being $^{64}_{30}Zn$.

(i) Complete the table.

(1)

	Number of protons	Number of neutrons
$^{64}_{30}Zn$	*30*	*34*

(ii) The relative isotopic mass of $^{64}_{30}Zn$ = 63.929.

Give the reason why the relative isotopic mass is not exactly 64.

(1)

Because the mass is measured relative to carbon-12 (1/12th of the mass of a ^{12}C atom), and on this scale the masses of protons and neutrons are not exactly 1.

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(iii) The table gives the relative abundances and isotopic masses of four of the five isotopes.

Symbol of isotope	$^{64}_{30}Zn$	$^{66}_{30}Zn$	$^{67}_{30}Zn$	$^{70}_{30}Zn$
Relative isotopic mass	63.929	65.926	66.927	69.925
Abundance / %	48.63	27.90	4.10	0.62

The relative atomic mass of the sample was found to be 65.396.

Calculate the relative isotopic mass of the fifth isotope, giving your answer to 3 decimal places, and hence give the symbol of the fifth isotope.

(4)

abundance of fifth isotope = 100 − (48.63 + 27.90 + 4.10 + 0.62)

= 18.75 %

65.396 = [(63.929 × 48.63) + (65.926 × 27.90) + (66.927 × 4.10)

+ (69.925 × 0.62) + (m × 18.75)] ÷ 100

6539.6 = 5265.96 + 18.75m

18.75m = 6539.6 − 5265.96 = 1273.64

m = 1273.64 ÷ 18.75

relative isotopic mass = 67.928

Symbol of the fifth isotope $^{68}_{30}Zn$

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(iv) The mass of an atom of $^{64}_{30}Zn = 1.06157 \times 10^{-22}$ g.

Calculate the value of the Avogadro constant using the mass of this atom and the relative isotopic mass, giving your answer to an appropriate number of significant figures. You **must** show your working.

(1)

$N_A = 63.929 \div (1.06157 \times 10^{-22})$

$N_A = 6.0221 \times 10^{23}\ mol^{-1}$

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(c) Both zinc and magnesium are essential elements for human health, and both can be taken as a dietary supplement in the form of their sulfates.
Hydrated zinc sulfate, $ZnSO_4 \cdot xH_2O$, can be taken orally as tablets.
The value of x can be found by heating the hydrated zinc sulfate until there is no further change in mass.

450 mg of hydrated zinc sulfate gave 253 mg of anhydrous zinc sulfate on heating.

Calculate the value of x in $ZnSO_4 \cdot xH_2O$.

(4)

mass of water lost = 450 − 253 = 197 mg

$n(H_2O)$ = 197 ÷ 18.0 = 10.94 mmol

$M_r(ZnSO_4)$ = 65.4 + 32.1 + (4 × 16.0) = 161.5

$n(ZnSO_4)$ = 253 ÷ 161.5 = 1.567 mmol

x = 10.94 ÷ 1.567 = 6.99

so x = 7 ($ZnSO_4 \cdot 7H_2O$)

(Total for Question 5 = 15 marks)

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6 When potassium iodide and concentrated sulfuric acid are mixed, several reactions occur.
The equation for one of these reactions is shown.

$$8KI + 9H_2SO_4 \rightarrow 4I_2 + 8KHSO_4 + H_2S + 4H_2O$$

(a) (i) Explain how the equation indicates that the reaction should be carried out in a fume cupboard rather than in the laboratory.

(2)

The equation shows that hydrogen sulfide (H_2S) is produced, which is a toxic (poisonous) gas with a foul smell.

Using a fume cupboard stops the toxic gas being released into the laboratory, so it is not breathed in.

(ii) Give **two** observations that would be made when the reaction shown by the equation is carried out in a fume cupboard.

(2)

A black (grey) solid forms.

A purple vapour is seen.

(b) Which change in oxidation number of sulfur, if any, occurs during the formation of H_2S?

(1)

☒ **A** from +6 to −2

☐ **B** from +6 to +2

☐ **C** from +2 to −2

☐ **D** no change

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(c) Deduce the two ionic half-equations for this reaction.
State symbols are not required.

(2)

Oxidation half-equation

$2I^- \rightarrow I_2 + 2e^-$

Reduction half-equation

$H_2SO_4 + 8H^+ + 8e^- \rightarrow H_2S + 4H_2O$

(d) When potassium chloride and concentrated sulfuric acid are mixed, misty fumes are observed from the only reaction that occurs.

(i) Identify, by name or formula, the misty fumes.

(1)

Hydrogen chloride, HCl(g)

(ii) Explain what this observation indicates about the relative strength of the chloride ion and the iodide ion as reducing agents.

(2)

Chloride ions do not reduce concentrated sulfuric acid: only an acid-base reaction occurs, so chlorine stays at −1 and no redox happens.

Iodide ions do reduce the sulfuric acid (to H_2S), so the iodide ion is a stronger reducing agent than the chloride ion.

(Total for Question 6 = 10 marks)

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7 This question is about periodic properties of elements.

(a) Explain why the atomic radius decreases across Period 3 from sodium to chlorine.

(2)

Across Period 3 the number of protons increases, so the nuclear charge increases.

The outer electrons are in the same shell with similar shielding, so they are attracted more strongly and pulled closer to the nucleus.

(b) Which equation does **not** represent the reaction that occurs during the first ionisation energy for a Period 2 element?

(1)

- ☐ **A** $B(g) \rightarrow B^+(g) + e^-$
- ☐ **B** $C(g) \rightarrow C^+(g) + e^-$
- ☒ **C** $\frac{1}{2}N_2(g) - e^- \rightarrow N^+(g)$
- ☐ **D** $Ne(g) - e^- \rightarrow Ne^+(g)$

(c) Which isoelectronic ion has the smallest ionic radius?

(1)

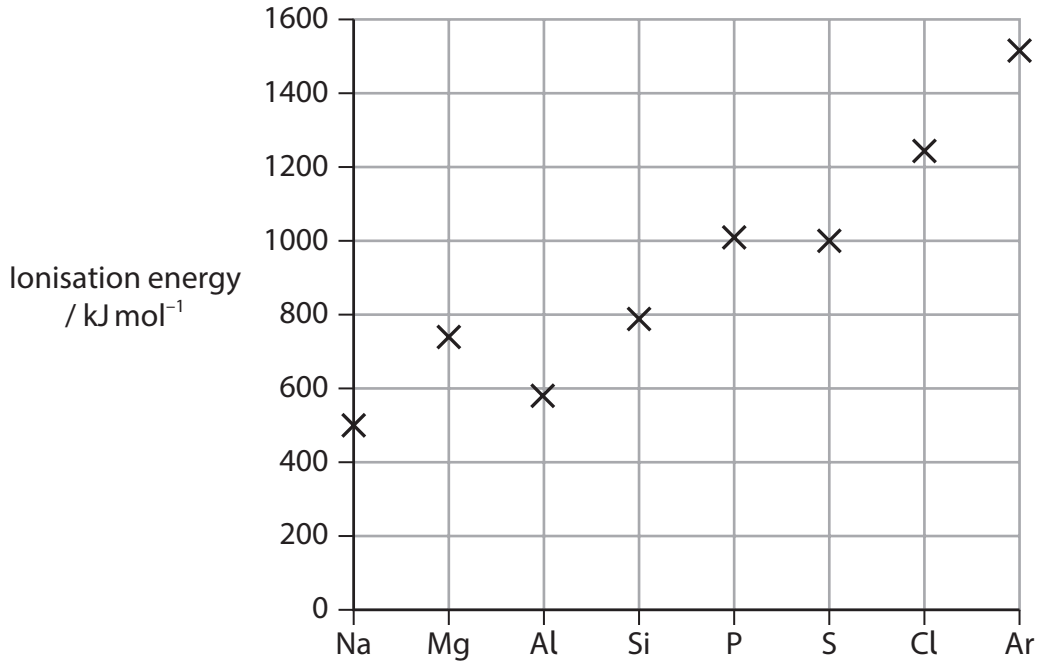
- ☐ **A** F^-
- ☒ **B** Mg^{2+}
- ☐ **C** Na^+
- ☐ **D** O^{2-}

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*(d) The graph shows the first ionisation energy values across Period 3.



Explain these changes in first ionisation energies.

(6)

In general, first ionisation energy increases across Period 3 from sodium to argon. This is because the number of protons, and so the nuclear charge, increases across the period.

The outer electrons are all in the same (third) shell, so the shielding by inner electrons is similar and they are a similar distance from the nucleus. Therefore the outer electron is attracted more strongly and more energy is needed to remove it.

However, the first ionisation energy of aluminium is lower than that of magnesium. This is because the electron removed from aluminium is in a 3p orbital, whereas the electron removed from magnesium is in the 3s orbital.

The 3p electron is shielded by the 3s electrons as well as by the inner shells, and the 3p subshell is higher in energy. This extra shielding outweighs the extra proton, so less energy is needed to remove the 3p electron of aluminium.

The first ionisation energy of sulfur is also lower than that of phosphorus. In phosphorus the three 3p electrons are each in a separate orbital (a half-filled subshell,

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which is stable), but in sulfur the electron removed is in a 3p orbital that contains two electrons, so spin-pairing has occurred.

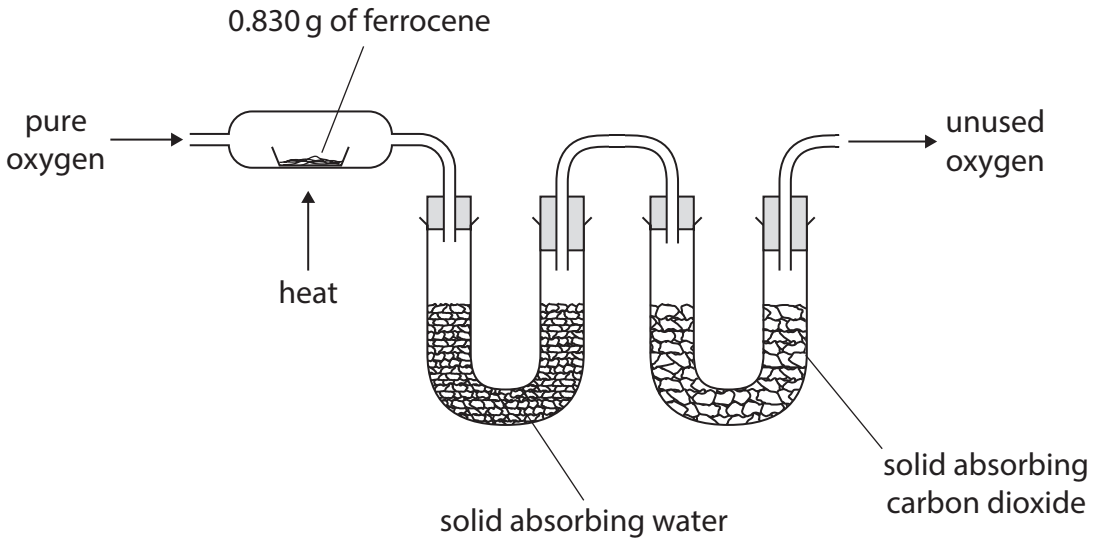
There is repulsion between the two paired electrons in the same orbital, so one of them is removed more easily and less energy is needed, even though sulfur has more protons.

After sulfur, the ionisation energy increases again to chlorine and argon, as the nuclear charge increases while the electrons are still in the same shell.

(Total for Question 7 = 10 marks)

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8 Ferrocene is a compound containing iron, carbon and hydrogen only.
The amounts of carbon and hydrogen in a sample can be determined using the apparatus shown.



The hydrogen atoms from the sample react with oxygen to form water, which is absorbed in the first U-tube.
The carbon atoms react with oxygen to form carbon dioxide, which is absorbed in the second U-tube.

A 0.830 g sample of ferrocene was analysed using this apparatus.

The table shows the mass of the U-tubes before and after combustion.

U-tube containing solid absorbing water	Mass before combustion / g	36.34
	Mass after combustion / g	36.74
U-tube containing solid absorbing carbon dioxide	Mass before combustion / g	35.28
	Mass after combustion / g	37.23

Mass spectrometry shows that ferrocene has a molecular ion peak at $m / z = 186$.

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Deduce the molecular formula of ferrocene using all of the data.

(6)

mass of H_2O = 36.74 – 36.34 = 0.40 g

mass of CO_2 = 37.23 – 35.28 = 1.95 g

$n(H_2O)$ = 0.40 ÷ 18.0 = 0.02222 mol

$n(H)$ = 2 × 0.02222 = 0.04444 mol

$n(C) = n(CO_2)$ = 1.95 ÷ 44.0 = 0.04432 mol

mass of C + H = (0.04432 × 12.0) + (0.04444 × 1.0) = 0.5763 g

mass of Fe = 0.830 – 0.5763 = 0.2537 g

$n(Fe)$ = 0.2537 ÷ 55.8 = 0.004547 mol

Fe : C : H = 0.004547 : 0.04432 : 0.04444

= 1 : 9.7 : 9.8 ≈ 1 : 10 : 10

empirical formula = $FeC_{10}H_{10}$

empirical formula mass = 55.8 + (10 × 12.0) + (10 × 1.0) = 185.8

185.8 ≈ 186 = m/z of molecular ion peak, so the molecular

formula is the same as the empirical formula.

(check: n(ferrocene) = 0.830 ÷ 186 = 0.00446 mol;

C = 0.0443 ÷ 0.00446 = 10, H = 0.0444 ÷ 0.00446 = 10)

Molecular formula = $FeC_{10}H_{10}$

(Total for Question 8 = 6 marks)

TOTAL FOR PAPER = 80 MARKS

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The Periodic Table of Elements

1	2											3	4	5	6	7	0 (8)
							1.0 H hydrogen 1										(18) 4.0 He helium 2
(1)	(2)		Key: relative atomic mass / atomic symbol / name / atomic (proton) number									(13)	(14)	(15)	(16)	(17)	
6.9 Li lithium 3	9.0 Be beryllium 4											10.8 B boron 5	12.0 C carbon 6	14.0 N nitrogen 7	16.0 O oxygen 8	19.0 F fluorine 9	20.2 Ne neon 10
23.0 Na sodium 11	24.3 Mg magnesium 12	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	27.0 Al aluminium 13	28.1 Si silicon 14	31.0 P phosphorus 15	32.1 S sulfur 16	35.5 Cl chlorine 17	39.9 Ar argon 18
39.1 K potassium 19	40.1 Ca calcium 20	45.0 Sc scandium 21	47.9 Ti titanium 22	50.9 V vanadium 23	52.0 Cr chromium 24	54.9 Mn manganese 25	55.8 Fe iron 26	58.9 Co cobalt 27	58.7 Ni nickel 28	63.5 Cu copper 29	65.4 Zn zinc 30	69.7 Ga gallium 31	72.6 Ge germanium 32	74.9 As arsenic 33	79.0 Se selenium 34	79.9 Br bromine 35	83.8 Kr krypton 36
85.5 Rb rubidium 37	87.6 Sr strontium 38	88.9 Y yttrium 39	91.2 Zr zirconium 40	92.9 Nb niobium 41	95.9 Mo molybdenum 42	[98] Tc technetium 43	101.1 Ru ruthenium 44	102.9 Rh rhodium 45	106.4 Pd palladium 46	107.9 Ag silver 47	112.4 Cd cadmium 48	114.8 In indium 49	118.7 Sn tin 50	121.8 Sb antimony 51	127.6 Te tellurium 52	126.9 I iodine 53	131.3 Xe xenon 54
132.9 Cs caesium 55	137.3 Ba barium 56	138.9 La* lanthanum 57	178.5 Hf hafnium 72	180.9 Ta tantalum 73	183.8 W tungsten 74	186.2 Re rhenium 75	190.2 Os osmium 76	192.2 Ir iridium 77	195.1 Pt platinum 78	197.0 Au gold 79	200.6 Hg mercury 80	204.4 Tl thallium 81	207.2 Pb lead 82	209.0 Bi bismuth 83	[209] Po polonium 84	[210] At astatine 85	[222] Rn radon 86
[223] Fr francium 87	[226] Ra radium 88	[227] Ac* actinium 89	[261] Rf rutherfordium 104	[262] Db dubnium 105	[266] Sg seaborgium 106	[264] Bh bohrium 107	[277] Hs hassium 108	[268] Mt meitnerium 109	[271] Ds darmstadtium 110	[272] Rg roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series	140 Ce cerium 58	141 Pr praseodymium 59	144 Nd neodymium 60	[147] Pm promethium 61	150 Sm samarium 62	152 Eu europium 63	157 Gd gadolinium 64	159 Tb terbium 65	163 Dy dysprosium 66	165 Ho holmium 67	167 Er erbium 68	169 Tm thulium 69	173 Yb ytterbium 70	175 Lu lutetium 71
* Actinide series	232 Th thorium 90	[231] Pa protactinium 91	238 U uranium 92	[237] Np neptunium 93	[242] Pu plutonium 94	[243] Am americium 95	[247] Cm curium 96	[245] Bk berkelium 97	[251] Cf californium 98	[254] Es einsteinium 99	[253] Fm fermium 100	[256] Md mendelevium 101	[254] No nobelium 102	[257] Lr lawrencium 103

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