PEARSON EDEXCEL IAL CHEMISTRY · YCH11

CHEMISTRY



EXAM QUESTION PACK

UNIT 1: ATOMIC STRUCTURE AND THE PERIODIC TABLE

SCORE	PERCENTAGE
/320	%

STEMUP

These questions belong to Pearson Edexcel, not to us.

The examination questions, mark schemes and examiner comments in this pack were written and published by Pearson Edexcel. They are past assessment materials, reproduced here so that students can revise from them.

What we do not own

STEMUP is not affiliated with Pearson Edexcel and does not own, and makes no claim to own, any of the question, mark scheme or examiner report material in this pack. Pearson Edexcel has not endorsed, approved or been involved in the production of it. Pearson Edexcel and the qualification titles used here belong to their respective owners and appear for identification only.

Where to find the originals

Pearson Edexcel publishes its past papers, mark schemes and examiner reports free of charge. Always check the current specification at qualifications.pearson.com before you revise, because content and wording can change between series.

If you hold the rights to any material in this pack and would like it amended or removed, contact admin@stemup.co.uk and we will act on it.

Q1.

This question is about compounds containing chlorine.

(a) A precipitate of silver chloride is formed when silver nitrate solution reacts with sodium chloride solution.

A student wrote an ionic equation for the reaction.

$$Ag^{2+}(l) + 2Cl^{-}(l) \rightarrow AgCl_2(s)$$

Explain why this equation is incorrect, even though it is balanced.

(2)

.....

.....

.....

.....

.....

.....

(b) A sample of a compound is analysed and found to contain **only** 3.09 g carbon, 0.26 g hydrogen and 9.15 g chlorine.

The molar mass of the compound is 97.0 g mol^{-1}.

Calculate the molecular formula of this compound.

You **must** show your working.

(3)

(c) Nitrogen trichloride has the formula NCl_3.

(i) A sample of nitrogen trichloride contained only nitrogen atoms with mass number 14, and chlorine atoms with mass numbers 35 and 37.

Give the formula and mass/charge ratio for each of the **four** ions responsible for the molecular ion peaks in the mass spectrum of nitrogen trichloride.

(2)

(ii) Complete the table to predict the shape and Cl—N—Cl bond angle in nitrogen trichloride.

(3)

Number of bonding pairs of electrons on nitrogen	
Number of lone pairs of electrons on nitrogen	
Shape of molecule	
Cl—N—Cl bond angle	

(d) Aluminium chloride exists as an ionic lattice in the solid state and as a covalent dimer, Al_2Cl_6, in the gas phase, just above its boiling temperature.

(i) Explain why aluminium chloride in the solid state has significant covalent character.

(2)

.....

.....

.....

.....

.....

.....

.....

.....

(ii) Describe how two $AlCl_3$ molecules are joined together in the dimer.

Include a diagram in your answer.

(2)

.....

.....

.....

.....

(Total for question = 14 marks)

Q2.

This question is about iron and some of its compounds.

(a) Complete the table to show the numbers of subatomic particles in $^{56}Fe^{2+}$.

(1)

Number of protons	Number of neutrons	Number of electrons

(b) A sample of iron contains the following isotopes.

Isotope	Percentage abundance
^{54}Fe	5.84
^{56}Fe	91.68
^{57}Fe	2.17
^{58}Fe	0.31

Calculate the relative atomic mass of this sample of iron.
Give your answer to **three** significant figures.

(2)

(c) Magnesium reacts with aqueous iron(II) sulfate in a displacement reaction.

Write the **ionic** equation for this reaction.
Include state symbols.

(2)

(d) 25.00 g of a compound contains 6.98 g of iron and 6.03 g of sulfur.

The remaining mass is oxygen.

Calculate the **empirical** formula of this compound.

[A_r values: O = 16.0 S = 32.1 Fe = 55.8]

(3)

(e) When 6.95 g of $FeSO_4.\mathbf{x}H_2O$ is heated, 2.00 g of iron(III) oxide, 0.80 g of sulfur dioxide and 1.00 g of sulfur trioxide
are produced.
The only other product is water.

Deduce the overall equation for the reaction using these data.
State symbols are not required.

You **must** show your working.

[A_r values: H = 1.0 O = 16.0 S = 32.1 Fe = 55.8]

(5)

(Total for question = 13 marks)

Q3.

This question is about nitrogen.

(a) The table shows the successive ionisation energies of nitrogen.

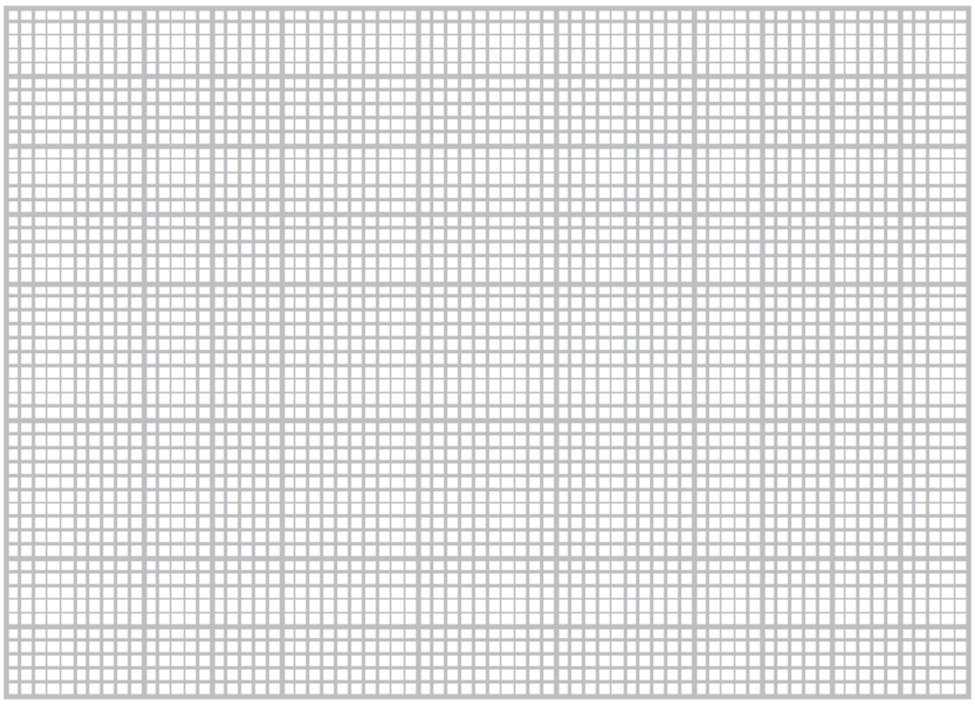
Ionisation number	Ionisation energy / kJ mol^{-1}	log (ionisation energy)
1	1 402	3.15
2	2 856	3.46
3	4 578	3.66
4	7 475	3.87
5	9 445	3.98
6	53 268	
7	64 362	

(i) Complete the table.

(1)

(ii) Plot a graph of log (ionisation energy) against ionisation number.

(3)



(iii) Give a reason why the logarithm of the ionisation energy, rather than just the ionisation energy, is used to plot this graph.

(1)

.....

.....

.....

(iv) Explain what can be deduced from the graph about the electronic structure of nitrogen.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

.....

(v) Explain why the first ionisation energy of oxygen is lower than that of nitrogen.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

.....

(b) Nitrogen gas consists of nitrogen molecules.

(i) Draw a dot-and-cross diagram to show the bonding in a molecule of nitrogen.

(1)

(ii) Calculate the number of nitrogen **atoms** in 5.60 g of nitrogen gas.

[Avogadro constant = $6.02 \times 10_{23}$ mol^{-1}]

(2)

(iii) A sample of nitrogen gas occupied 108 cm^3 at a temperature of 25 °C and a pressure of 1.36×10^5 Pa.

Using the ideal gas equation, calculate the number of moles of nitrogen gas in this sample.

[$pV = nRT$ $R = 8.31$ J mol^{-1} K^{-1}]

(4)

(Total for question = 18 marks)

Q4.

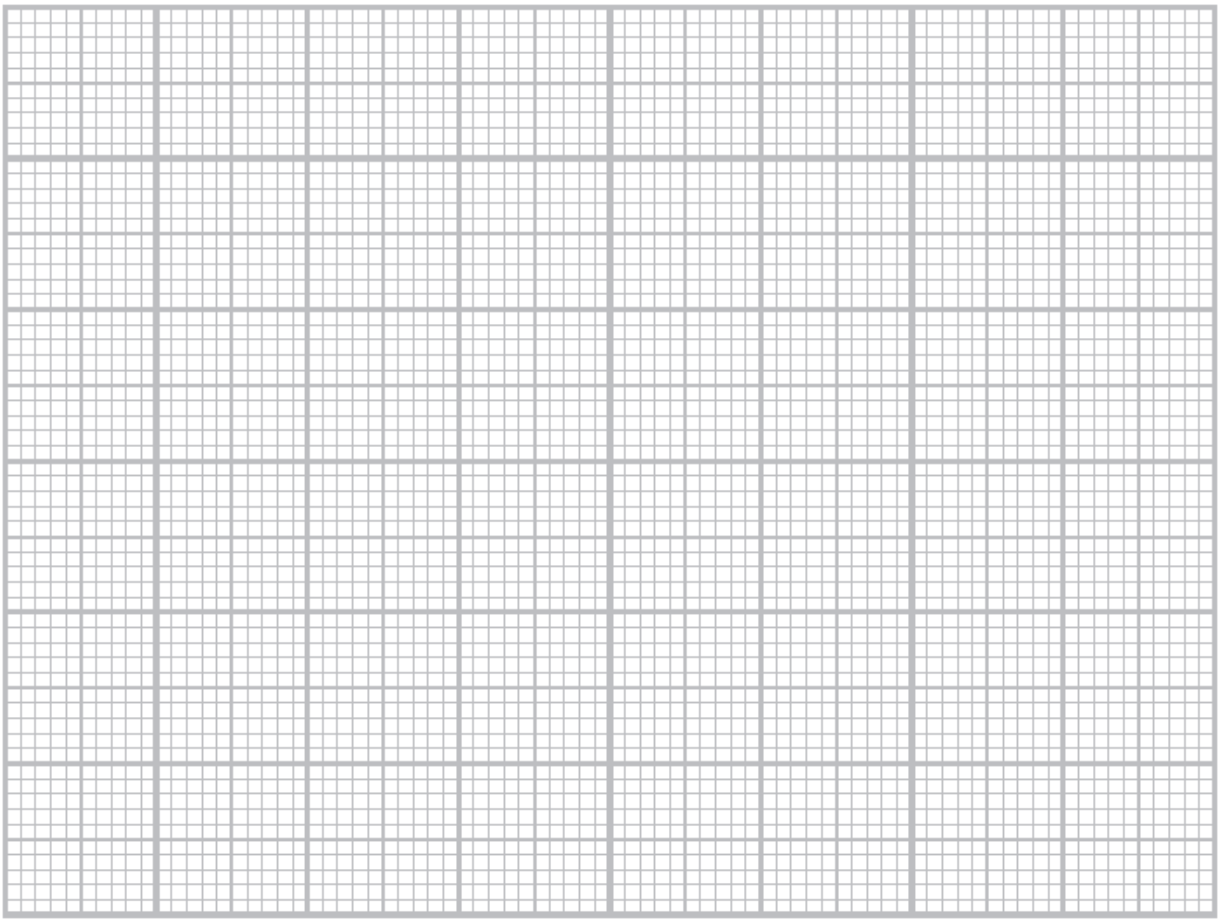
This question is about the elements in Period 3 of the Periodic Table, and some of their compounds.

(a) The atomic radii of six of the elements are given.

Symbol	Na	Mg	Al	Si	P	S	Cl	Ar
Atomic number	11	12	13	14	15	16	17	18
Atomic radius / nm	0.191	0.160	0.130			0.102	0.099	0.095

(i) Plot a graph of atomic radius against atomic number.

(2)



(ii) Use the graph to estimate the atomic radius of silicon, Si.

(1)

.....

(iii) Suggest an explanation for the decrease in atomic radius as atomic number increases across a period.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

.....

(b) The melting temperatures of sodium, sodium chloride and chlorine are given in the table.

Complete the table to show the type of structure, the type of bond or force broken on melting and the particles involved.

(6)

Substance	Sodium	Sodium chloride	Chlorine
Melting temperature / °C	98	801	−101
Type of structure	giant		simple molecular
Type of bond or force broken on melting			
Particles involved			chlorine molecules

(c) Solid phosphorus(V) chloride contains PCl_4^+ ions.

(i) Draw a dot-and-cross diagram of a PCl_4^+ ion.

Show only outer shell electrons.

(1)

(ii) Predict the shape of a PCl_4^+ ion.

Justify your answer.

(3)

Shape .....

Justification

.....

.....

.....

.....

.....

.....

.....

(Total for question = 16 marks)

Q5.

This question is about atomic structure and gases.

(a) Chlorine exists as two isotopes with mass numbers 35 and 37.

(i) State the number and type of each of the particles in the **nucleus** of a chlorine-35 atom.

(2)

.....

.....

(ii) Complete the electronic configuration of a chloride **ion**, Cl^-, using the s, p, d notation.

(1)

$1s^2$ .....

(iii) A sample of chlorine contains 75.53 % of chlorine-35 atoms.

Calculate the relative atomic mass of this sample of chlorine.
Give your answer to **two** decimal places.

(2)

(b) Fluorine has one naturally occurring isotope with mass number 19.

Chlorine and fluorine react to form chlorine trifluoride, ClF_3 .

(i) Draw a dot-and-cross diagram to show the bonding in a molecule of chlorine trifluoride.

Show the outer shell electrons only.

(2)

(ii) State, in terms of electrons, what is unusual about the dot-and-cross diagram you have drawn.

(1)

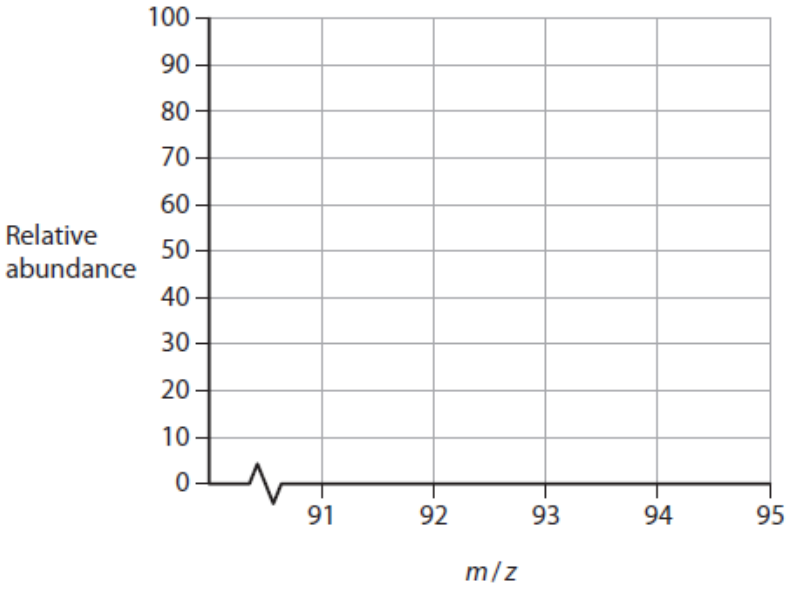
.....

.....

.....

(iii) Complete the mass spectrum to show the peaks you would expect for the molecular ion ClF_3^+ .

(3)



(iv) Calculate, using the ideal gas equation, the volume in **cm^3** occupied by 0.0200 mol of ClF_3 gas at a temperature of 60 °C and a pressure of 1.28×10^5 Pa.

Give your answer to an appropriate number of significant figures.

[$pV = nRT$ $R = 8.31$ J mol^{-1} K^{-1}]

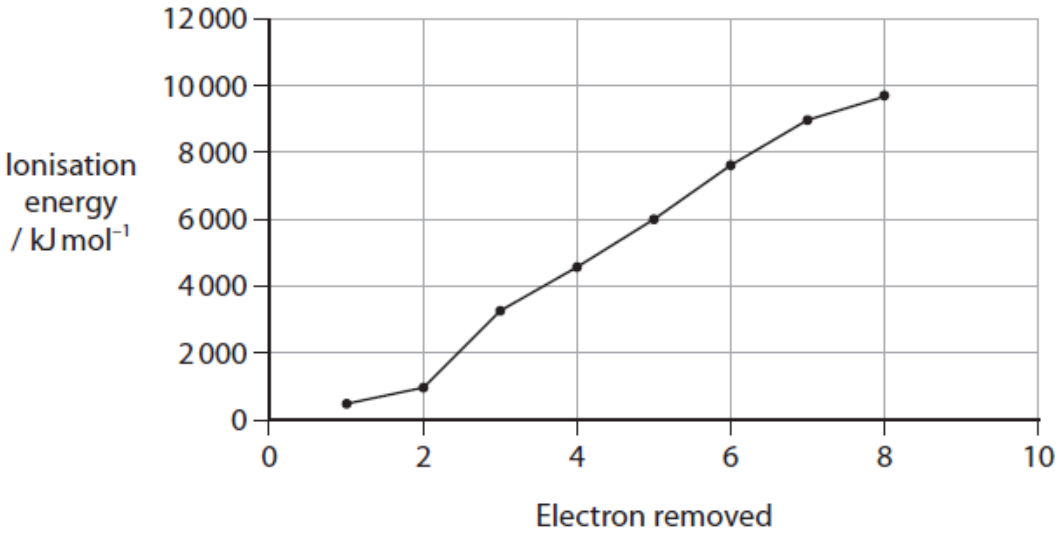
(4)

(Total for question = 15 marks)

Q6.

This question is about barium and barium compounds.

(a) The graph shows the first eight ionisation energies of barium.



(i) Write an equation, including state symbols, for the **third** ionisation energy of barium.

(1)

(ii) State how the graph confirms that barium is in Group 2 in the Periodic Table.

(1)

.....

.....

.....

.....

(b) An acidified aqueous solution of barium chloride, $BaCl_2$, is used to test for sulfate ions.

(i) Draw a dot-and-cross diagram for barium chloride.

Show the outer electrons only.

(2)

(ii) Calculate the mass of barium chloride needed to form 150 cm^3 of $BaCl_2(aq)$ with a concentration of 0.200 mol dm^{-3}.

Give your answer to an appropriate number of significant figures.

(2)

(iii) The barium chloride solution is acidified to prevent carbonate ions giving a false positive result.

Write the **ionic** equation for the reaction of hydrochloric acid with carbonate ions. State symbols are not required.

(1)

(c) Give a reason why solid barium chloride does not conduct electricity.

(1)

.....

.....

(Total for question = 8 marks)

Q7.

This question is about the bonding in the elements of Period 3 in the Periodic Table.

The melting temperatures of the Period 3 elements are shown in the table.

Element	Na	Mg	Al	Si	P	S	Cl	Ar
Melting temperature / °C	98	650	660	1423	44	120	–101	–189

(a) Sodium, magnesium and aluminium are metals.

(i) State what is meant by metallic bonding.

(1)

.....

.....

.....

(ii) Melting temperature depends on the strength of metallic bonding.

Explain why the metallic bonding in magnesium is much stronger than that in sodium.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

.....

(b) (i) In the elements silicon, phosphorus, sulfur and chlorine, the atoms are joined by covalent bonds.

Describe the attraction between the atoms in a covalent bond.

(1)

.....

.....

(ii) Explain why the melting temperature of silicon is much higher than that of phosphorus, by referring to their structures.

(3)

.....

.....

.....

.....

.....

.....

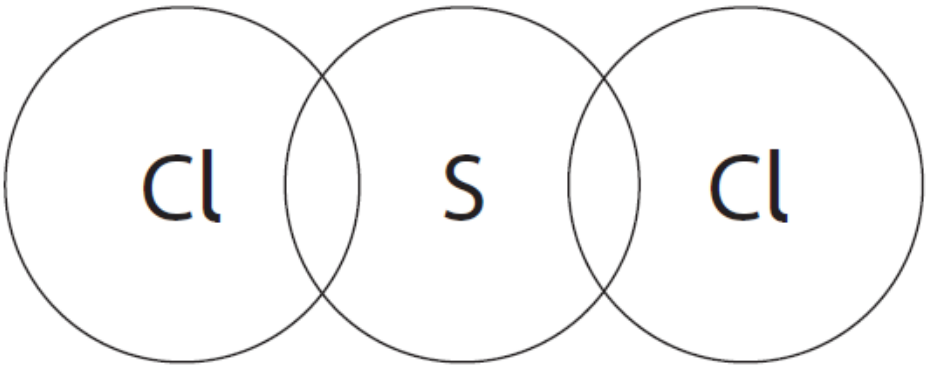
.....

.....

(c) Sulfur reacts with chlorine to form sulfur dichloride, SCl_2.

(i) Complete the dot-and-cross diagram of a molecule of sulfur dichloride. Use dots (•) for the chlorine electrons and crosses (×) for the sulfur electrons. Show the outer shell electrons only.

(2)



(ii) Suggest a value for the Cl—S—Cl bond angle. Justify your answer.

(3)

.....

.....

.....

.....

.....

.....

.....

(Total for question = 13 marks)

Q8.

Naturally occurring bromine has two isotopes: bromine-79 and bromine-81.

(a) State what is meant by the term isotopes.

(1)

.....

.....

.....

(b) Complete the table to show the numbers of subatomic particles in the two isotopes of bromine.

(2)

Isotope	Protons	Neutrons	Electrons
bromine-79			
bromine-81			

(c) The mass spectrum of a sample of bromine is obtained.

(i) Draw a dot-and-cross diagram to show the bonding in a molecule of bromine.

Only the outer electrons should be shown.

(2)

(ii) Describe the formation of the molecular ion of bromine in the mass spectrometer. Include an equation.

State symbols are not required.

(2)

.....

.....

.....

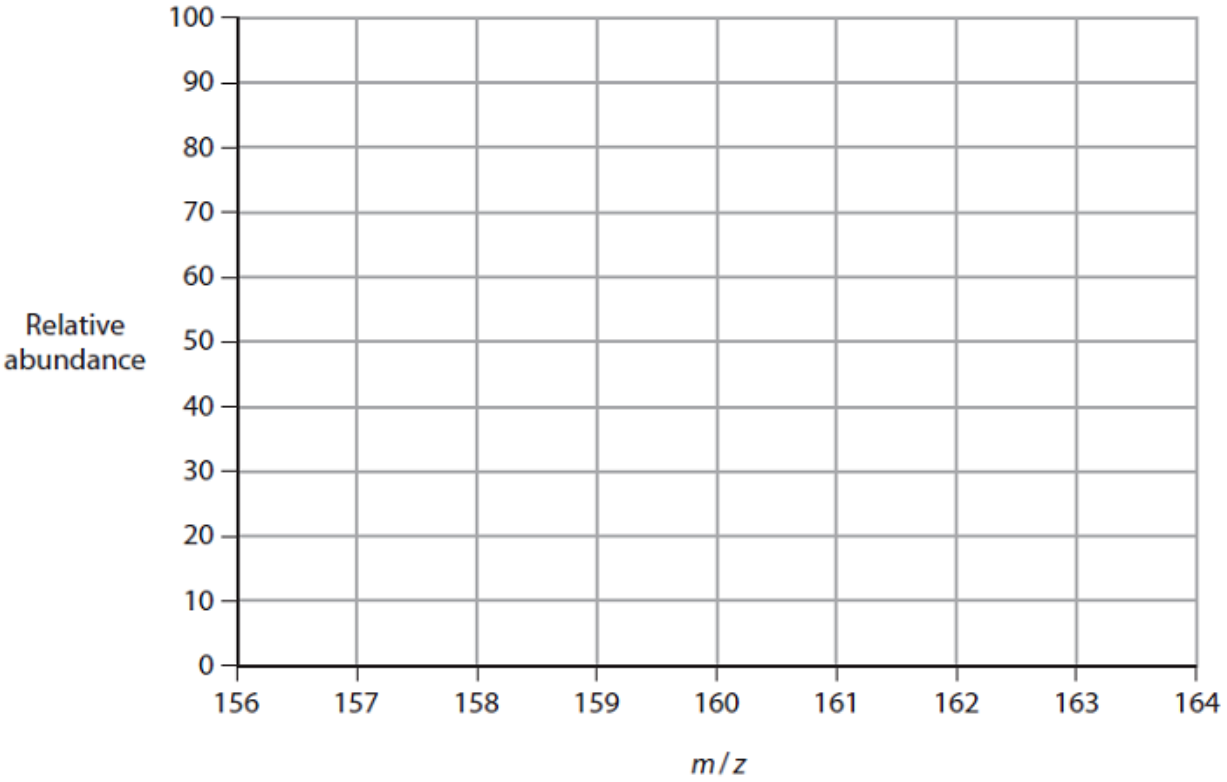
.....

.....

(iii) On the mass spectrum grid, draw the peaks for the bromine molecular ions, showing the relative peak heights.

The bromine isotopes in this sample have the **same** relative abundance.

(2)



(d) The percentage abundances of the isotopes in a different sample of bromine are shown.

Isotope	Percentage abundance
bromine-79	56.38%
bromine-81	43.62%

Calculate the relative **molecular** mass of this sample of bromine, giving your answer to **two** decimal places.

(3)

(Total for question = 12 marks)

Q9.

This question is about bromine.

(a) Complete the electronic configuration for a bromine atom, using the s, p, d notation.

(1)

[Ar] .....

(b) Bromine exists as two isotopes with mass numbers 79 and 81.

(i) Complete the table to show the numbers of subatomic particles in a ^{79}Br atom and a $^{81}Br^-$ ion.

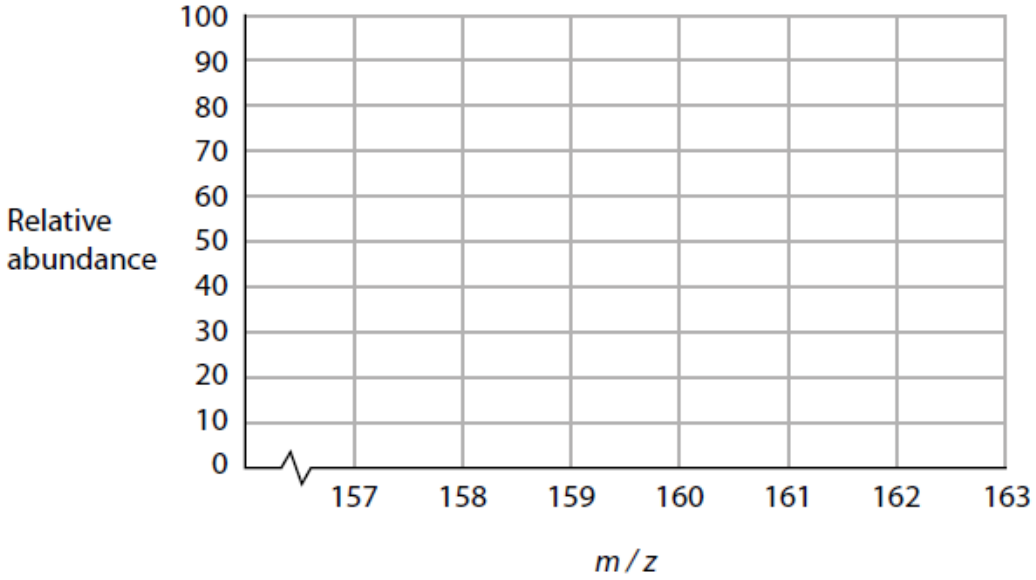
(2)

Species	Protons	Neutrons	Electrons
^{79}Br			
$^{81}Br^-$			

(ii) A sample of bromine contained equal amounts of the two isotopes.

Complete the mass spectrum to show the peaks you would expect for Br_2^+ from this sample of bromine gas.

(2)



(iii) Calculate the number of bromine molecules in 2.00 g of Br_2.

[Avogadro constant = 6.02×10^{23} mol^{-1}]

(2)

Number of molecules = ...

(c) A sample of bromine gas occupied 200 cm^3 at a temperature of 77 °C and a pressure of 1.51×10^5 Pa.

Calculate, using the ideal gas equation, the amount in moles of bromine molecules in this sample.

[$pV = nRT$ $R = 8.31$ J mol^{-1} K^{-1}]

(4)

Amount of bromine molecules = ... mol

(Total for question = 11 marks)

Q10.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

What is the total number of orbitals in a sulfur atom which contain at least one electron?

☐ **A** 3

☐ **B** 5

☐ **C** 8

☐ **D** 9

(Total for question = 1 mark)

Q11.

This question is about copper and its compounds.

(a) Complete the electronic configurations of Cu and Cu^{2+}.

(2)

Cu [Ar] .....

Cu^{2+} [Ar]
.....

(b) A sample of copper contains the isotopes ^{63}Cu and ^{65}Cu.

(i) Complete the table to show the numbers of subatomic particles in the atoms of these two isotopes of copper.

(2)

Isotope	Protons	Neutrons	Electrons
^{63}Cu			
^{65}Cu			

(ii) Explain the term isotopes, using the information in the table.

(2)

.....

.....

.....

.....

.....

(iii) State why the two isotopes of copper have the same chemical reactions.

(1)

.....

.....

(iv) The relative atomic mass of copper in this sample is 63.4.

Calculate the percentage abundances of the isotopes ^{63}Cu and ^{65}Cu in this sample.
You must show your working.

(2)

(c) Copper(II) sulfate, CuSO4, can be made by reacting solid copper(II) carbonate with dilute sulfuric acid.

(i) Write an equation for the reaction that occurs.

State symbols are not required.

(1)

(ii) An experiment was carried out to produce pure, dry crystals of hydrated copper(II) sulfate, $CuSO_4 \cdot 5H_2O$.

Copper(II) carbonate was mixed with 50.0 cm^3 of 1.00 mol dm^{-3} sulfuric acid until no more reacted.
The mass of $CuSO_4 \cdot 5H_2O$ obtained was 10.87 g.

Calculate the percentage yield for this reaction, giving your answer to an appropriate number of significant figures.

[Molar mass of $CuSO_4 \cdot 5H_2O$ = 249.6 g mol^{-1}]

(4)

(Total for question = 14 marks)

Q12.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Isotopes are atoms of an element that have different

☒ **A** electronic structures

☒ **B** numbers of electrons

☒ **C** numbers of protons

☒ **D** numbers of neutrons

(Total for question = 1 mark)

Q13.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which is the electronic configuration of the Sc^{3+} ion?

☒ **A** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

☒ **B** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5\ 3d^1$

☒ **C** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^1\ 4s^2$

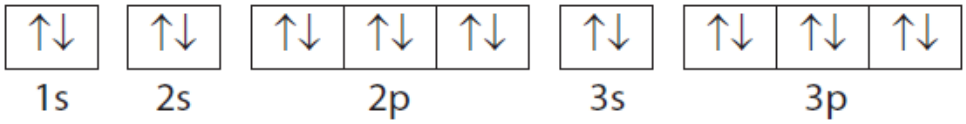
☒ **D** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^4\ 4s^2$

(Total for question = 1 mark)

Q14.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which ion does **not** have the electronic configuration shown?



☒ **A** K^+

☒ **B** Ca^{2+}

☒ **C** Ti^{2+}

☒ **D** Sc^{3+}

(Total for question = 1 mark)

Q15.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

What is the electronic configuration of the nitride ion, N^{3-} ?

☒ **A** $1s^2\ 2s^2$

☒ **B** $1s^2\ 2s^2\ 2p^3$

☒ **C** $1s^2\ 2s^2\ 2p^4$

☒ **D** $1s^2\ 2s^2\ 2p^6$

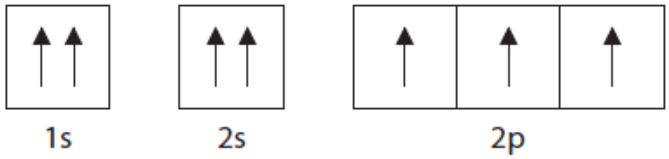
(Total for question = 1 mark)

Q16.

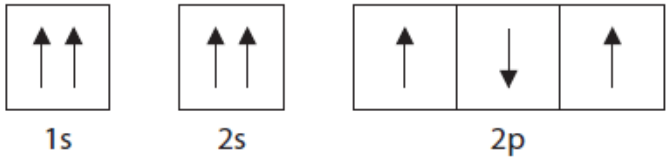
Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

What is the electronic configuration of a nitrogen atom?

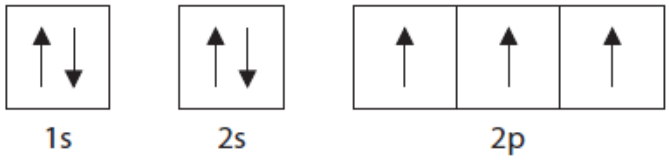
☒ **A**



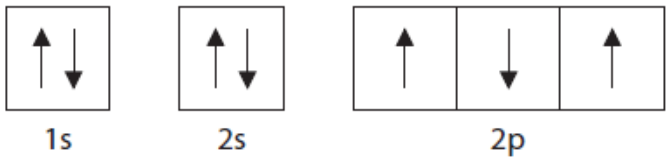
☒ **B**



☒ **C**



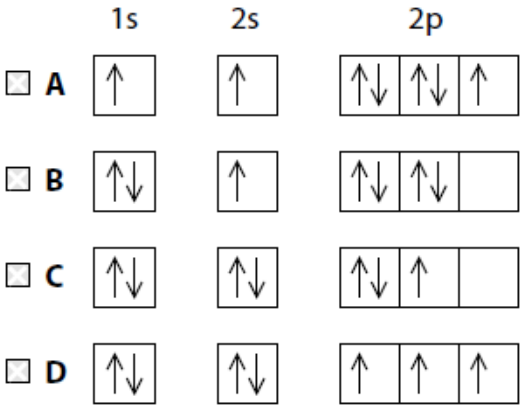
☒ **D**



(Total for question = 1 mark)

Q17.

Which is the electronic configuration of nitrogen?



(Total for question = 1 mark)

Q18.

This question is about the chlorides of beryllium and calcium.

(a) Complete the electronic configurations of the atoms of beryllium and calcium using the s, p, d notation.

(2)

Be $1s^2$

.....

Ca $1s^2$

.....

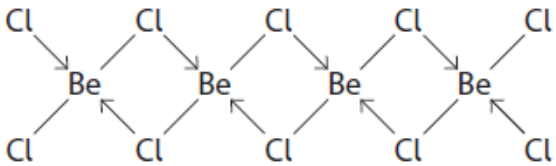
(b) In the gaseous state, beryllium chloride is molecular.

Draw a dot-and-cross diagram to show the bonding in a molecule of beryllium chloride, $BeCl_2$.

(2)

(c) In the solid state, beryllium chloride forms a polymeric structure.

The diagram shows part of this structure.



The diagram uses lines and arrows to represent the two different types of covalent bond.

Describe how each type of bond is formed.

(2)

.....

.....

.....

.....

.....

.....

(d) The Cl—Be—Cl bond angle is different in the two forms of beryllium chloride.

Predict the two bond angles, justifying your answers by referring to electron-pair repulsion theory.

(4)

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(e) Anhydrous calcium chloride is a crystalline, ionic solid which melts at 772 °C.

Draw a dot-and-cross diagram for calcium chloride.
Show the outer electrons only.

(2)

(f) Explain why gaseous beryllium chloride and solid calcium chloride have different types of bonding.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

.....

(Total for question = 15 marks)

Q19.

What are the maximum numbers of electrons in a 2p orbital and in the third quantum shell?

	Maximum number of electrons in a 2p orbital	Maximum number of electrons in the third quantum shell
☒ **A**	2	8
☒ **B**	2	18
☒ **C**	6	8
☒ **D**	6	18

(Total for question = 1 mark)

Q20.

Which element is in the d-block of the Periodic Table?

(1)

☒ **A** argon

☒ **B** chlorine

☒ **C** iron

☒ **D** sodium

(Total for question = 1 mark)

Q21.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which is the equation for the **second** ionisation energy of an element, A?

☒ **A** $A(g) \rightarrow A^{2+}(g) + 2e^-$

☒ **B** $A^+(g) \rightarrow A^{2+}(g) + e^-$

☒ **C** $A^{2+}(g) \rightarrow A^{3+}(g) + e^-$

☒ **D** $A^{2+}(g) \rightarrow A^{4+}(g) + 2e^-$

(Total for question = 1 mark)

Q22.

Which equation represents the first ionisation energy of iodine?

☒ **A** $I_2(s) \rightarrow 2I^+(g) + 2e^-$

☒ **B** $I_2(g) \rightarrow 2I^+(g) + 2e^-$

☒ **C** $\frac{1}{2}I_2(s) \rightarrow I^+(g) + e^-$

☒ **D** $I(g) \rightarrow I^+(g) + e^-$

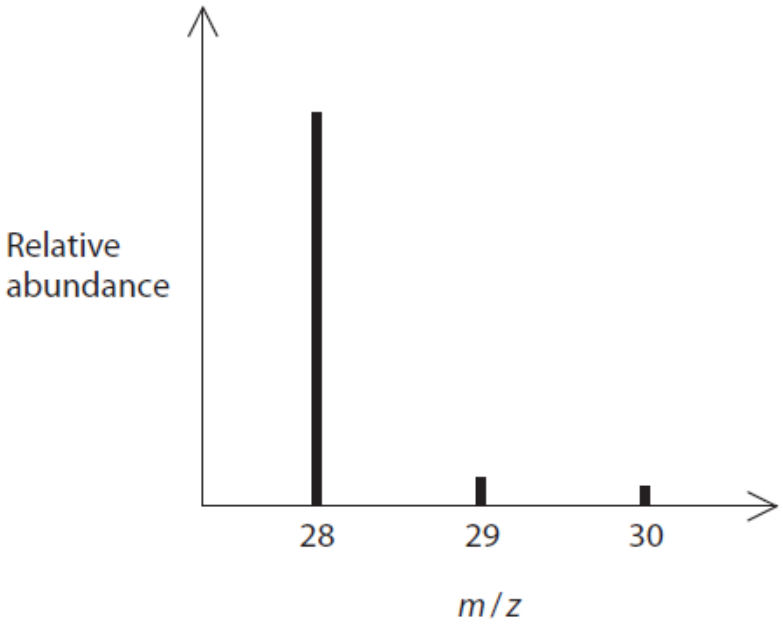
Use this space for any rough working. Anything you write in this space will gain no credit.

(Total for question = 1 mark)

Q23.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The mass spectrum of a sample of silicon is shown.



What is the **best** estimate for the relative atomic mass of silicon in this sample?

☒ **A** 28.0

☒ **B** 28.2

☒ **C** 28.8

☒ **D** 29.0

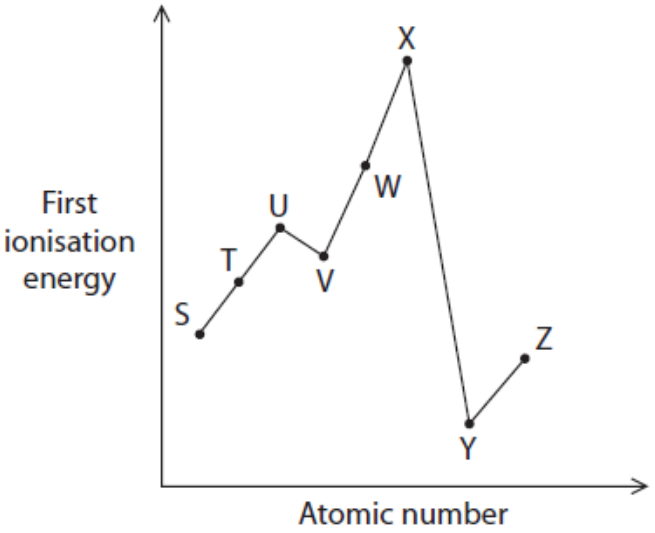
(Total for question = 1 mark)

Q24.

Answer the questions with a cross in the boxes you think are correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The graph shows the first ionisation energies of some consecutive elements from Periods 2 and 3 of the Periodic Table.

The letters used to label the elements are **not** their chemical symbols.



(a) Which element has only **one** p orbital containing a pair of electrons?

(1)

☒ **A** element U

☒ **B** element V

☒ **C** element W

☒ **D** element X

(b) Which element is the least reactive?

(1)

☒ **A** element S

☒ **B** element X

☒ **C** element Y

☒ **D** element Z

(c) Which element has the greatest **second** ionisation energy?

(1)

☒ **A** element S

☒ **B** element T

☒ **C** element X

☒ **D** element Y

(Total for question = 3 marks)

Q25.

This question is about the Group 4 element germanium and some of its compounds.

(a) Naturally-occurring germanium consists of five stable isotopes.

Explain what is meant by the term isotopes.

(2)

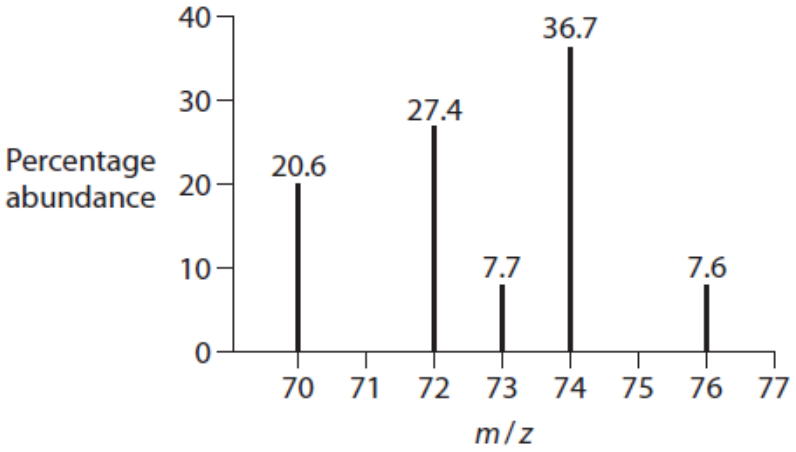
.....

.....

.....

.....

(b) The mass spectrum of a sample of germanium is shown.



Calculate the relative atomic mass of this sample of germanium.

(2)

(c) Give the electronic configuration of a germanium atom.

(1)

.....

(d) Germane is a compound with the formula GeH_4.

It can be formed by the reaction shown.

$$Na_2GeO_3 + NaBH_4 + H_2O \rightarrow GeH_4 + 2NaOH + NaBO_2$$

(i) Calculate the atom economy, by mass, for the formation of germane.

Use A_r of Ge = 72.6

(2)

(ii) Germane can donate a proton to ammonia, forming the ion GeH_3^-.

$$NH_3 + GeH_4 \rightarrow NH_4^+ + GeH_3^-$$

Draw a dot-and-cross diagram of the ion GeH_3^-. Show the outer electrons only.

(2)

(iii) Use your answer to (d)(ii) and electron-pair repulsion theory to predict the name of the shape and bond angle of the ion GeH_3^-

(2)

Name of the shape

.....

Bond angle

.....

(iv) Germane is toxic and the maximum permitted concentration is 0.640 mg m^{-3} in air.

Calculate the maximum number of germane molecules permitted in a laboratory with a volume of 231 m^3.

[Avogadro constant (L) = 6.02×10^{23} mol^{-1}]

(4)

(e) A halide of germanium, GeX_4, reacts with water as shown.

$$GeX_4 + 2H_2O \rightarrow GeO_2 + 4HX$$

1.50 g of GeX_4 was added to excess water.
The insoluble GeO_2 was removed by filtration.
The solution of hydrogen halide formed was then added to excess magnesium carbonate, forming 335.5 cm^3 of carbon dioxide at room temperature and pressure (r.t.p.).

$$MgCO_3 + 2HX \rightarrow MgX_2 + CO_2 + H_2O$$

[Molar volume of a gas at r.t.p. = 24 000 cm^3 mol^{-1}]

(i) Calculate the number of moles of carbon dioxide formed.

(1)

(ii) Deduce the number of moles of HX formed when GeX_4 reacted with the excess water.

(1)

(iii) Deduce the number of moles of GeX_4 that reacted with the excess water.

(1)

(iv) Calculate the molar mass of GeX_4 and hence identify X.

(2)

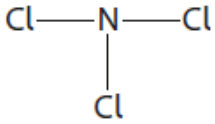
(Total for question = 20 marks)

Q26.

This question is about the structure and bonding of Group 5 chlorides.

(a) Nitrogen trichloride, NCl_3 , has a molecular structure.

The displayed formula of a molecule of NCl_3 is shown.



Complete the table for this molecule.

(3)

Number of bond pairs around N atom	
Number of lone pairs around N atom	
Cl-N-Cl bond angle	
Name of shape of molecule	

(b) Under standard conditions, phosphorus(V) chloride (PCl_5) is a solid made up of PCl_4^+ cations and PCl_6^- anions.

Antimony(V) chloride ($SbCl_5$) is a liquid made up of $SbCl_5$ molecules.

(i) Explain why PCl_5 has a higher melting temperature than $SbCl_5$.

(2)

.....

.....

.....

.....

.....

.....

(ii) Draw a dot-and-cross diagram to show the bonding in a molecule of $SbCl_5$.

Use dots (•) to represent the Sb electrons, and crosses (**x**) to represent the Cl electrons. Show outer electrons only.

(2)

(c) At low temperatures, $SbCl_5$ converts to Sb_2Cl_{10} which contains dative covalent bonds.

(i) State what is meant by the term dative covalent bond.

(1)

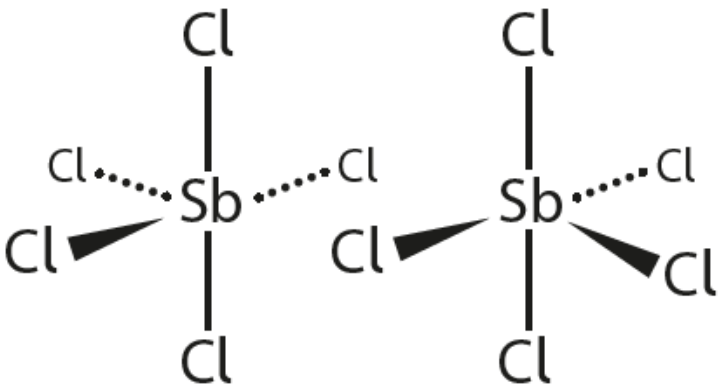
.....

.....

.....

(ii) Complete the diagram to show the dative covalent bonds in Sb_2Cl_{10} .

(1)



(d) Arsenic also forms a pentachloride with the formula $AsCl_5$.

Give **one** possible reason why nitrogen is the only Group 5 element that does **not** form a pentachloride.

(1)

.....

.....

.....

.....

(Total for question = 10 marks)

Q27.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which ion has the electronic configuration $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ in its ground state?

☐ **A** Al^{3+}

☐ **B** Cl^-

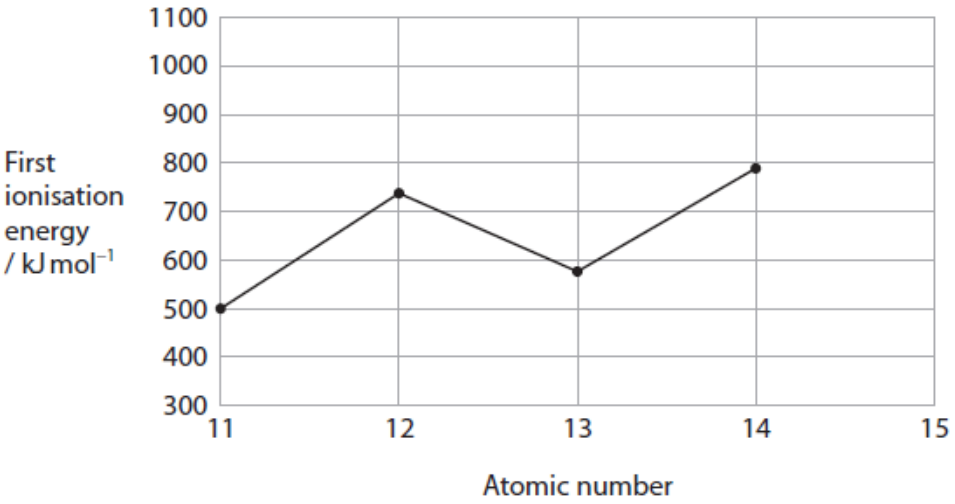
☐ **C** N^{3-}

☐ **D** Na^+

(Total for question = 1 mark)

Q28.

The diagram shows the first ionisation energy for the elements from sodium to silicon.



What is the approximate first ionisation energy, in kJ mol^{-1}, of phosphorus (atomic number 15)?

☒ **A** 400

☒ **B** 500

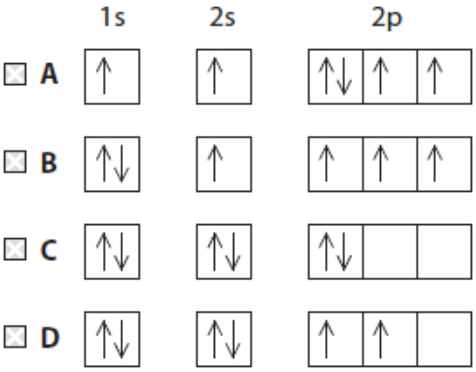
☒ **C** 700

☒ **D** 1000

(Total for question = 1 mark)

Q29.

Which is the electronic configuration of a carbon atom in its ground state?



(Total for question = 1 mark)

Q30.

The first six ionisation energies of an element, in kJ mol^{-1}, are shown.

578 1817 2745 11578 14831 18378

Which group of the Periodic Table includes this element?

☒ **A** Group 2

☒ **B** Group 3

☒ **C** Group 4

☒ **D** Group 5

(Total for question = 1 mark)

Q31.

What is the maximum number of electrons in the 3p subshell, and in the third quantum shell of an atom?

	Maximum number of electrons in the 3p subshell	Maximum number of electrons in the third quantum shell
☒ **A**	2	8
☒ **B**	2	18
☒ **C**	6	8
☒ **D**	6	18

(Total for question = 1 mark)

Q32.

The hydroxide ion, OH^-, has a total of 9 protons.

How many neutrons and electrons are there in this ion?

	Number of neutrons	Number of electrons
☒ **A**	8	8
☒ **B**	8	10
☒ **C**	9	8
☒ **D**	9	9

(Total for question = 1 mark)

Q33.

A sample of silicon contains the following isotopes.

Isotope	Percentage abundance
^{28}Si	81.21
^{29}Si	14.10
^{30}Si	4.69

What is the relative atomic mass of silicon, to one decimal place, in this sample?

☒ **A** 28.0

☒ **B** 28.2

☒ **C** 29.0

☒ **D** 29.8

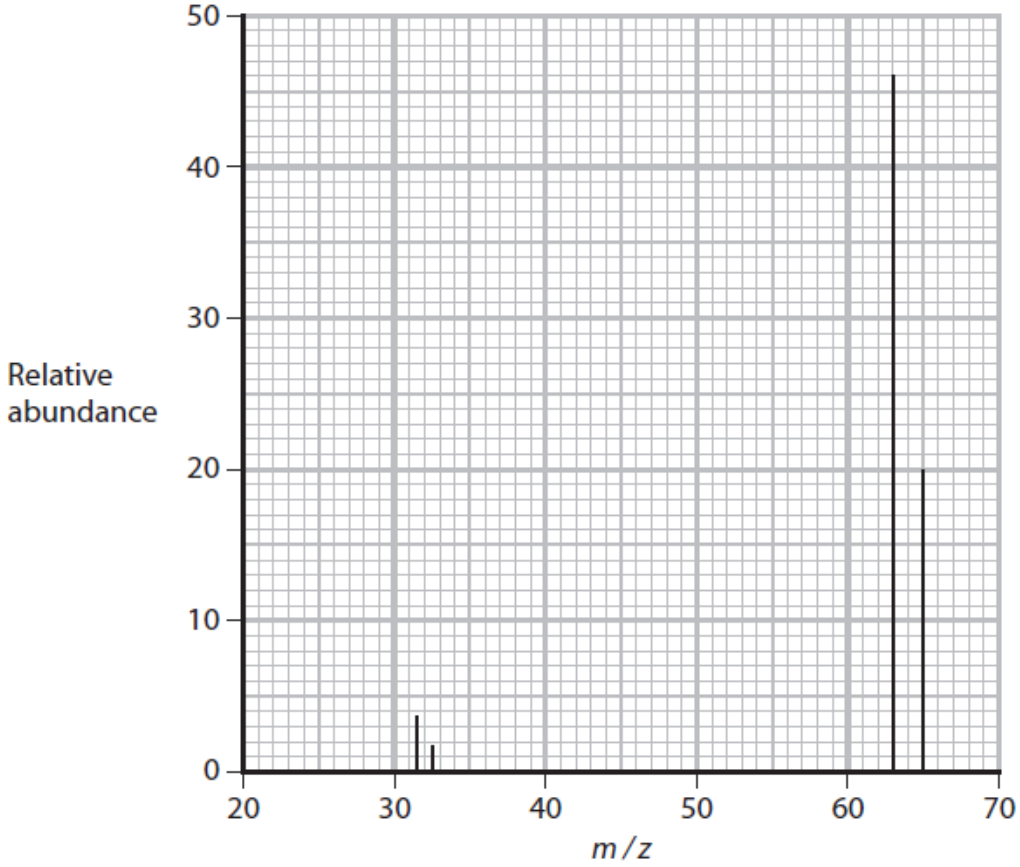
(Total for question = 1 mark)

Q34.

Answer the questions with a cross in the boxes you think are correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new

answer with a cross ☒.

The mass spectrum of a sample of an element is shown.



(a) What is the A_r of the element?

(1)

☒ **A** 42.0

☒ **B** 48.0

☒ **C** 63.6

☒ **D** 64.0

(b) Which species could be responsible for the peak at $m/z = 32.5$?

(1)

☒ **A** $^{32}S^{+}$

☒ **B** $^{63}Cu^{2+}$

☒ **C** $^{65}Cu^{2+}$

☒ **D** $^{98}Tc^{3+}$

(Total for question = 2 marks)

Q35.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which equation represents the **second** ionisation energy of magnesium?

☒ **A** $Mg(g) \rightarrow Mg^{2+}(g) + 2e^-$

☒ **B** $Mg^+(g) \rightarrow Mg^{2+}(g) + e^-$

☒ **C** $Mg(s) \rightarrow Mg^{2+}(s) + 2e^-$

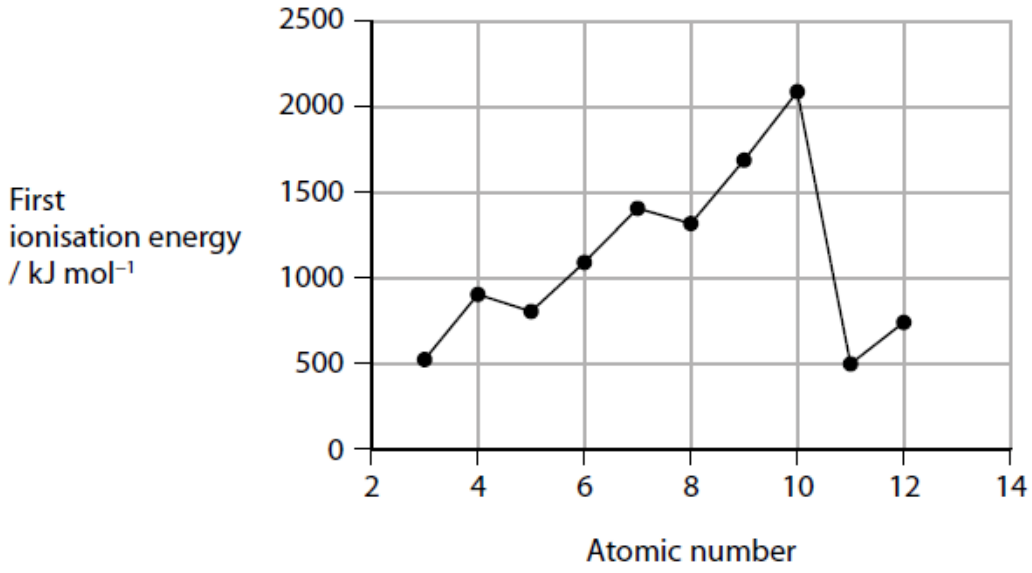
☒ **D** $Mg^+(s) \rightarrow Mg^{2+}(s) + e^-$

Use this space for any rough working. Anything you write in this space will gain no credit.

(Total for question = 1 mark)

Q36.

The graph shows the first ionisation energies for the elements with atomic numbers from 3 to 12.



(a) Write the equation for the first ionisation energy of nitrogen. Include state symbols.

(2)

(b) Explain the changes in first ionisation energy for the elements with atomic numbers from 3 to 10.

(4)

.....

.....

.....

.....

.....

.....

.....

.....

(c) Explain why the first ionisation energy of element 11 is lower than that of element 3.

(2)

.....

.....

.....

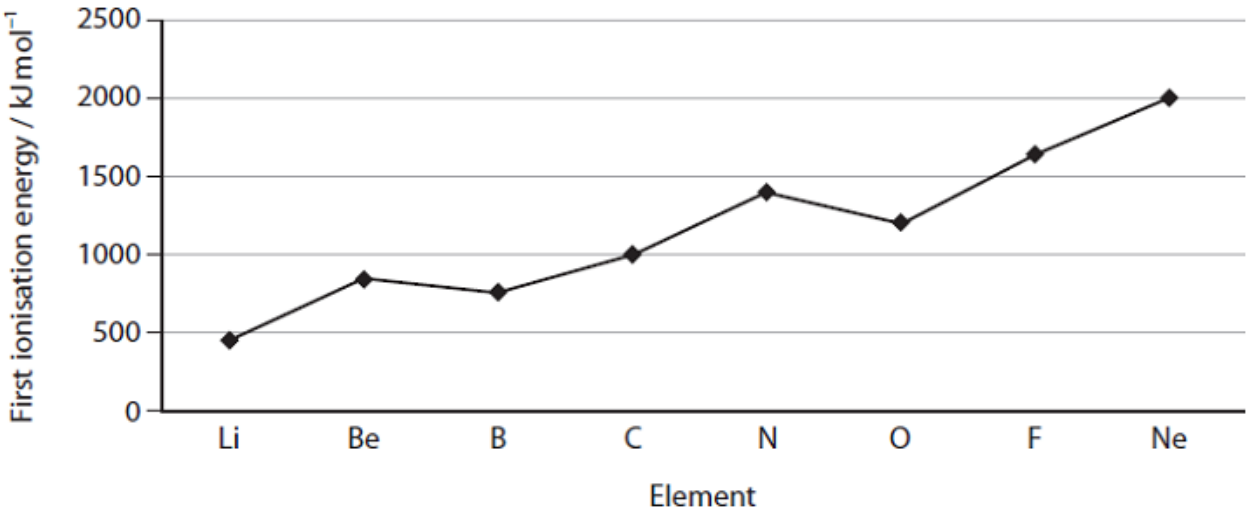
.....

(Total for question = 8 marks)

Q37.

This question is about the ionisation energies of the elements in Period 2 of the Periodic Table.

(a) The first ionisation energies of the Period 2 elements are shown.



(i) Give an equation that represents the first ionisation energy of lithium. Include state symbols.

(1)

(ii) Explain why there is a general increase in the first ionisation energy across the period.

(2)

.....

.....

.....

.....

.....

.....

(iii) Explain why the first ionisation energy of oxygen is lower than that of nitrogen.

(2)

.....

.....

.....

.....

.....

.....

(b) All the successive ionisation energies of nitrogen are shown in the table.

Ionisation number	1	2	3	4	5	6	7
Ionisation energy / kJ mol^{-1}	1402	2856	4578	7475	9445	53 267	64 360

Explain the trend in the successive ionisation energies of nitrogen.

(2)

.....

.....

.....

.....

.....

.....

(Total for question = 7 marks)

Q38.

The decrease in first ionisation energy down Group 1 in the Periodic Table is caused by the **increase** in

(1)

☒ **A** force of attraction between the nucleus and outer electron

☒ **B** number of neutrons in the nucleus

☒ **C** number of protons in the nucleus

☒ **D** shielding of the outer electron from the nuclear charge

(Total for question = 1 mark)

Q39.

What is the equation for the **third** ionisation energy of aluminium?

(1)

☒ **A** $Al(g) \rightarrow Al^{3+}(g) + 3e^-$

☒ **B** $Al(s) \rightarrow Al^{3+}(s) + 3e^-$

☒ **C** $Al^{2+}(g) \rightarrow Al^{3+}(g) + e^-$

☒ **D** $Al^{2+}(s) \rightarrow Al^{3+}(s) + e^-$

(Total for question = 1 mark)

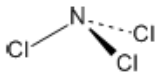
Mark Scheme

Q1.

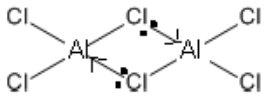
Question number	Answer	Additional guidance	Mark
24(a)	An explanation that makes reference to the following points: • (I) is incorrect because the solutions are aqueous **or** ions are (in the) aqueous (state) the state symbols should be (aq) instead of (I) • silver ions should have one positive charge / Ag^+ **or** silver chloride is AgCl	Allow silver nitrate and sodium chloride are aqueous Do not award if incorrect state symbol for one of the species in the equation e.g. Ag is (s) / AgCl is (aq) Ignore just the charge on the silver ion is incorrect / the formula of silver chloride is incorrect	**(2)**

Question number	Answer	Additional guidance	Mark
(b)	• calculation of mol of C, H and Cl **(1)** • calculation of empirical formula **(1)** • calculation of molecular formula **(1)**	Example of calculation: C : H : Cl mol $\frac{3.09}{12} : \frac{0.26}{1} : \frac{9.15}{35.5}$ = 0.2575 : 0.26 : 0.2577 (ratio 1 : 1 : 1) Empirical formula is CHCl molar mass CHCl = 12 + 1 + 35.5 = 48.5 $\frac{\text{molar mass } (CHCl)_n}{\text{molar mass CHCl}} = \frac{97}{48.5} = 2$ Molecular formula is $C_2H_2Cl_2$ Allow symbols in any order Do not award 2CHCl Ignore SF in mol and ratio Correct molecular formula with some working scores (3) **Alternative method** scores (3) no. C atoms = $\frac{3.09 \times 97}{12.5 \times 12} = 2 / 1.9982$ no. H atoms = $\frac{0.26 \times 97}{12.5 \times 1} = 2(.0176)$ no. Cl atoms = $\frac{9.15 \times 97}{12.5 \times 35.5} = 2$	**(3)**

Question number	Answer	Additional guidance	Mark
(c)(i)	• all 4 ion formulae • all 4 (corresponding) *m* / *z* values	Example of answer: ions *m* / *z* $N(^{35}Cl)_3^+$ 119 $N(^{35}Cl)_2{}^{37}Cl^+$ 121 $N^{35}Cl(^{37}Cl)_2^+$ 123 $N(^{37}Cl)_3^+$ 125 Allow any other unambiguous way of representing the formulae e.g. in words Allow (1) for any two *m* / *z* values with corresponding ion formulae Ignore missing / incorrect charge on ion Ignore mass number on N Ignore bonds or + between Cl atoms / order of atoms e.g. $N\text{-}^{35}Cl\text{-}^{35}Cl\text{-}^{35}Cl$	(2)

Question number	Answer	Additional guidance	Mark
(c)(ii)	• number of bonding pairs **and** number of lone pairs • shape • bond angle	Example of table: Number of bonding pairs of electrons on nitrogen: 3 Number of lone pairs on electrons on nitrogen: 1 Shape of molecule: trigonal pyramidal Bond angle: 107° **Shape:** Allow 3-dimensional drawing e.g.  There must be at least 1 dotted/dashed line or wedge for 3-d Allow just 'pyramidal' Allow pyramid for pyramidal Do not award tetrahedral **Bond angle:** Allow any number in the range 106-108° Ignore missing °	(3)

Question number	Answer	Additional guidance	Mark
24(d)(i)	An explanation that makes reference to one of the following pairs of points: **Polarisation route** • an aluminium ion / cation is (very) small **and** highly charged **or** Al^{3+} has a small ionic radius / is small • so it polarises / distorts the chloride ion / Cl^- / anion **Allow Electronegativity route** • there is a (relatively) small difference in electronegativity between aluminium and chlorine • so the electrons are (partially) shared	Marks must come from the same route – maximum 1 mark if one point from one route and one point from the other route Allow the aluminium ion has a high charge density Allow a description of polarisation Allow chlorine anion / ion Ignore the aluminium chloride is polarised Ignore size of chloride ion	(2)

Question number	Answer	Additional guidance	Mark
24(d)(ii)	A description including the following points: • diagram showing two $AlCl_3$ molecules joined through two chlorine atoms • dative (covalent) bonds **or** coordinate bonds	Example of diagram:  Allow dot-and-cross diagram Ignore missing arrow heads and lone pairs from diagram Do not award diagram with Al-Al / Cl-Cl bond(s) Allow dative covalent bonds labelled on diagram / shown as arrows from Cl to Al Allow description of dative bonds Allow M2 even if only 1 dative bond shown / mentioned Do not award M2 if dative bonds starting from aluminium Do not award M2 for any answer that mentions ions / ionic bonds	**(2)**

Q2.

Q	Answer	Additional guidance	Mark
(a)	• all three numbers correct	Example of table: Number of protons: 26 Number of neutrons: 30 Number of electrons: 24	**1**

Q	Answer	Additional guidance	Mark
(b)	• expression to calculate relative atomic mass **(1)** • correct answer to 3SF **(1)**	Example of calculation: $\frac{(54 \times 5.84) + (56 \times 91.68) + (57 \times 2.17) + (58 \times 0.31)}{100}$ Relative atomic mass (= 55.911) = 55.9 TE on incorrect numbers in correct expression Ignore units of g mol^{-1} or g mol^{-} Do not award other incorrect units e.g. g or % Correct answer with some working scores (2)	**2**

Q	Answer	Additional guidance	Mark
(c)	• ionic equation **(1)** • all state symbols **(1)**	Example of equation: $Mg(s) + Fe^{2+}(aq) \rightarrow Fe(s) + Mg^{2+}(aq)$ Allow multiples State symbols conditional on correct equation Allow state symbols if equation includes correct metals combined with ions with incorrect charges e.g. $3Mg(s) + 2Fe^{3+}(aq) \rightarrow 2Fe(s) + 3Mg^{2+}(aq)$ Or $2Mg(s) + Fe^{2+}(aq) \rightarrow Fe(s) + 2Mg^{+}(aq)$ Allow state symbols for balanced non-ionic equation $Mg(s) + FeSO_4 \rightarrow Fe(s) + MgSO_4(aq)$ or multiples	**2**

Q	Answer	Additional guidance	Mark
(d)	• calculation of mass of oxygen **and** working to find mol **(1)** • calculation of mol of Fe, S and O **(1)** • calculation of simplest whole number ratio **and** deduction of empirical formula **(1)**	Example of calculation: mass of oxygen = 25.00 – 6.98 – 6.03 = 11.99 (g) Fe : S : O mol $\frac{6.98}{55.8}$: $\frac{6.03}{32.1}$: $\frac{11.99}{16.0}$ = 0.12509 : 0.18785 : 0.74938 Ignore SF except 1 SF in M2 ratio 1 : 1.5 : 6 = 2 : 3 : 12 **and** empirical formula is $Fe_2S_3O_{12}$ TE on mol Fe, S and O Allow symbols in any order Correct empirical formula with no working scores (3) Penalise incorrect rounding / truncation of numbers once only in M2 e.g. 0.12 / 0.18 / 0.74 **Note** Allow (3) for correct working with $Fe_2(SO_4)_3$ but $Fe_2(SO_4)_3$ with no working scores (0)	**3**

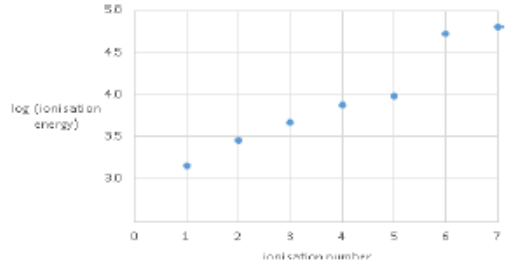
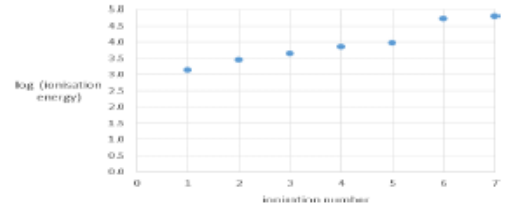
STEMUP.CO.UK

Q	Answer	Additional guidance	Mark
(e)	• calculation of mol of iron(III) oxide **(1)** • calculation of mol of sulfur dioxide **and** mol of sulfur trioxide **(1)** • calculation of mass **and** mol of H_2O **(1)** • calculation of value of x **(1)** • balanced equation **(1)**	Example of calculation: mol Fe_2O_3 = $\frac{2.00}{159.6}$ = 0.012531 / 1.2531 x 10^{-2} mol SO_2 = $\frac{0.80}{64.1}$ = 0.0124805 / 1.24805 x 10^{-2} **and** mol SO_3 = $\frac{1.00}{80.1}$ = 0.012484 / 1.2484 x 10^{-2} mass of H_2O = 6.95 – (2.00 + 0.80 + 1.00) = 3.15 (g) **and** mol of H_2O = $\frac{3.15}{18}$ = 0.175 (mol) Ratio SO_2 : SO_3 : H_2O = 1 :1 : 14 There must be $2FeSO_4$ to produce SO_2 and SO_3 So x = 7 TE on M1, M2, and M3 This mark may be awarded in M5 Example of equation: $2FeSO_4.7H_2O \rightarrow Fe_2O_3 + SO_2 + SO_3 + 14H_2O$ Stand alone mark Allow multiples Allow fractions for numbers of moles TE on value of x in M4 provided equation is balanced Ignore state symbols even if incorrect See next page for alternative methods Alternative methods for M3 and M4:	**5**

Q	Answer	Additional guidance	Mark
		Method 1 mol $FeSO_4$ = 2 x 1.2531 x 10^{-2} = 0.025062 (1) M_r of hydrate = 6.95 / 0.025062 = 277.305 **and** mass of water = 265.34 – 151.9 = 125.405 (g) **and** mol water = 125.405/18 = 6.9669 = 7 (1) **Method 2** mass of water = 6.95 – (2.00 + 0.80 + 1.00) = 3.15 (g) **and** mass of $FeSO_4$ = 3.8(0) (g) (1) mol $FeSO_4$ and water: $FeSO_4$ $\frac{3.80}{151.9}$ = 0.025; H_2O $\frac{3.15}{18}$ = 0.175 simplest ratio: 1 : 7 (1)	
		(Total for Question = 13 marks)	

Q3.

Question number	Answer	Additional guidance	Mark
(a)(i)	• two correct values	(6) (53 268) 4.73 (7) (64 362) 4.81 Both numbers correct and must be to 2 d.p.	(1)

Question number	Answer	Additional guidance	Mark
(a)(ii)	• axes correct way round **and** linear scale points covering at least half the grid horizontally **(1)** • both axes labelled **(1)** • points plotted correctly **(1)**	Example of graph:  Allow  **Labels**: Allow log(IE / kJ mol^{-1}) Do not award log(IE) / kJ mol^{-1} **Points**: TE on values in table for 6th and 7th log(IE) Allow ±1 small square Allow points joined by lines / bar chart Ignore lines drawn from x axis to each point Do not award a best fit straight line Do not award lines joined to the origin	**(3)**

Question number	Answer	Additional guidance	Mark
(a)(iii)	An answer that makes reference to the following: • the range of numbers / 1402 to 64362 is too large (to fit on a graph / axis) **or** logarithms make it easier to plot the numbers	Allow: A (very) long y axis would be needed The difference between the ionisation energies is too large So the numbers will fit on the graph Allow logs give smaller (range of) numbers	**(1)**

Question number	Answer	Additional guidance	Mark
(a)(iv)	An explanation that makes reference to the following points: • the (large) jump (between ionisations 5 and 6) shows the start of a new (quantum) shell **(1)** • there are two electrons that are harder to remove and they are closer to the nucleus **(1)** • there are five electrons that are easier to remove and they are further from the nucleus **(1)**	Penalise use of orbitals instead of shells once only Allow any answer relating the jump / large increase to two (quantum) shells Allow jump linked to **1s** and **2s** sub-shells Do not award jump between incorrect numbers Allow there are two electrons in the inner (quantum) shell Allow there are five electrons in the outer (quantum) shell / five valence electrons	**(3)**

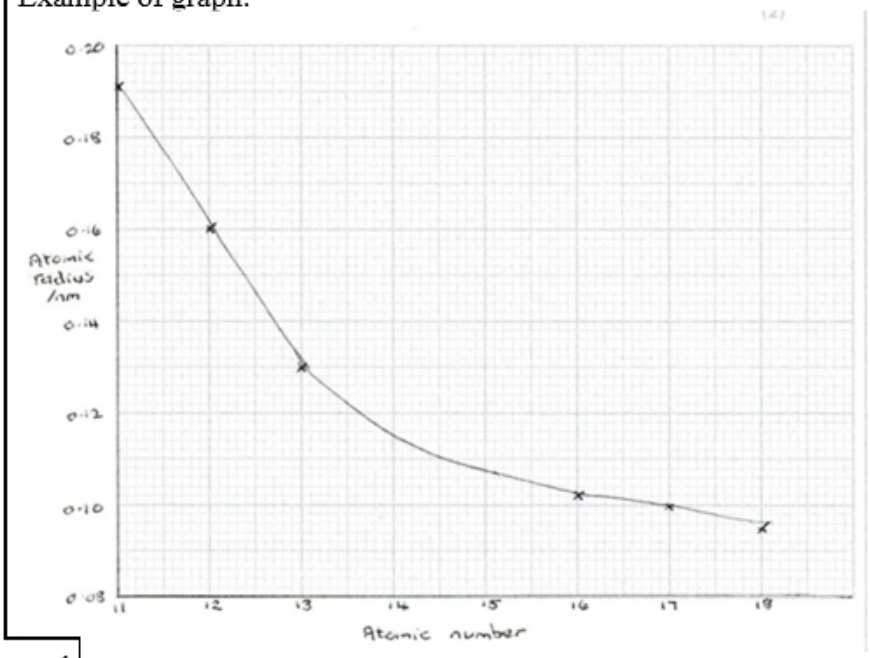
Question number	Answer	Additional guidance	Mark
(a)(v)	An explanation that makes reference to the following points: **Oxygen** • oxygen (atom) loses a paired electron (from a 2p orbital / 2p sub-shell) **or** electron is lost from a full (2p) orbital **(1)** **Nitrogen** • nitrogen (atom) loses an electron from a singly-occupied orbital **or** loses an electron from a half-filled subshell **(1)** **Repulsion** • there is (more) repulsion between **paired** electrons (than between electrons in different orbitals so less energy is required to remove the electron in oxygen) **(1)**	Penalise mention of incorrect orbital e.g. 3p once only Ignore any reference to nuclear charge / numbers of protons / shielding / atomic radius Allow M1 and M2 from diagrams showing electrons in boxes Allow oxygen has a pair of electrons in a (2)p orbital **or** there is spin pairing in oxygen in a (2)p orbital Allow nitrogen has no paired electrons in the (2)p sub-shell / (2)p orbitals **or** nitrogen only has 1 electron in each (2)p orbital / has 3 unpaired (2)p electrons / has a half-filled (2)p sub-shell / has half-filled (2)p orbitals Do not award just 'nitrogen has a half-filled p orbital'	**(3)**

Question number	Answer	Additional guidance	Mark
(b)(i)	• dot-and-cross diagram	Example of dot-and-cross diagram:  Allow overlapping circles Allow all dots / all crosses Allow dots and crosses in any order in the triple bond Allow the dots and crosses side-by-side in the triple bond e.g. x o x o x o Allow the non-bonded electrons on each N shown separately Ignore inner shell electrons, even if incorrect Ignore lines as bonds e.g. x x x o o o	(1)

Question number	Answer	Additional guidance	Mark
(b)(ii)	• calculation of moles of nitrogen atoms • calculation of number of nitrogen atoms	Example of calculation: mol $N_2 = \frac{5.60}{28} = 0.20$ **and** mol N atoms = 0.20 x 2 = 0.40 **or** $\frac{5.60}{14} = 0.40$ number of N atoms = $0.40 \times 6.02 \times 10^{23}$ $= 2.408 \times 10^{23}$ / 2.41×10^{23} / 2.4×10^{23} TE on moles of nitrogen Ignore SF except 1SF Correct answer with no working scores (2)	(2)

Question number	Answer	Additional guidance	Mark
(b)(iii)	• conversion of volume to m^3 **(1)** • conversion of temperature to K **(1)** • rearrangement of ideal gas equation **(1)** • evaluation to give n **(1)**	Example of calculation: volume of $N_2 = \frac{108}{1 \times 10^6} = 1.08 \times 10^{-4}$ m^3 temperature = 25 + 273 = 298 K $n = \frac{pV}{RT}$ **or** $n = \frac{1.36 \times 10^5 \times 1.08 \times 10^{-4}}{8.31 \times 298}$ TE on volume and temperature $n = 5.9312 \times 10^{-3}$ / 0.0059312 (mol) Conditional on correctly rearranged equation in M3 Ignore SF except 1SF Correct answer with no working scores full marks	**(4)**

Q4.

Q	Answer	Additional guidance	Mark
(a)(i)		Example of graph:  	**2**
	• axes correct and labelled with atomic radius /nm and atomic number **(1)**	Allow y axis with 191 etc and label as pm or x 10^{-3} nm Ignore symbols on x axis Do not award M1 if x axis scale starts at 0	
	• points plotted correctly **(1)**	The points for Si / atomic number 14 and P / atomic number 15 do not need to be marked Accept graph with or without line drawn **Comment** If atomic radius is plotted on the x axis, allow (1) for correct graph	

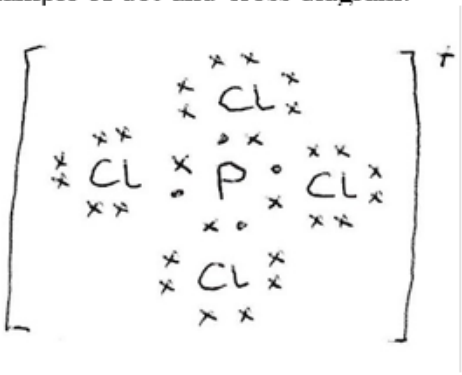
Q	Answer	Additional guidance	Mark
(a)(ii)	• value in allowed range	Allow 0.112 to 0.118 (nm) Allow value written in table Ignore any value given for phosphorus	**1**

Q	Answer	Additional guidance	Mark
(a)(iii)	An explanation that makes reference to the following points: • (as the atomic number increases / across the period) the nuclear charge increases / the number of protons (in the nucleus) increases **(1)** **Any two from:** • this is only partially offset by the increased electron (-electron) repulsion as the number of electrons in the (outer) shell increases **(1)** • the electrons are all the same (quantum) shell / experience similar shielding **(1)** • so there is an increase in attractive force between the nucleus and (outer) electrons **(1)**	Allow effective nuclear charge increases Allow the same amount of shielding Allow same number of (occupied quantum) shells Do not award electrons in the same subshell / orbital	**3**

Q	Answer	Additional guidance	Mark
(b)	• giant for structure of sodium chloride **(1)** • metallic bonding for sodium **(1)** • ionic bonding for sodium chloride **(1)** • intermolecular (forces) for chlorine **(1)** • Na^+ **and** electrons / cations **and** electrons (particles in sodium) **(1)** • Na^+ **and** Cl^- /cations **and** anions (particles in sodium chloride) **(1)**	Allow giant ionic / (giant) lattice Ignore metal Ignore ion(s) Ignore electrostatic attractions in M2 and M3 Accept London / dispersion (forces) Allow van der Waals' (forces) Ignore weak (forces) Allow positive ions **and** electrons Allow sodium atoms / ions **and** electrons Allow positive (sodium) ion and negative (chloride / chlorine) ion Ignore just sodium ions and chloride ions Penalise incorrect charge on an ion once only e.g. Na^{2+}	**6**

Example of table:

Substance	Sodium	Sodium chloride	Chlorine
Melting temperature /°C	(98)	(801)	(−101)
Type of structure	(giant)	giant	(simple molecular)
Type of bond or force broken on melting	metallic	ionic	intermolecular forces
Particles involved	Na^+ **and** electrons / cations **and** electrons	Na^+ **and** Cl^- /cations **and** anions	(chlorine molecules)

Q	Answer	Additional guidance	Mark
(c)(i)	• correct dot-and-cross diagram	Example of dot-and-cross diagram:  Allow any combination of dots and crosses, including all dots or all crosses Allow overlapping circles Allow electrons in bonds along the axis of the bond Ignore missing bracket and charge Ignore lines representing covalent bonds e.g. x	1

Q	Answer	Additional guidance	Mark
(c)(ii)	• Shape – tetrahedral **(1)** • Justification – (four) bonding pairs /pairs of electrons (around P) **(1)** • (electron pairs) arranged to minimise repulsion **(1)**	Stand alone No TE on (c)(i) for shape Allow the number of electron pairs shown in (c)(i) Allow regions of electron density for electron pairs Ignore reference to lone pair-lone pair / lone pair-bond pair repulsion Allow (electron pairs) arranged for maximum separation / as far apart as possible Ignore electron pairs repel equally Penalise use of bonds for electron pairs once only in M2 and M3	3
			(Total for Question = 16 marks)

STEMUP.CO.UK

Q5.

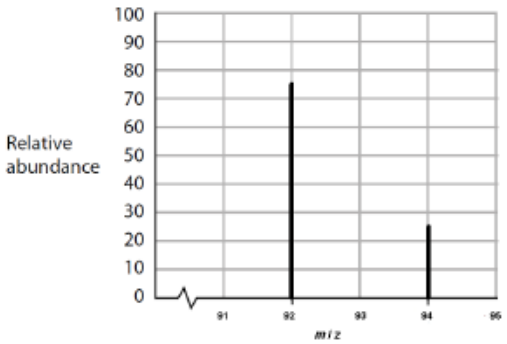
Question number	Answer	Additional guidance	Mark
(a)(i)	• 17 protons (1) • 18 neutrons (1)	Any reference to electrons scores (1) for an answer that includes 17 protons **and** 18 neutrons	(2)

Question number	Answer	Additional guidance	Mark
(a)(ii)	• $(1s^2)2s^22p^63s^23p^6$	Allow $2p_x^2 2p_y^2 2p_z^2$ and/or $3p_x^2 3p_y^2 3p_z^2$ Allow numbers of electrons written as subscripts or large numbers Ignore repeated $1s^2$	(1)

Question number	Answer	Additional guidance	Mark
(a)(iii)	• correct working (1) • answer given to 2 dp (1)	Example of calculation: $\frac{(35 \times 75.53) + (37 \times 24.47)}{100}$ (= 35.4894) or (35 x 0.7553) + (37 x 0.2447) (= 35.4894) 35.49 TE on working involving two different species Correct answer to 2 dp with no working scores (2) 35.50 with no working scores (0) Ignore units, even if incorrect	(2)

Question number	Answer	Additional guidance	Mark
(b)(i)	• dot-and-cross diagram showing three pairs of electrons between one Cl and three F atoms (1) • rest of diagram correct conditional on M1 (1)	Example of dot-and-cross diagram:  Allow overlapping circles Allow all dots / all crosses Allow 4 non-bonded electrons on Cl shown as: 2 lone pairs together or 2 lone pairs between any two of the bonded pairs or 1 lone pair and 2 unpaired electrons or 3 electrons and 1 electron Ignore inner shell electrons / lines for bonds Penalise a charged species in M2 only	(2)

Question number	Answer	Additional guidance	Mark
(b)(ii)	• there are 10 electrons / 5 pairs of electrons in the outer / valence shell of chlorine	Allow there are more than 8 electrons in the outer / valence shell of chlorine Allow there are 3 bond pairs and 2 lone pairs (in the outer shell of chlorine) Allow chlorine has expanded its octet Allow chlorine does not have a noble gas electronic structure / does not have 8 electrons in the outer / valence shell Allow just 'chlorine has 10 electrons' / 'more than 8 electrons' Ignore chlorine is the central atom Ignore just 'chlorine has 2 lone pairs' Do not award incorrect numbers of electrons / orbitals	(1)

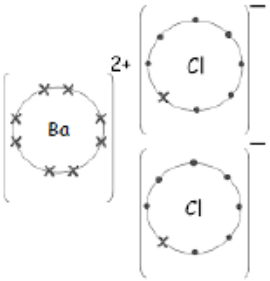
Question number	Answer	Additional guidance	Mark
(b)(iii)	• a peak at *m/z* = 92 (1) • a peak at *m/z* = 94 (1) • peaks at 92 and 94 are in the ratio 3:1 approximately (1)	Example of mass spectrum:  Allow any 3:1 ratio for the peaks e.g. 100:33, 30:10 Ignore any labels on the peaks M3 is a stand alone mark for peaks at 92 and 94 only	(3)

Question number	Answer	Additional guidance	Mark
(b)(iv)	• conversion of temperature to K (1) • rearrangement of Ideal Gas Equation (1) • evaluation to give volume (1) • conversion of volume to cm^3 **and** answer given to 2 or 3 SF (1)	Example of calculation: temperature = 60 + 273 = 333 K $V = \frac{nRT}{P}$ or $V = \frac{0.0200 \times 8.31 \times 333}{1.28 \times 10^5}$ V = 4.3238×10^{-4} (m^3) TE on temperature volume = $4.3238 \times 10^{-4} \times 1 \times 10^6$ = (432.38) = 432 / 430 / 4.32×10^2 / 4.3×10^2 (cm^3) TE on volume in M3 Penalise rounding to 1SF once only in M1, M2 and M3 Correct answer with no working scores full marks	(4)

Q6.

Question Number	Correct Answers	Additional Guidance	Mark
(a)(i)	$Ba^{2+}(g) \rightarrow Ba^{3+}(g) + e^{(-)}$ OR $Ba^{2+}(g) - e^{(-)} \rightarrow Ba^{3+}(g)$	Allow $e^{(-)}(g)$ / $1e^{(-)}$ Do not award multiples Allow ions shown as $Ba^{+2}(g)$ and $Ba^{+3}(g)$ Allow Ba^{++} / Ba^{+++} Comment – allow lower case 'ba^{2+}' etc	1

Question Number	Correct Answers	Additional Guidance	Mark
(a)(ii)	An answer that makes reference to the following: • there is a **large** increase (in ionisation energy) **and** • between the 2nd and 3rd ionisations	Note – there must be some indication of a significant increase Allow just there is a jump Allow 'after 2 electrons are removed' / between the 2nd and 3rd electrons Ignore comments related to first ionisation energy	1

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(i)	An answer that makes reference to one of the following points: • barium ion shown correctly (1) • one chloride ion shown correctly **and** an indication of two chloride ions present (1) example of dot-and-cross diagram  	Allow barium ion with no electrons shown Allow lower case 'ba' Ignore any inner shells shown for Ba^{2+} If inner shells shown for Cl^- they must be correct Allow all dots or all crosses Ignore absence of square brackets Ignore any working Do not award covalent diagrams Comment If all charges are omitted, we assume the bonding is covalent so scores zero	2

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(ii)	• calculation of moles of barium chloride (1) • calculation of mass of barium chloride to 2 or 3 SF (1)	<u>Example of calculation</u> $0.200 \times (150 \div 1000) = 0.03$ (mol) Ignore units in M1 even if incorrect $0.03 \times 208.3 = 6.249$ = 6.2 / 6.25 (g) Do not award 6.3 Ignore absence of units but if given must be correct in M2 Correct answer with no working scores 2 marks Allow 0.03 x 208 = 6.24 / 6.2 for M2 Allow TE from M1 to M2	2

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(iii)	$2H^+ + CO_3^{2-} \rightarrow H_2O + CO_2$	Accept $2H_3O^+ + CO_3^{2-} \rightarrow 3H_2O + CO_2$ Allow H_2CO_3 Allow multiples Ignore state symbols even if incorrect Do not award uncancelled chloride ions	1

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)	An answer that makes reference to the following point: • (the) ions are not free to move (and carry charge) / (the) ions are in a fixed position (so cannot carry charge)	Do not award 'electrons are not free to move' Do not award if any statement that $BaCl_2$ is covalent	1

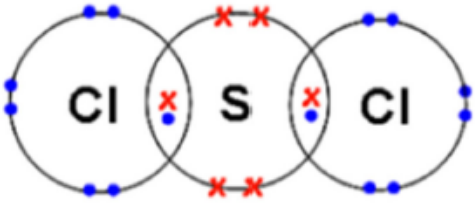
Q7.

Question Number	Answer	Additional Guidance	Mark
(a)(i)	• (metallic bonding is) the **attraction** between positive ions/cations and **delocalised** electrons	Can be shown as a labelled diagram including the word **attraction.** Allow **electrostatic forces** as an alternative to **attraction** Allow **attraction** between metal ions and **delocalised** electrons Allow **attraction** between (positive) nuclei and **delocalised** electrons Ignore just 'ions' Ignore free moving electrons/ sea of electrons	**(1)**

Question Number	Answer	Additional Guidance	Mark
(a)(ii)	An explanation that makes reference to three of the following points • M1 Mg has more **delocalised** electrons **(1)** • M2 Mg^{2+} is smaller (than Na^+) **(1)** • M3 Mg^{2+} has a higher charge (than Na^+) **(1)** • M4 Greater attraction between the **delocalised** electrons and the Mg^{2+} ions/ Mg^{2+} nuclei **(1)**	Allow Mg loses two electrons **and** Na one to form **delocalised** electrons Ignore free moving electrons Allow Mg ion is smaller (than Na^+) Allow Mg smaller ionic radius Do not award atomic radius Allow Mg ion has a higher charge (than Na^+) Ignore the number of protons Just Mg^{2+} 'has a greater charge density' scores (1) for M2 & M3 Allow greater attraction between the delocalised electrons and Mg Ignore attraction to the protons Ignore outer shell electrons Allow reverse argument for all points	**(3)**

Question Number	Answer	Additional Guidance	Mark
(b)(i)	• (the electrostatic attraction between) the shared (pair of) electrons and the (two) nuclei (of the bonded atoms)	Allow single nucleus	**(1)**

Question Number	Answer	Additional Guidance	Mark
(b)(ii)	An explanation that makes reference to the following points: • phosphorus (P) simple molecular **(1)** • silicon (Si) giant (covalent/molecular) structure **(1)** • when phosphorus melts weak London forces are broken **and** when silicon melts strong covalent bonds are broken **(1)**	Allow (small) molecules/ P_4/ just 'molecular'/simple covalent Allow lattice instead of giant Ignore macromolecular Do not award giant metallic/ionic Allow / dispersion /van der Waals forces/ instantaneous dipole-induced dipole/intermolecular forces Do not award if any mention of intermolecular forces for silicon.	**(3)**

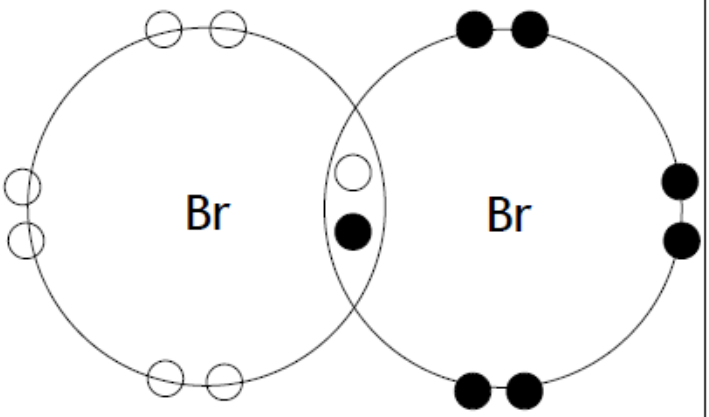
Question Number	Answer	Additional Guidance	Mark
(c)(i)	An explanation that makes reference to the following points: • dot-and-cross diagram showing two shared pairs of electrons between S and Cls (1) • rest of diagram correct (1)	Example of dot-and-cross diagram  Allow all dots/all crosses/dots crosses the wrong way round Allow the non-bonded pairs of electrons on S and Cl anywhere and allow non-bonding electrons unpaired. Ignore inner shells Charged species/ions scores 0	(2)

Question Number	Answer	Additional Guidance	Mark
(c)(ii)	An answer that makes reference to the following points: • bond angle 104.5(°) (1) • four pairs of electrons/ 2 bonding pairs and 2 lone pairs occupy a position of minimum repulsion (1) • (2)lone pairs repel more than bonding pairs (so the angle is reduced from 109.5 (°)) (1)	Allow 102-105 (actual answer 103°) Allow just electron pairs occupying a position of minimum repulsion and do not penalise for an incorrect number of electron pairs if quoted. Allow maximum separation Ignore bonds/ areas of electron density/atoms Ignore any reference to shapes e.g. angular, V-shaped	(3)

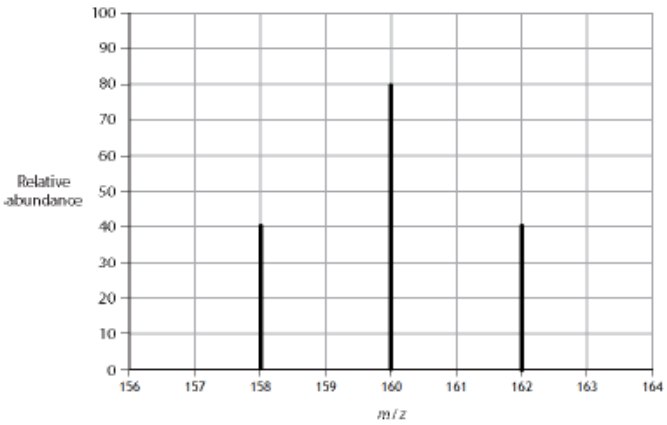
Q8.

Question number	Answer	Additional guidance	Mark
(a)	An answer that makes reference to • (atoms with the) same atomic number and different mass numbers	Accept proton number for atomic number or same number of protons but different numbers of neutrons Allow bromine-79 has 35 protons & 44 neutrons **and** bromine-81 has 35 protons & 46 neutrons Allow "an atom" or "element" Do not award molecule Ignore same number of electrons	1

Question number	Answer	Additional guidance	Mark
(b)	An answer that makes reference to: • all subatomic particles correct for bromine-79 (1) • all subatomic particles correct for bromine-81 (1)	<table><tr><th>Protons</th><th>Neutrons</th><th>Electrons</th></tr><tr><td>35</td><td>44</td><td>35</td></tr><tr><td>35</td><td>46</td><td>35</td></tr></table> Any four correct scores 1	2

Question number	Answer	Additional guidance	Mark
(c)(i)	A diagram showing: • one shared pair of electrons (1) • six non-bonding electrons on **both** atoms in the molecule (1)	Example of diagram:  Accept shared electrons on circles between the atoms Accept omission of circles or chemical symbols Allow any symbols for the electrons or elements (even if incorrect) Allow non-bonding electrons to be unpaired Allow horizontal sharing of bond pair Ignore horizontal line representing the bond	2

Question number	Answer	Additional guidance	Mark
(c)(ii)	An answer that makes reference to: • (a beam of) high energy electrons striking the (gaseous) bromine (molecule) (1) • equation for the formation of the molecular ion (1)	Both marks may be scored with a correct equation and any indication the **bombarding** electrons are high energy Allow 'high speed electrons' Allow electron gun Allow "fast moving" Allow bromine atoms $Br_2 + e^{(-)} \rightarrow Br_2^+ + 2e^{(-)}$ Allow $Br_2 \rightarrow Br_2^+ + e^{(-)}$ $Br_2 - e^{(-)} \rightarrow Br_2^+$ Allow $^{81}Br^{81}Br$ (etc) instead of Br_2 on either side of the equation Ignore state symbols even if incorrect Do not award $Br_2 \rightarrow 2Br^+ + 2e^{(-)}$ or $\frac{1}{2}Br_2 \rightarrow Br^+ + e^{(-)}$	2

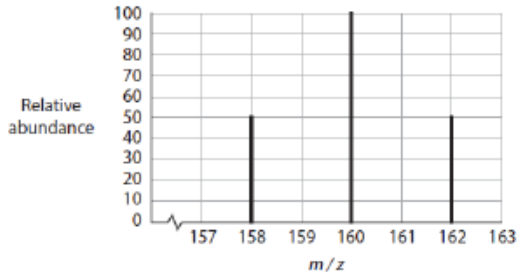
Question number	Answer	Additional guidance	Mark
(c)(iii)	An answer on the grid showing: • three peaks: at *m/z* = 158, *m/z* = 160 and *m/z* = 162 (1) • peak heights in the ratio 1:2:1 (for 158: 160: 162) (1)	Example of grid:  Allow bars or "X" at the top of any lines Allow bars shown around the m/z values Do not award if a line is drawn from peak to peak Do not award if more than three peaks Allow any abundance values No TE on incorrect *m/z* values	2

Question number	Answer	Additional guidance	Mark
(d)	• weighted mean mass expression (1) • evaluation of relative atomic mass for Br (1) • calculation of relative molecular mass for Br_2 corrected to 2 d.p. (1)	Example of calculation: $A_r = \frac{79 \times 56.38 + 81 \times 43.62}{100}$ = 79.87 2 x 79.87 = 159.74 = 159.74 Allow TE to M2 for values between 79 and 81 Allow TE for M3 of double M2 value Ignore units even if incorrect Penalise rounding errors once only Correct answer to 2 d.p. scores (3) A **final** answer of 79.9 or 79.872 only scores 1 mark	3

Q9.

Question number	Answer	Additional guidance	Mark
(a)	• $[Ar]3d^{10}4s^24p^5$	Allow $4s^23d^{10}4p^5$ Ignore $1s^22s^22p^63s^23p^6$ for (Ar) written out but do not allow incorrect electronic configuration for Ar	1

Question number	Answer					Additional guidance	Mark
(b)(i)						1 mark for each row correct	2
	Species	Protons	Neutrons	Electrons			
	^{79}Br	35	44	35	(1)		
	$^{81}Br^-$	35	46	36	(1)		

Question number	Answer	Additional guidance	Mark
(b)(ii)	 • lines at 158 and 160 and 162 (1) • relative abundances 50:100:50 (1)	Allow relative abundances in any ratio 1:2:1, e.g. 25:50:25	2

Question number	Answer	Additional guidance	Mark
(b)(iii)	• calculation of amount (mol) of Br_2 (1) • calculation of molecules of Br_2 (1)	Example of calculation: Amount of Br_2 = $\frac{2.00}{160}$ = 0.0125 (mol) Molecules of Br_2 = $0.0125 \times 6.02 \times 10^{23}$ = 7.525×10^{21} or Amount of Br_2 = $\frac{2.00}{(2 \times 79.9)}$ = 0.012516 (mol) Molecules of Br_2 = $0.012516 \times 6.02 \times 10^{23}$ = 7.5344×10^{21} TE on amount Br_2 Correct answer with no working scores both marks Ignore SF except 1 SF	2

Question number	Answer	Additional guidance	Mark
(c)	• conversion of volume to m^3 (1) • conversion of temperature to K (1) • rearrangement of expression (1) • evaluation to give n (1)	Example of calculation: Volume of bromine = $\frac{200}{1 \times 10^6} = 2.00 \times 10^{-4}$ m^3 77+273 = 350 $1.51 \times 10^5 \times 2.00 \times 10^{-4} = n \times 8.31 \times 350$ TE on volume bromine $n = \frac{1.51 \times 10^5 \times 2.00 \times 10^{-4}}{8.31 \times 350}$ $n = 1.03834 \times 10^{-2}$ Ignore SF except 1SF Correct answer with no working scores full marks	4

Q10.

Question Number	Correct Answer	Mark
	The only correct answer is D (9) *A is incorrect because it is the number of occupied quantum shells* *B is incorrect because it is the number of occupied subshells* *C is incorrect because the electrons in the 3p subshell have been paired before each orbital is occupied*	1

Q11.

Question Number	Answer	Additional Guidance	Mark
(a)	An answer that makes reference to the following points • Cu ([Ar]) $3d^{10}\ 4s^1$ **(1)** • Cu^{2+} ([Ar]) $3d^9$ **(1)**	ALLOW $4s^1\ 3d^{10}$ ALLOW $4s^0\ 3d^9$ Ignore $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ in both cases	**(2)**

Question Number	Answer	Additional Guidance	Mark
(b)(i)	<table><tr><th>Isotope</th><th>Protons</th><th>Neutrons</th><th>Electrons</th></tr><tr><td>^{63}Cu</td><td>29</td><td>34</td><td>29</td></tr><tr><td>^{65}Cu</td><td>29</td><td>36</td><td>29</td></tr></table> **(1)** **(1)**	One mark for each correct row Four or five correct scores one mark Ignore working	**(2)**

Question Number	Answer	Additional Guidance	Mark
(b)(ii)	An answer that makes reference to the following points: • (atoms/elements that have) same number of protons/same proton number/ quoted same number of protons even if wrong **(1)** • (but) different numbers of neutrons/neutron number **(1)**	Ignore any reference to electrons but do not award if different to the number of protons Ignore if they state the wrong number of neutrons in the 2 isotopes. If they fail to mention numbers of protons and neutrons 'same atomic number but different mass number' scores (1) Do not award atomic mass for mass number Do not award molecules but penalise once only	**(2)**

STEMUP.CO.UK

Question Number	Answer	Additional Guidance	Mark
(b)(iii)	• (isotopes have) the same electronic configuration	Allow same electron arrangement/electron(ic) structure Allow the same number of electrons Ignore the same number of protons Ignore the same number of electrons in the outer shell/same number of valence electrons Ignore same period/same group Ignore any given electronic configurations/number of electrons even if wrong Ignore any reference to neutrons	(1)

Question Number	Answer	Additional Guidance	Mark
(b)(iv)	An explanation that makes reference to the following points: • expression relating isotopic masses A_r and X **(1)** • abundance of (Cu) 63 = 0.8 or 80% **(1)** abundance of (Cu) 65 = 0.2 or 20% Alternative method 65- 63.4 = 1.6 63.4-63 = 0.4 **(1)** 0.4/2.0 × 100 = 20% 65 1.6/2.0 × 100 = 80% 63 **(1)**	Example of calculation $63.4 = \frac{(1-X) \times 65) + (X \times 63)}{1}$ $63.4 = 65 - 65X + 63X$ $63.4 = 65 - 2X$ $-1.6 = -2X$ $X / 63 = 0.8$ OR $63.4 = \frac{(1-X) \times 63) + (X \times 65)}{1}$ $63.4 = 63 - 63X + 65X$ $63.4 = 63 + 2X$ $0.4 = 2X$ $X / 65 = 0.2$	(2)

		OR $63.4 = \frac{(100 - X) \times 65) + (X \times 63)}{100}$ $6340 = 6500 - 65X + 63X$ $6340 = 6500 - 2X$ $-160 = -2X$ $X / 63 = 80\%$ OR $63.4 = \frac{(100 - X) \times 63) + (X \times 65)}{100}$ $6340 = 6300 - 63X + 65X$ $6340 = 6300 + 2X$ $40 = 2X$ $X / 65 = 20\%$ Correct answer with or without working scores (2)	

Question Number	Answer	Additional Guidance	Mark
(c)(i)	• a correct balanced equation	$CuCO_3 + H_2SO_4 \rightarrow CuSO_4 + CO_2 + H_2O$ or $CuCO_3 + 2H^+ \rightarrow Cu^{2+} + CO_2 + H_2O$ Allow multiples Ignore state symbols even if incorrect Do not award H_2CO_3 as a product	(1)

Question Number	Answer	Additional Guidance	Mark
(c)(ii)	• M1moles of sulfuric acid **(1)** • M2 maximum mass of copper(II) sulfate **(1)** • M3 percentage yield calculation **(1)** • M4 answer to 2 or 3 SF **(1)** • M1moles of sulfuric acid **(1)** • M2 moles of copper sulfate **(1)** • M3 percentage yield calculation **(1)** • M4 answer to 2 or 3 SF **(1)** Correct answer with some working scores (4)	<u>Example of calculation</u> $50 \times 1.00 \div 1000 = 0.05$ (mol) / 5×10^{-2} (mol) $0.05 \text{ (mol)} \times 249.6 = 12.48$ (g) Allow TE on M1 $100 \times 10.87 \div 12.48 = 87.099$ Allow TE on M2 unless over 100% 87(%) / 87.1(%) Alternative method $50 \times 1.00 \div 1000 = 0.05$ (mol) / 5×10^{-2} (mol) 10.87 (g) / 249.6 (g) = 0.04355 (mol) /4.355×10^{-2} (mol) $100 \times 4.355 \times 10^{-2} / 5 \times 10^{-2} = 87.099$ Allow TE on M1 and M2 unless over 100% 87(%) / 87.1(%) M4 dependent on a sensible calculation that involves either a mass or moles that has been calculated. Ignore incorrect rounding by truncating intermediate figures eg 0.435 (mol)	**(4)**

Q12.

Question Number	Answer	Mark
	The only correct answer is D (number of neutrons) **A** *is not correct because one atom would be in an excited state* **B** *is not correct because one would be an ion* **C** *is not correct because these would be different elements*	**(1)**

Q13.

Question Number	Answer	Mark
	The only correct answer is A ($1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$) **B** *is not correct because the wrong electron has been removed* **C** *is not correct because this is the electronic structure of the atom* **D** *is not correct because this is the electronic configuration of a* Sc^{3-} *ion*	**(1)**

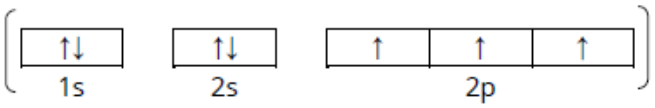
Q14.

Question number	Answer	Mark
	The only correct answer is C (Ti^{2+}) *A is incorrect because* K^+ *has the electronic structure shown* *B is incorrect because* Ca^{2+} *has the electronic structure shown* *D is incorrect because* Sc^{3+} *has the electronic structure shown*	**(1)**

Q15.

Question number	Answer	Mark
	The only correct answer is D ($1s^2\ 2s^2\ 2p^6$) *A is incorrect because this would be for losing three electrons* *B is incorrect because this would be for the nitrogen atom* *C is incorrect because this would be for gaining one electron*	**(1)**

Q16.

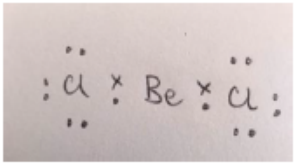
Question number	Answer	Mark
	The only correct answer is C  ***A*** *is not correct because the paired 1s and 2s electrons have parallel spin* ***B*** *is not correct because the paired electrons have parallel spin and the 2p electrons do not have parallel spin* ***D*** *is not correct because the unpaired 2p electrons do not have parallel spin*	**1**

Q17.

Question number	Answer	Mark
	D 	1

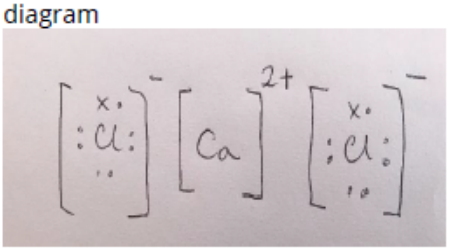
Q18.

Question Number	Answer	Additional Guidance	Mark
(a)	• $2s^2$ **(1)** • $2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$ **(1)**	Ignore extra $1s^2$ for both Be and Ca Accept $p_x^2\ p_y^2\ p_z^2$ for p^6	**(2)**

Question Number	Answer	Additional Guidance	Mark
(b)	Answer that shows ..... • 2 single covalent bonds **(1)** • 6 non-bonding electrons shown on chlorine **(1)**	Example of correct dot-and-cross diagram:  Allow non-bonding electrons unpaired Allow all dots or all crosses Allow shared electrons on the axis of the bond If Ca in place of Be Max 1 Ignore line showing covalent bond Ignore overlapping circles Ionic bond scores 0 overall Reject incorrect total number of electrons for M2	**(2)**

Question Number	Answer	Additional Guidance	Mark
(c)	• a line/covalent bond is when electron(s) come from both/each atom(s) **(1)** • arrow / dative covalent/ co-ordinate bond which is (a lone pair of) electrons donated from chlorine/ (only) one atom **(1)**	Ignore references to attraction between bonding pair and nucleus. Do not award any statement stating that the donation comes from Beryllium	**(2)**

Question Number	Answer	Additional Guidance	Mark
(d)	• bond angle in $BeCl_2$(g)/linear is 180° **(1)** • bond angle in $BeCl_2$(s)/polymeric is 109.5° **(1)** • electron pairs/bonds repel each other to minimise repulsion **(1)** • 4 electron pairs/bonds in solid **or** 2 bonding pairs/2 bonds (no lone pairs) in gas	Ignore references to shape ALLOW any bond angle between 110 ° and 95 °. [98° actual value] Ignore references to shape Allow to a maximum separation Do not award repulsion between atoms/elements or between lone pairs Ignore references to lp-lp/lp-bp repulsion	**(4)**

Question Number	Answer	Additional Guidance	Mark
(e)	• correct charges shown and two chloride ions (1) • electronic configuration of all ions (1)	Example of correct dot-and-cross diagram  Accept Ca with 8 electrons Allow all dots or all crosses or any combination Ignore inner electron shells	(2)

Question Number	Answer	Additional Guidance	Mark
(f)	• Beryllium is smaller /has fewer electron shells/ has a higher charge density (than calcium) OR beryllium is more electronegative (than calcium) (1) • Beryllium ion/ Be^{2+} is more polarising (than calcium /ion Ca^{2+}) OR calcium loses (outer) electrons more easily (than beryllium) OR difference in electronegativity between calcium and chlorine is greater (than between beryllium and chlorine) (1) • beryllium-chlorine bond has a higher degree of covalency (than calcium-chlorine bond)	Allow beryllium is more polarising than calcium Accept bonding in beryllium chloride is (more) covalent/ bonding in calcium chloride is (more) ionic. M3 is dependent on either M1 or M2 being scored Allow reverse arguments throughout	(3)

Q19.

Question number	Answer	Mark
	B 2 electrons in a 2p orbital, 18 electrons in the third quantum shell	1

Q20.

Question number	Answer	Mark
	The only correct answer is C (iron) ***A*** *is incorrect because argon is in the p-block* ***B*** *is incorrect because chlorine is in the p-block* ***D*** *is incorrect because sodium is in the s-block*	**(1)**

Q21.

Question Number	Answer	Mark
	The only correct answer is B ($A^+(g) \rightarrow A^{2+}(g) + e^-$) **A** *is not correct because this shows the first plus the second ionisation* **C** *is not correct because this shows the third ionisation* **D** *is not correct because this shows the third plus the fourth ionisation*	**(1)**

Q22.

Question number	Answer	Mark
	The only correct answer is D ($I(g) \rightarrow I^+(g) + e^-$) ***A*** *is not correct because the iodine is molecular and in the solid state and forms 2 mol of ions* ***B*** *is not correct because the iodine is molecular and forms 2 mol of ions* ***C*** *is not correct because the iodine is molecular and in the solid state*	**1**

Q23.

Question Number	Answer	Mark
	The only correct answer is B (28.2) **A** *is not correct because 28.0 is the mode of these values* **C** *is not correct because the relative abundance at 28 has not been properly taken into account* **D** *is not correct because 29.0 is the median of these values*	**(1)**

Q24.

Question Number	Correct Answer	Mark
(a)	**The only correct answer is B** (element V) *A is incorrect because in element U each p orbital contains a single electron* *C is incorrect because in element W two p orbitals contain electron pairs* *D is incorrect because in element X three p orbitals contain electron pairs*	1

Question Number	Correct Answer	Mark
(b)	**The only correct answer is B** (element X) *A is incorrect because element S is in Group 3* *C is incorrect because element Y is in Group 1* *D is incorrect because element Z is in Group 2*	1

Question Number	Correct Answer	Mark
(c)	**The only correct answer is D** (element Y) *A is incorrect because in element S the second electron is not removed from an inner shell* *B is incorrect because in element T the second electron is not removed from an inner shell* *C is incorrect because in element X the second electron is not removed from an inner shell*	1

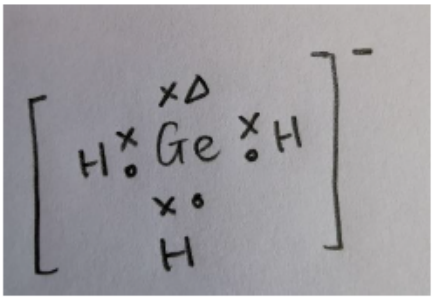
Q25.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	An explanation that makes reference to the following points: • **atoms** (of the same element) with the same number of protons / **atoms** with same atomic number / **atoms** with same proton number **(1)** • with a different number of neutrons / neutron number / mass number **(1)**	NOTE answers with no reference to atoms can score 1 max for correct statements about the number of protons and neutrons or atomic number and mass number e.g. 'elements with same number of protons but different number of neutrons' scores 1 mark e.g. 'isotopes have the same atomic number and different mass number' scores 1 mark Ignore references to same number of electrons Ignore references to relative atomic mass	**2**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)	• numerator of weighted mean expression **(1)** • calculation of relative atomic mass **(1)**	Example of calculation $(70 \times 20.6) + (72 \times 27.4) + (73 \times 7.7) + (74 \times 36.7) + (76 \times 7.6)$ $\frac{(70 \times 20.6) + (72 \times 27.4) + (73 \times 7.7) + (74 \times 36.7) + (76 \times 7.6)}{100}$ = 72.703 / 72.70 / 72.7 TE on one transcription error Final answer must be to at least 1 decimal place Correct answer with no working scores 2 Ignore units	**2**

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)	• $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^2$	Allow [Ar] $3d^{10}4s^2 4p^2$ Allow $4s^2$ immediately before $3d^{10}$ Allow $3p_x^2 3p_y^2 3p_z^2$ Allow numbers of electrons not shown as superscripts Allow upper case letters for 'S', 'P' and 'D'	**1**

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(i)	• calculation of $\sum M_r$ (all reactants) / $\sum M_r$ (all products) (1) • calculation of atom economy as a percentage (1)	Example of calculation 46+72.6 +48+23+10.8+4+18 = 222.4 / 72.6+4+80+23+10.8+32) = 222.4 (76.6 ÷ 222.4) × 100 = 34.442% Allow TE in M2 from M1 provided atom economy is less than 100% Allow use of A_r = 72.7 for Ge calculated in (b) which gives the answer 34.472% Ignore SF except 1 SF	2

Question Number	Acceptable Answers	Additional Guidance	Mark
(d) (ii)	An explanation that makes reference to the following points: • 3 bond pairs between Ge atom and **three** H atoms (1) • lone pair on Ge atom (and charge on ion) (1)	 Allow any combination of dots and / or crosses Ignore missing charge on ion Ignore lines showing covalent bonds	2

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(iii)	An answer that makes reference to the following points: • trigonal pyramid(al) (1) • angle between 106 and 108° (1)	Allow pyramidal Comment – the correct shape and angle are standalone marks. However allow trigonal planar and 120° for 2 marks if (d)(ii) shows only 3 bond pairs.	2

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(iv)	• calculation of maximum mass of germane in laboratory in mg **(1)** • conversion of mass from mg to g **(1)** • calculation of moles of germane **(1)** • calculation of maximum number of germane molecules in laboratory **(1)** NOTE – do not award M1 and M2 if there is evidence that candidates believe the values 147.84 / 0.14784 are moles. Such answers are likely to only be able to access M4	Example of calculation $0.640 \times 231 = 147.84$ (mg) $147.84 \div 1000 = 0.14784$ (g) Allow TE from M1 to M2 $= 0.14784 \div 76.6 = 1.9300 \times 10^{-3}$ (mol) Allow TE from M2 to M3 $1.9300 \times 10^{-3} \times 6.02 \times 10^{23} = 1.1619 \times 10^{21}$ (molecules) Allow TE from M3 to M4 Allow use of 76.7 for 76.6 giving 1.1604×10^{21} Correct answer with no working scores 4 marks Ignore SF except 1 SF	4

Question Number	Acceptable Answers	Additional Guidance	Mark
(e)(i)	• calculation of moles of carbon dioxide	$(335.5 \div 24000)$ $= 0.013979 / 1.3979 \times 10^{-2}$ (mol) Ignore SF except 1 SF	1

Question Number	Acceptable Answers	Additional Guidance	Mark
(e)(ii)	• answer to (i) × 2	(0.013979×2) $= 0.027958 / 2.7958 \times 10^{-2}$ (mol) Ignore SF except 1 SF Allow TE from (i)	1

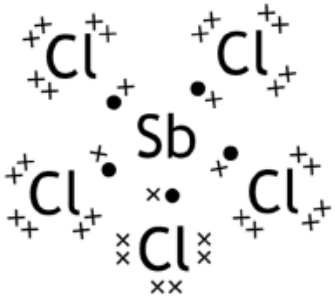
Question Number	Acceptable Answers	Additional Guidance	Mark	
(e)(iii)	• answer to (ii) ÷ 4	$(0.027958 \div 4)$ $= 0.0069896 / 6.9896 \times 10^{-3}$ (mol) Ignore SF except 1 SF Allow TE from (ii)	1	

Question Number	Acceptable Answers	Additional Guidance	Mark
(e)(iv)	• 1.50 ÷ (answer to (iii)) (1) • identification of X (1)	$1.50 \div 6.9897 \times 10^{-3} =$ 214.6 ($g\ mol^{-1}$) 214.6 – 72.6 = 142.01 142.01 ÷ 4 = 35.501 ; so X = Cl Allow TE from (iii) Must be some correct working to score M2	2

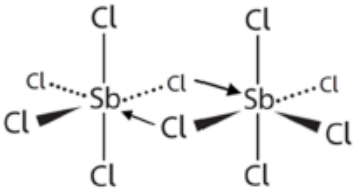
Q26.

Question Number	Answer	Additional guidance	Mark
(a)	A completed table showing: • correct number of bond pairs **and** lone pairs (1) • correct Cl–N–Cl bond angle (1) • correct name of shape (1)	**Mark all points independently** Number of bond pairs around N atom: 3 Number of lone pairs around N atom: 1 Cl–N–Cl bond angle: 107(o) Allow 106(o) – 108(o) Name of shape of molecule: (Trigonal) pyramidal Allow pyramid Ignore tetrahedral Do not award bipyramidal	3

Question Number	Answer	Additional guidance	Mark
(b)(i)	An explanation that makes reference to the following points: • strong(er) (electrostatic) attraction between ions (in PCl_5) (1) • (than) weak intermolecular forces (in $SbCl_5$) (1)	**Mark M1 and M2 independently** Ignore reference to solid/liquid Allow strong ionic bonds / strong ionic lattice Allow strong attraction between positive and negative charges Allow strong attraction between cations and anions / PCl_4^+ and PCl_6^- Ignore just PCl_5 is (giant) ionic Do not award reference to PCl_5 molecules/ intermolecular forces Do not award reference to breaking of covalent bonds Accept just London/van der Waals/dispersion/ temporary-induced dipole/instantaneous-induced dipole forces Ignore just $SbCl_5$ is (simple) molecular Do not award reference to breaking of covalent/ionic bonds Ionic bonding is stronger than intermolecular forces scores (2)	2

Question Number	Answer	Additional guidance	Mark
(b)(ii)	Dot-and-cross diagram showing the following: • central Sb with five bond pairs and no lone pairs (1) • five Cl atoms each with one bond pair and three lone pairs (1)	**Mark M1 and M2 independently** Example of dot-and-cross diagram:  TE on M1 for three or four Cl atoms Allow any combination of crosses and dots Allow circles to indicate outer shells Ignore inner shells Ignore lines showing the covalent bonds	2

Question Number	Answer	Additional guidance	Mark
(c)(i)	• suitable description of a dative covalent bond	For credit to be awarded, it must be clear that: i) a pair of / two electrons are involved ii) these electrons are shared/bonding iii) these electrons come from the same atom eg shared electrons in which both electrons come from the same atom eg lone pair/full orbital from one atom overlaps with empty orbital of another Allow element for atom Allow just both electrons in the bond come from the same element Allow one element donates/gives/shares both electrons to the bond Allow one atom shares both electrons Do not award just one atom donates/gives both electrons (or any reference to ions being formed) Do not award ion/molecule/species for atom	1

Question Number	Answer	Additional guidance	Mark
(c)(ii)	• two correct dative covalent bonds shown as arrows	 Ignore lone pairs shown on Cl Do not award dative bonds from any other Cl atoms	1

Question Number	Answer	Additional guidance	Mark
(d)	An answer that makes reference to one of the following points: • no 2d orbitals **or** (nitrogen) cannot expand its octet **or** • (nitrogen is) too small (to bond to 5 atoms) **or** • repulsion between electron **pairs** would be too great	Accept reverse arguments Allow no d orbitals as only two (quantum) shells Allow no d orbitals (accessible) Allow (nitrogen) cannot have more than eight electrons in its outer shell Ignore just cannot expand its outer/valence shell Ignore just nitrogen obeys the octet rule Ignore just (nitrogen has a) very small/smallest atomic radius Ignore Cl atoms too large Ignore nitrogen has fewest/only two shells Ignore just repulsion between electron pairs Ignore repulsion between Cl atoms Ignore not enough room for 5 electron pairs	1

Q27.

Q	Answer	Mark
	The only correct answer is B (Cl^-) ***A*** *is incorrect because* Al^{3+} *has electronic configuration* $1s^2 2s^2 2p^6$ ***C*** *is incorrect because* N^{3-} *has electronic configuration* $1s^2 2s^2 2p^6$ ***D*** *is incorrect because* Na^+ *has electronic configuration* $1s^2 2s^2 2p^6$	1

Q28.

Question number	Answer	Mark
	The only correct answer is D (1000) ***A*** *is incorrect because this is less than the first ionisation energy of sodium and phosphorus has 4 more protons* ***B*** *is incorrect because this is less than the first ionisation energy of aluminium and phosphorus has 2 more protons* ***C*** *is incorrect because this is less than the first ionisation energy of silicon and phosphorus has 1 more proton*	**(1)**

Q29.

Question number	Answer	Mark
	The only correct answer is D  ***A*** *is incorrect because the 1s and 2s electrons should be paired* ***B*** *is incorrect because the 2s electrons should be paired* ***C*** *is incorrect because the 2p electrons should not be paired*	**(1)**

Q30.

Question number	Answer	Mark
	The only correct answer is B (Group 3) ***A*** *is incorrect because the biggest jump is after the third ionisation energy not after the second* ***C*** *is incorrect because the biggest jump is not after the fourth ionisation energy* ***D*** *is incorrect because the biggest jump is not after the fifth ionisation energy*	**(1)**

Q31.

Question number	Answer	Mark
	The only correct answer is D (3p subshell 6, third quantum shell 18) ***A*** *is incorrect because 2 is the number of electrons in a 3p orbital and the 3d electrons have been omitted from the third quantum shell* ***B*** *is incorrect because 2 is the number of electrons in a 3p orbital* ***C*** *is incorrect because the 3d electrons have been omitted from the third quantum shell*	**(1)**

Q32.

Question number	Answer	Mark
	The only correct answer is B (8 neutrons and 10 electrons) ***A*** *is incorrect because in a negative ion the number of electrons should be more than the number of protons* ***C*** *is incorrect because the numbers of neutrons and electrons are incorrect* ***D*** *is incorrect because oxygen has 8 neutrons and hydrogen has 0*	**(1)**

Q33.

Question number	Answer	Mark
	The only correct answer is B (28.2) ***A*** *is incorrect because this is the mass number of the most abundant isotope* ***C*** *is incorrect because this is the average of the mass numbers without considering their abundances* ***D*** *is incorrect because the percentages have been mixed up*	**(1)**

Q34.

Question number	Answer	Mark
(a)	**The only correct answer is C** (63.6) *A is incorrect as this is the answer when the abundance of the single charge peaks are used but are divided by 100* *B is incorrect because this is the average of the mass of all the ions with the abundancies not considered* *D is incorrect because this is the A_r when the mass of the two single charge peaks are averaged with the abundancies not considered*	(1)

Question number	Answer	Mark
(b)	**The only correct answer is C** ($^{65}Cu^{2+}$) *A is incorrect because sulphur would not produce the rest of the peaks* *B is incorrect because this is the peak at 31.5* *D is incorrect because this would give a peak at 32.7*	(1)

Q35.

Q	Answer	Mark
	The only correct answer is B ($Mg^{+}(g) \rightarrow Mg^{2+}(g) + e^{-}$) ***A*** *is incorrect because this represents the first and second ionisations* ***C*** *is incorrect because this represents the first and second ionisations and the state symbols are incorrect* ***D*** *is incorrect because the state symbols are incorrect*	**1**

Q36.

Question number	Answer	Additional guidance	Mark
(a)	• correct species in equation (1) • correct state symbols (1)	Examples of equation: $N(g) \rightarrow N^{+}(g) + e^{(-)}$ or $N(g) - e^{(-)} \rightarrow N^{+}(g)$	2

Question number	Answer	Additional guidance	Mark
(b)	An explanation that makes reference to the following points: • general increase across a period/atomic numbers 3-10 due to increase in nuclear charge (1) • the (outer) electrons are added to the same quantum shell or the shielding is the same. (1) Irregularities: • atom with atomic number 5 has lower IE than atom with atomic number 4 as the (2)p electron is better shielded than the (2)s electron (so requires less energy to be removed) (1) • atom with atomic number 8 has lower IE than atom with atomic number 7 as there is repulsion between the pair of electrons in the 2(p) orbital (so less energy is required to remove one of them). (1)	Allow increase in effective nuclear charge Accept reverse arguments Accept names for atomic numbers Allow the 2p sub-shell is further from the nucleus than the 2s orbital Allow a half-filled p sub shell is more stable	4

Question number	Answer	Additional guidance	Mark
(c)	An explanation that makes reference to the following points: • (decrease down a group due to) (there is an increase in nuclear charge from 3 to 11 but this is offset by) the outer electron is in a higher quantum shell/higher energy level (1) • therefore further from the nucleus/better shielded. (1)		2

Q37.

Question Number	Answer	Additional Guidance	Mark
(a)(i)	• $Li(g) \rightarrow Li^{+}(g) + e^{(-)}$	Both species and states must be correct Allow $Li(g) - e^{(-)} \rightarrow Li^{+}(g)$ Ignore state symbol on e^{-}	(1)

Question Number	Answer	Additional Guidance	Mark
(a)(ii)	An explanation that makes reference to the following points: • (on moving across the period) there is an increase in the number of protons/atomic number/nuclear charge **(1)** • (The electrons are in the same shell so there is a) greater attraction between the nucleus and electron(s) **(1)**	Allow effective nuclear charge Allow smaller atomic radius Allow same/ similar shielding Allow attraction between protons and electrons	**(2)**

Question Number	Answer	Additional Guidance	Mark
(a)(iii)	An explanation that makes reference to the following points: Oxygen (even though it has one more proton) • M1 the electron is being removed from a (2)**p orbital** that is **paired / full** **(1)** • M2 less energy is needed to remove a **paired** electron / there is repulsion between the **paired** electrons **(1)** OR Nitrogen (even though it has one fewer proton) • M1 the electron is being removed from a (2) **p orbital** that is **unpaired** **(1)** • M2 more energy is needed to remove an **unpaired** electron **(1)**	Allow the electron is being removed from the **pair** of electrons in the (2)**p sub-shell** Allow the **p orbital** contains **two electrons** Do not award p shell Do not award 3p Allow there is spin-pair repulsion Allow easier to remove a paired electron Allow there is repulsion between the electrons if pairing or 2 electrons of full orbital is mentioned in M1 Allow the electron is being removed from a half-filled (2)**p sub-shell** Allow the electron is being removed from a (2)**p orbital** that only contains **one** electron. Do not award p shell Do not award 3p Allow more energy is required to remove this electron if unpaired is mentioned in M1 Allow this arrangement is stable, so more energy is needed to remove the electron M1 can be scored with a diagram Ignore reference to shielding/lone pairs	**(2)**

STEMUP.CO.UK

Question Number	Answer	Additional Guidance	Mark
(b)	An answer that makes reference to two of the following points: ○ M1 (General increase because there is the same positive charge) but fewer electrons/ less repulsion between elections/ electrons getting closer to the nucleus/ ion becoming increasingly more positive/increase in effective nuclear charge **(1)** ○ M2 there is a big jump between 5^{th}-6^{th} ionisation energies as the 6^{th} electron is removed from a new shell/ quantum shell/ energy level (closer to the nucleus) **(1)** ○ M3 there is a jump between 3^{rd} - 4^{th} ionisation energies as the 4^{th} electron is removed from a new sub shell/2s (closer to the nucleus) **(1)**	Allow there is a big jump between 5^{th}-6^{th} ionisation energies as nitrogen has 5 electrons in its outer shell Ignore it is in group 5 Allow there is a big jump between 5^{th}-6^{th} ionisation energies as the inner electrons have no shielding	**(2)**

Q38.

Question number	Answer	Mark
	The only correct answer is D (shielding of the outer electron from the nuclear charge) *A is incorrect because the force of attraction between the nucleus and outer electron decreases* *B is incorrect because neutrons do not affect ionisation energy* *C is incorrect because if this were the only reason, the ionisation energies would increase*	1

Q39.

Question number	Answer	Mark
	The only correct answer is C ($Al^{2+}(g) \rightarrow Al^{3+}(g) + e^-$) *A is incorrect because ionisation energies are successive so only one electron is lost at a time* *B is incorrect because the state symbols are incorrect and ionisation energies are successive so only one electron is lost at a time* *D is incorrect because the state symbols are incorrect*	**(1)**

Q1.

The first three ionisation energies of carbon are shown.

	1st	2nd	3rd
Ionisation energy / kJ mol^{-1}	1086	2353	4621

Which is the approximate fourth ionisation energy, in kJ mol^{-1}, of carbon?

(1)

☒ **A** 3500

☒ **B** 6200

☒ **C** 11 000

☒ **D** 38 000

(Total for question = 1 mark)

Q2.

Aluminium is an abundant metal with many uses.

(a) The first four ionisation energies of aluminium are shown.

Ionisation number	Energy / kJ mol^{-1}
1	578
2	1820
3	2750
4	11 600

Explain how this information shows that aluminium is in Group 3 of the Periodic Table.

(2)

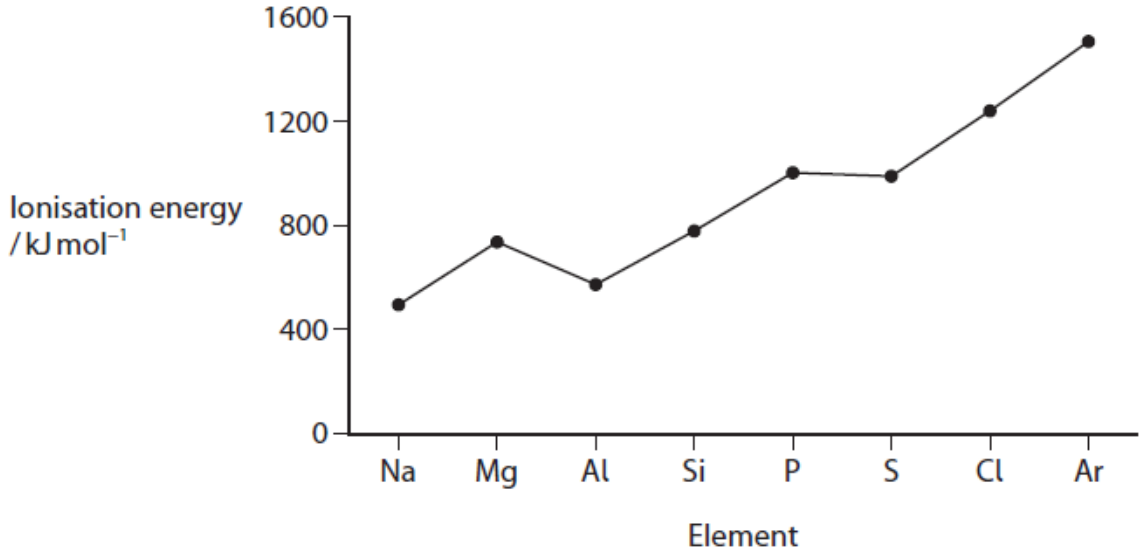
.....

.....

.....

.....

(b) The graph shows the first ionisation energies for the elements in Period 3.



(i) Explain the general increase in the first ionisation energy from sodium to argon.

(2)

.....

.....

.....

.....

(ii) Explain why the first ionisation energy of aluminium is less than the first ionisation energy of magnesium.

(2)

.....

.....

.....

.....

(c) (i) Describe the bonding in aluminium metal.

(2)

.....

.....

.....

.....

(ii) Give two possible reasons why aluminium is used for overhead power cables.

(2)

.....

.....

.....

.....

(d) New uses for waste aluminium cans are being investigated. One possible use is to make nanoparticle alloys to produce hydrogen for fuel.

(i) Aluminium nanoparticles react with water to produce aluminium oxide and hydrogen.

Complete the following equation. State symbols are not required.

(1)

..... Al + ... H_2O → ..... + ...

(ii) Give **two** possible reasons for producing hydrogen from aluminium rather than from fossil fuels.

(2)

.....

.....

.....

.....

.....

(Total for question = 13 marks)

Q3.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The numbers of subatomic particles present in four species **W**, **X**, **Y** and **Z** are given in the table.

Species	Number of protons	Number of neutrons	Number of electrons
W	19	20	18
X	19	20	19
Y	20	20	18
Z	20	22	20

Which of these species are isotopic?

☒ **A** **W** and **X**

☒ **B** **W** and **Y**

☒ **C** **X** and **Z**

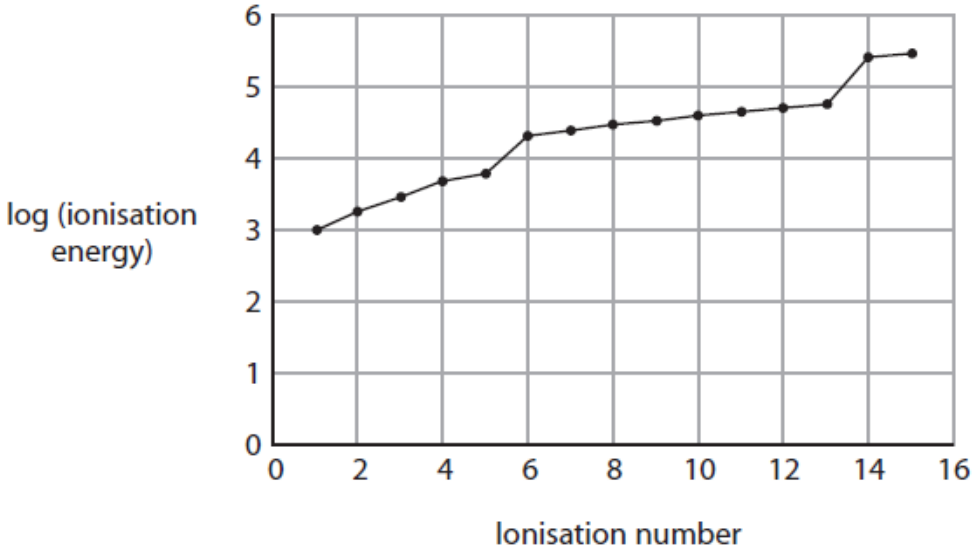
☒ **D** **Y** and **Z**

(Total for question = 1 mark)

Q4.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The graph shows log (ionisation energy) against ionisation number for the successive ionisations of an element.



In this element, how many quantum shells contain electrons, and how many electrons are in the

outer quantum shell?

	Number of quantum shells containing electrons	Number of electrons in the outer quantum shell
☒ **A**	3	2
☒ **B**	3	5
☒ **C**	5	2
☒ **D**	5	5

(Total for question = 1 mark)

Q5.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Iodine exists as one isotope with mass number 127.

Chlorine exists as two isotopes with mass numbers 35 and 37.

How many molecular ion (ICl_3^+) peaks are there in the mass spectrum of ICl_3?

☒ **A** 2

☒ **B** 3

☒ **C** 4

☒ **D** 5

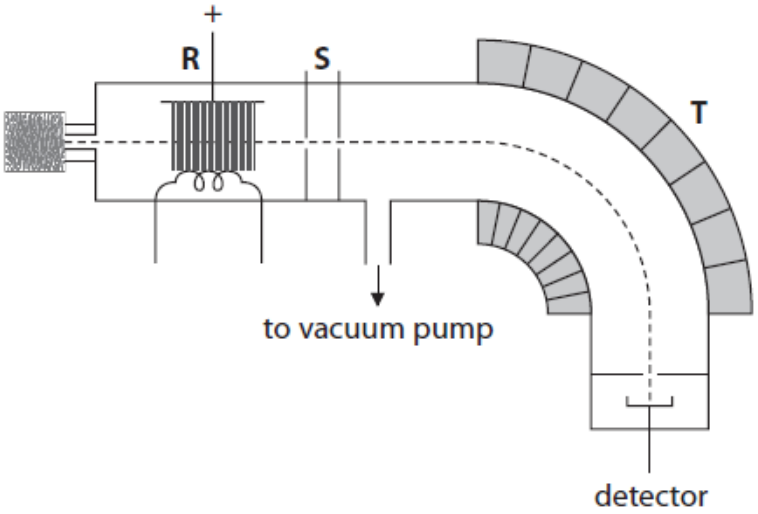
(Total for question = 1 mark)

Q6.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new

answer with a cross ☒ .

The diagram shows a mass spectrometer.



(a) Which process occurs in region **R**?

(1)

☒ **A** the sample is vaporised using a heater

☒ **B** electrons are removed from molecules or atoms and positive ions are formed

☒ **C** electrons are added to the molecules or atoms and negative ions are formed

☒ **D** ions are accelerated by an electric field

(b) Which statement is correct for region **T**?

(1)

☒ **A** ions with a greater mass have a smaller deflection

☒ **B** ions with a greater mass have a greater deflection

☒ **C** ions with a greater charge have a smaller deflection

☒ **D** ions are speeded up by a magnetic field

(Total for question = 2 marks)

Q7.

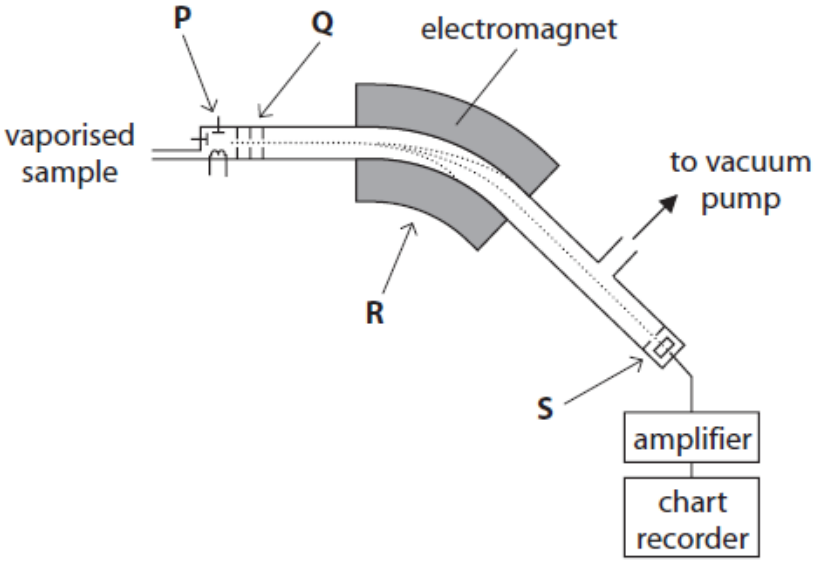
Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer

with a cross ☒.

Mass spectrometers are used in chemical analysis.

(a) In which region of this mass spectrometer are the ions accelerated?

(1)



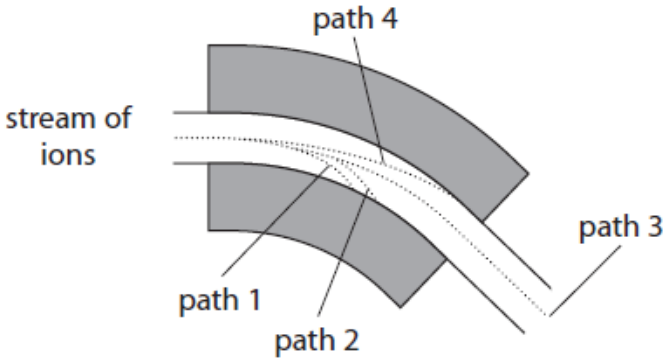
☒ **A** region **P**

☒ **B** region **Q**

☒ **C** region **R**

☒ **D** region **S**

(b) Four iron ions are present in a stream of ions in a mass spectrometer. The paths of these ions are shown.



Which of these ions will follow path 1 through the mass spectrometer?

(1)

☒ **A** $^{54}Fe^{+}$

☒ **B** $^{54}Fe^{2+}$

☒ **C** $^{56}Fe^{+}$

☒ **D** $^{56}Fe^{2+}$

(c) Naturally-occurring chlorine has two isotopes, ^{35}Cl and ^{37}Cl.

How many peaks due to the singly-charged **molecular** ions are seen in the mass spectrum of chlorine, Cl_2?

(1)

☒ **A** 1

☒ **B** 2

☒ **C** 3

☒ **D** 4

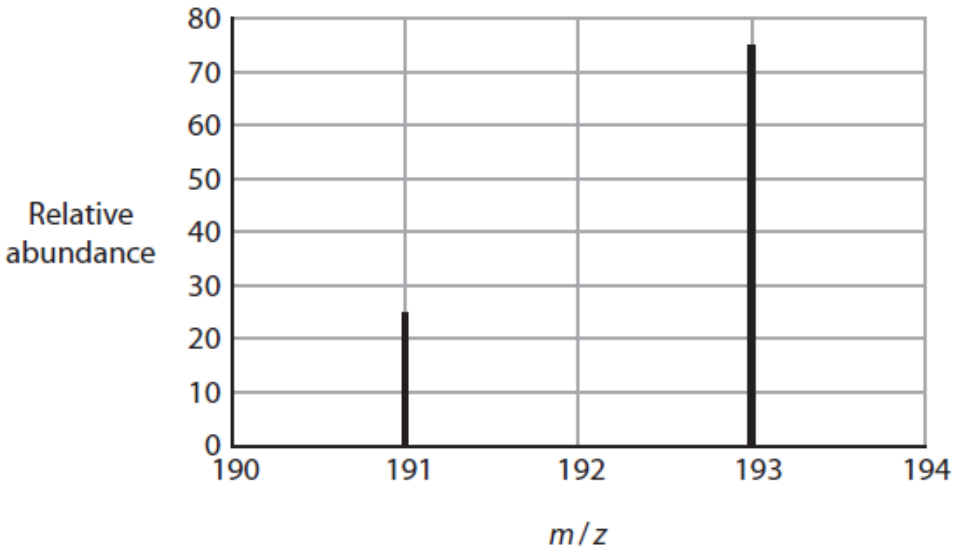
(Total for question = 3 marks)

Use this space for any rough working. Anything you write in this space will gain no credit.

Q8.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The mass spectrum of a sample of an element has only two peaks.



What is the approximate relative atomic mass of the element in this sample?

☒ **A** 191.5

☒ **B** 192.0

☒ **C** 192.5

☒ **D** 193.0

(Total for question = 1 mark)

Q9.

Data from the mass spectrum of a sample of pure iron is given in the table.

m / z	Relative peak height
28	0.1
54	6.3
56	100.0
57	2.4
58	0.3

Which species is most likely to cause the peak at $m/z = 28$?

(1)

☒ **A** $^{28}Fe^{+}$

☒ **B** $^{56}Fe^{2+}$

☒ **C** $^{28}Si^{+}$

☒ **D** $^{84}Sr^{3+}$

(Total for question = 1 mark)

Q10.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

The **Period 2** element with the **highest** melting temperature is

☒ **A** aluminium

☒ **B** boron

☒ **C** carbon

☒ **D** silicon

(Total for question = 1 mark)

Q11.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

Which of these atoms has the most neutrons?

☒ **A** $^{115}_{49}In$

☒ **B** $^{124}_{50}Sn$

☒ **C** $^{123}_{51}Sb$

☒ **D** $^{124}_{52}Te$

(Total for question = 1 mark)

Q12.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The element manganese has the atomic number $Z = 25$.

What are the numbers of s, p and d electrons in an atom of manganese?

	s electrons	p electrons	d electrons
☒ **A**	6	12	7
☒ **B**	8	12	5
☒ **C**	6	18	1
☒ **D**	8	17	0

Use this space for any rough working. Anything you write in this space will gain no credit.

(Total for question = 1 mark)

Q13.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

A p-block element in **Period 3** of the Periodic Table reacts to form an ionic compound.

What could be the electronic configuration of the **ion** formed by this element?

☒ **A** $1s^2 2s^2 2p^6 3s^2$

☒ **B** $1s^2 2s^2 2p^6 3s^2 3p^6$

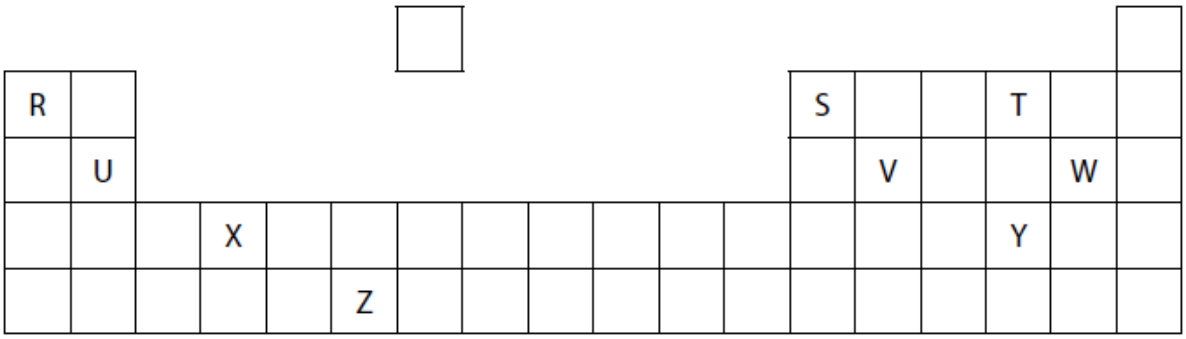
☒ **C** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$

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

(Total for question = 1 mark)

Q14.

An outline of part of the Periodic Table is shown.
The letters are not the usual symbols of the elements.



(a) Which elements are in the s-block of the Periodic Table?

(1)

☒ **A** R and U

☒ **B** T and Y

☒ **C** V and W

☒ **D** X and Z

(b) Which element has four occupied quantum shells, with six electrons in the outermost shell?

(1)

☒ **A** V

☒ **B** X

☒ **C** Y

☒ **D** Z

(c) In which pair do the ions have the same electronic configuration?

(1)

☒ **A** R^{+} and T^{2-}

☒ **B** T^{2-} and Y^{2-}

☒ **C** U^{2+} and T^{2-}

☒ **D** U^{2+} and W^{-}

(Total for question = 3 marks)

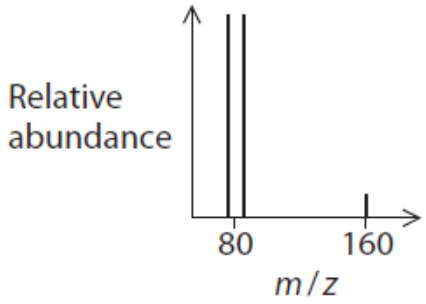
Q15.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

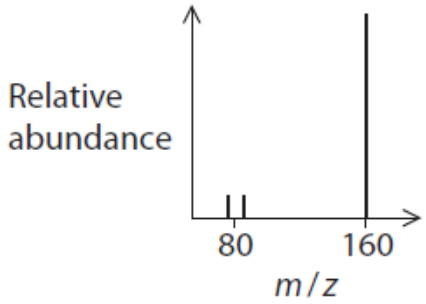
The two stable isotopes of bromine have relative masses of 79 and 81.

Which is the correct pattern of peaks in the mass spectrum of molecular bromine?

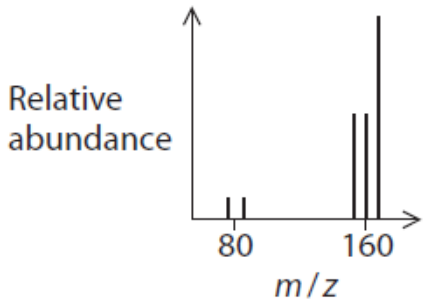
☒ **A**



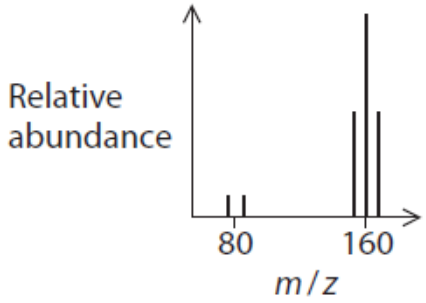
☒ **B**



☒ **C**



☒ **D**



(Total for question = 1 mark)

Q16.

This question is about phosphorus and some of its compounds.

(a) The atomic number of phosphorus is 15.

(i) Complete the electronic configuration of a phosphorus atom using the electrons-in-boxes notation.

(1)



(ii) Explain why the first ionisation energy of phosphorus is greater than that of sulfur.

(2)

.....

.....

.....

.....

.....

.....

(b) Phosphorus has a melting temperature of 44 °C.

Silicon has a melting temperature of 1410 °C.

Explain why the melting temperature of phosphorus is much lower than that of silicon.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(c) Phosphorus(V) chloride, PCl_5 , exists as covalent molecules in the gaseous state.

(i) Complete the table for a PCl_5 molecule.

(3)

Number of bonding pairs of electrons on phosphorus		
Number of lone pairs of electrons on phosphorus		
Shape of molecule		
Cl—P—Cl bond **angles**		

(ii) In the solid state, phosphorus(V) chloride is ionic.

The cation and anion each have one phosphorus atom but a different number of chlorine atoms.

The cation is tetrahedral and the anion is octahedral.

Predict the formula of each ion. Include the charge on each ion.

(2)

.....

.....

(d) In an experiment, 8.00 cm^3 of 0.250 mol dm^{-3} sodium hydroxide, NaOH, reacted completely with 10.0 cm^3 of 0.100 mol dm^{-3} phosphoric acid, H_3PO_4 .

Use these data to deduce the balanced equation for this reaction.
You **must** show your working.

(3)

(e) Hydrated magnesium phosphate has the formula $Mg_3(PO_4)_2.\mathbf{y}H_2O$.

A sample of this compound contains 78.5% by mass of anhydrous magnesium phosphate.

Deduce the value of **y**.

You **must** show your working.

[Molar mass of anhydrous magnesium phosphate, $Mg_3(PO_4)_2$ = 262.9 g mol^{-1}]

(2)

(Total for question = 16 marks)

Q17.

This question is about phosphorus and sulfur.

Which species contains 15 protons, 16 neutrons and 18 electrons?

(1)

☒ **A** P^{3-}

☒ **B** P^{3+}

☒ **C** S^{2-}

☒ **D** S^{2+}

(Total for question = 1 mark)

Q18.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A stable ion, $\mathbf{M^{3+}}$, contains 18 electrons.

In which block of the Periodic Table is element **M** found?

☒ **A** s

☒ **B** p

☒ **C** d

☒ **D** f

(Total for question = 1 mark)

Q19.

A sample of neon contains the following isotopes.

Isotope	Percentage abundance
^{20}Ne	90.92
^{21}Ne	0.26
^{22}Ne	8.82

What is the relative atomic mass of neon to two decimal places?

(1)

☒ **A** 20.00

☒ **B** 20.09

☒ **C** 20.18

☒ **D** 21.00

(Total for question = 1 mark)

Q20.

This question is about silicon and carbon.

(a) Silicon is a semiconductor.

(i) Data obtained using the mass spectrum of silicon are shown.

Isotope mass number	Relative abundance
28	92.17
29	4.71
30	3.12

Calculate the relative atomic mass of silicon to **two** decimal places.

(2)

(ii) Suggest a reason why there is a small peak in the mass spectrum of silicon at $m/z = 14$

(1)

.....

.....

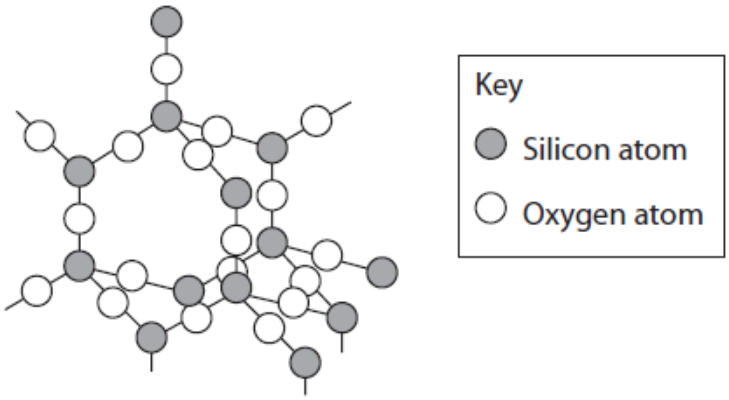
.....

(iii) Complete the table to show the number of protons and neutrons in each isotope of silicon.

Isotope	Number of protons	Number of neutrons
^{28}Si		
^{29}Si		
^{30}Si		

(1)

(b) Silicon dioxide, SiO_2, is the main constituent of sand and has a giant lattice structure similar to that of diamond.



Crystalline silicon dioxide is used on the surface of semiconductor devices to provide a heat-resistant, electrically insulating layer.

Explain how the structure and bonding of silicon dioxide make it useful for this application.

(3)

.....

.....

.....

.....

.....

.....

(c) Calcium silicate is formed in the removal of silicon dioxide impurities in the extraction of iron from its ores. A sample of calcium silicate composed of calcium, silicon and oxygen was found to contain 12.0 g of calcium, 8.43 g of silicon and 14.47 g of oxygen.

Determine the empirical formula of calcium silicate.
You **must** show your working.

(3)

(d) Carbon dioxide is a gas at room temperature. A fizzy drink is canned at 5.0 °C and 1.3×10^5 Pa and contains approximately 3 g of carbon dioxide.

Calculate the volume, in cm^3, occupied by 3.00 g of carbon dioxide gas at 5.0 °C and 1.3×10^5 Pa.

[$pV = nRT$ $R = 8.31$ J mol^{-1} K^{-1}]

(4)

(Total for question = 14 marks)

Q21.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The atomic number of the element scandium is 21 and the mass number of its only isotope is 45.

(a) What is the number of electrons in a scandium ion, Sc^+ ?

(1)

☐ **A** 20

☐ **B** 21

☐ **C** 22

☐ **D** 23

(b) In a mass spectrometer, scandium forms Sc^+ and Sc^{2+} ions.

What is the m / z value for the mass spectrum peak due to the Sc^{2+} ions?

☒ **A** 22.5

☒ **B** 33.0

☒ **C** 45.0

☒ **D** 90.0

(Total for question = 2 marks)

Q22.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

Which equation represents the **second** ionisation energy of chlorine?

☒ **A** $Cl^-(g) + e^- \rightarrow Cl^{2-}(g)$

☒ **B** $Cl(g) + 2e^- \rightarrow Cl^{2-}(g)$

☒ **C** $2Cl(g) \rightarrow 2Cl^+(g) + 2e^-$

☒ **D** $Cl^+(g) \rightarrow Cl^{2+}(g) + e^-$

(Total for question = 1 mark)

Q23.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which statement about subatomic particles is correct?

☒ **A** neutral atoms always contain the same number of protons and electrons

☒ **B** neutral atoms always contain the same number of protons and neutrons

☒ **C** electrons have a relative mass of 1 and a charge of −1

☒ **D** protons have a relative mass of 1 and no charge

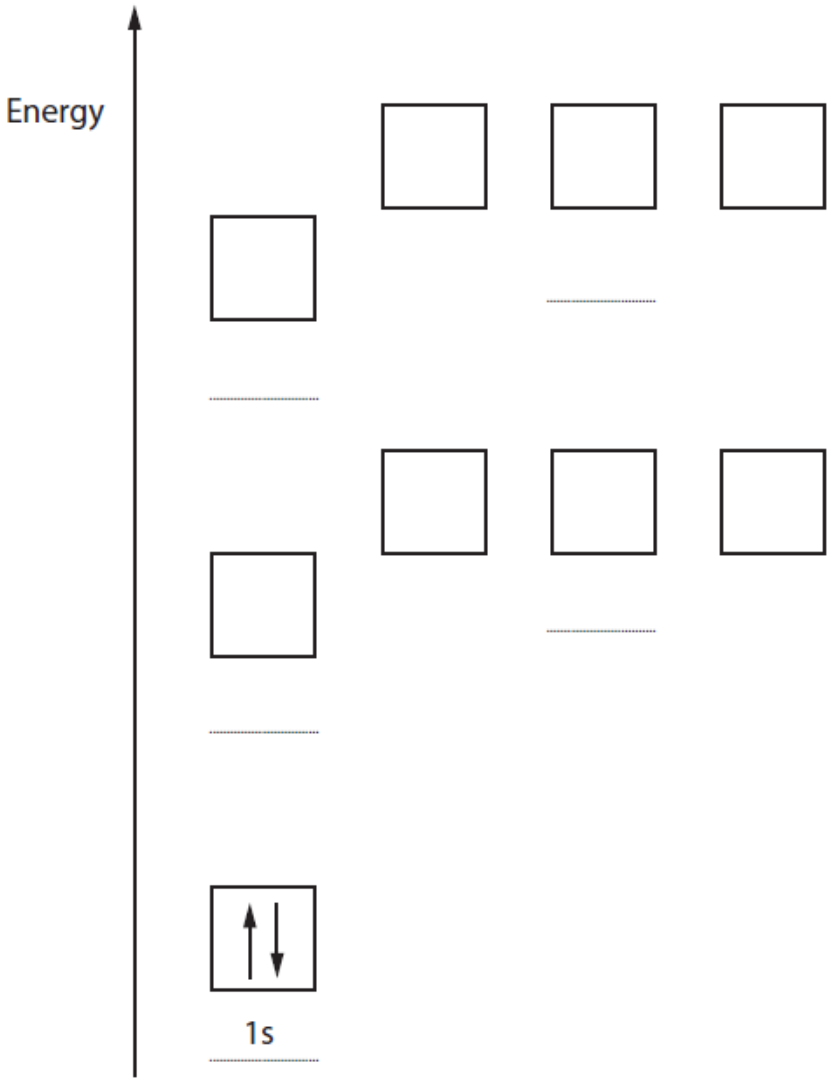
(Total for question = 1 mark)

Q24.

This question is about the element sulfur.

(a) Complete the diagram to show the electronic configuration for a sulfur atom in the ground state.
Include labels for each subshell.

(2)



(b) Write an equation for the **first** ionisation energy of sulfur.
Include state symbols.

(2)

(c) Explain why the first ionisation energy of sulfur is less than the first ionisation energies of **both** phosphorus and chlorine.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

.....

(d) A sample of sulfur contains four isotopes.

Isotope	^{32}S	^{33}S	^{34}S	^{36}S
Percentage abundance	94.88	0.83	4.27	0.02

(i) State what is meant by the term **isotopes**, in terms of subatomic particles.

(2)

.....

.....

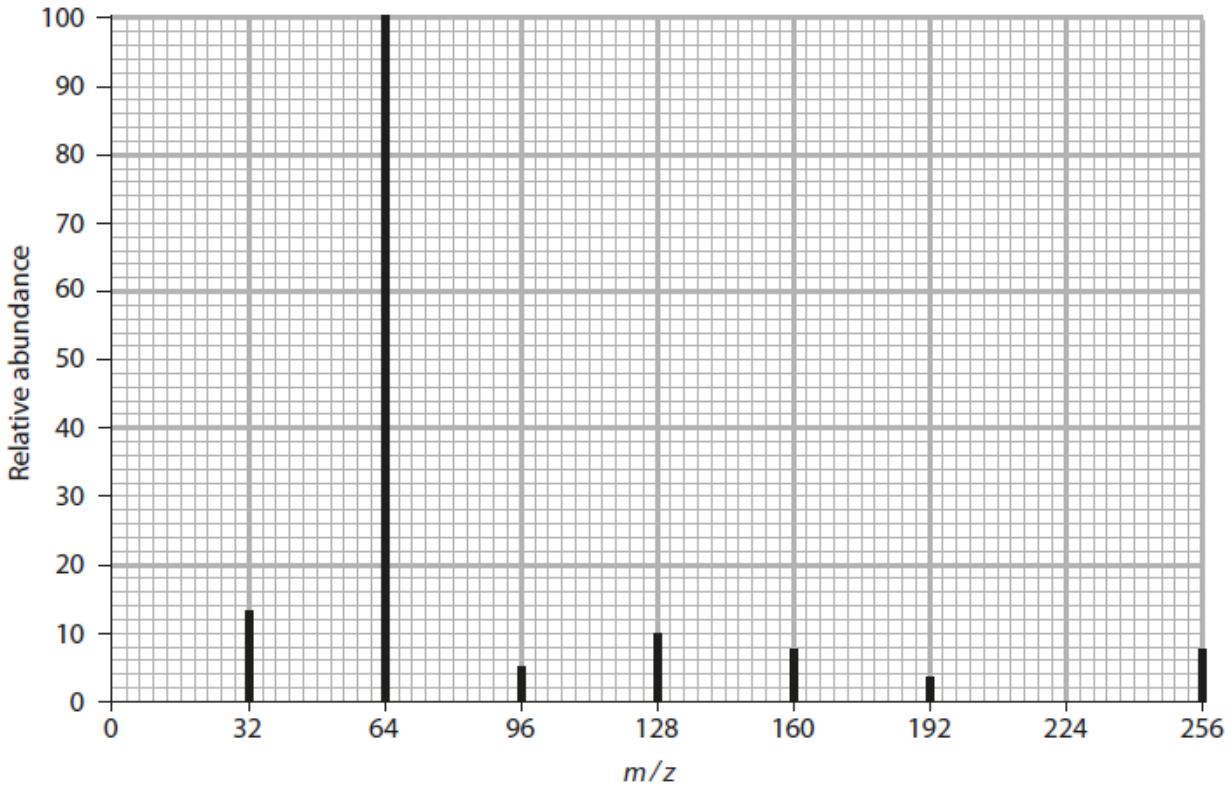
.....

(ii) Calculate the relative atomic mass of sulfur in this sample.

Give your answer to **two** decimal places.

(2)

(e) The mass spectrum of a sample of sulfur with ^{32}S as the only isotope is shown.



(i) Calculate the number of sulfur atoms in the molecular ion.

You **must** show your working.

(1)

(ii) Suggest the **formula** of the **most stable ion** shown by this spectrum.

(2)

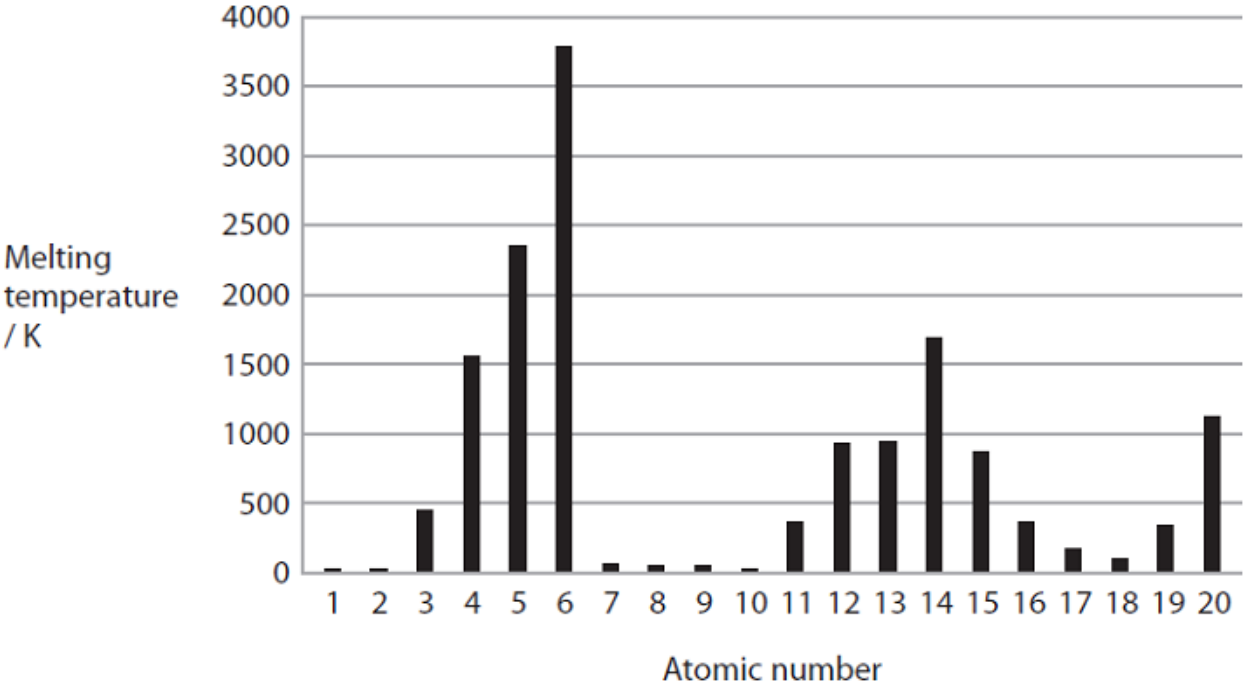
.....

(Total for question = 14 marks)

Q25.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The bar chart shows the melting temperatures of the first twenty elements.



The bar chart shows that melting temperatures

☒ **A** of giant covalent structures are the highest in Period 2 and in Period 3

☒ **B** of metals are always higher than non-metals

☒ **C** increase going down each group

☒ **D** increase across Period 2 and Period 3

(Total for question = 1 mark)

Q26.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

An atom of $^{15}_{7}N$ forms a nitride ion, N^{3-}.

What are the numbers of protons, neutrons and electrons in this ion?

	Protons	Neutrons	Electrons
☒ A	7	8	7
☒ B	7	8	4
☒ C	7	8	10
☒ D	8	7	10

(Total for question = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

Q27.

This question is about the structure of atoms.

(a) State what is meant by the term orbital.

(2)

.....

.....

.....

.....

.....

(b) State the shape of an s orbital and the shape of a p orbital.

(1)

.....

.....

(c) Describe what can be deduced about the electronic structure of sodium from its successive ionisation energies.

(3)

.....

.....

.....

.....

.....

.....

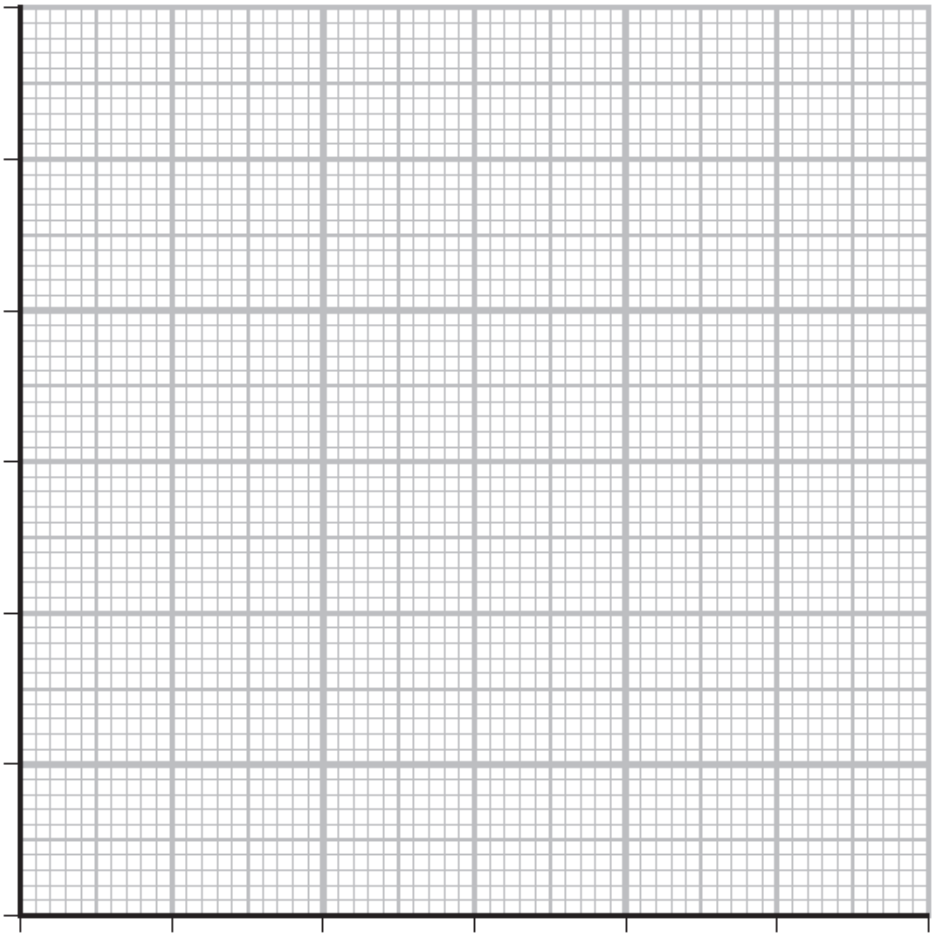
.....

(d) (i) The log of the **fourth** ionisation energy for six elements is shown in the table.

Element	$\log_{10}$ (fourth ionisation energy / kJ mol^{-1})
O	3.87
F	3.92
Ne	3.97
Na	
Mg	4.02
Al	4.06

Plot a graph of these data.

(3)



(ii) Use your graph to estimate the fourth ionisation energy for sodium, in kJ mol^{-1}.

(1)

(iii) Suggest why the fourth ionisation energies of neon and sodium are similar in magnitude even though the elements are in different periods of the Periodic Table.

(1)

.....

.....

.....

.....

.....

(Total for question = 11 marks)

Q28.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which equation represents the **third** ionisation energy for element J?

☒ **A** $J^{2+}(g) \rightarrow J^{3+}(g) + e^-$

☒ **B** $J^{3+}(g) \rightarrow J^{4+}(g) + e^-$

☒ **C** $J(g) \rightarrow J^{3+}(g) + e^-$

☒ **D** $J(g) \rightarrow J^{3+}(g) + 3e^-$

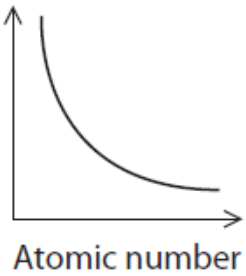
(Total for question = 1 mark)

Q29.

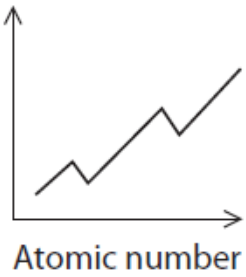
Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which sketch graph shows the trend in first ionisation energy values going down Group 1 in the Periodic Table?

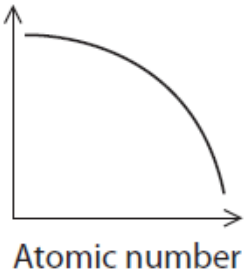
☒ **A**



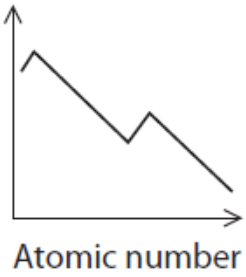
☒ **B**



☒ **C**



☒ **D**



(Total for question = 1 mark)

Q30.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

In which series are the elements in order of **increasing** melting temperature?

☒ **A** $I_2 < Br_2 < Cl_2 < F_2$

☒ **B** Li < Be < B < C

☒ **C** Li < Na < K < Rb

☒ **D** Si < P < S < Cl

(Total for question = 1 mark)

Mark Scheme

Q1.

Question number	Answer	Mark
	The only correct answer is B (6200) *A is incorrect because successive ionisation energies always increase* *C is incorrect because this is too big an increase* *D is incorrect because this very large value indicates a new quantum shell*	**(1)**

Q2.

Question Number	Answer	Additional Guidance	Mark
(a)	• there is a "jump"/much bigger increase between the third and fourth ionisation energies **(1)** • (First) 3 electrons in outer shell **(1)**	Accept fourth electron is removed from a different (quantum) **shell** (which is closer to the nucleus)	**(2)**

Question Number	Answer	Additional Guidance	Mark
(b)(i)	• the number of protons increases /nuclear charge increases **(1)** • the additional electrons are in the same shell/same energy level/ little additional shielding from electrons **(1)**	Allow "same shielding" Ignore references to atomic radius even if incorrect Ignore electron repulsion	**(2)**

Question Number	Answer	Additional Guidance	Mark
(b)(ii)	• the first electron is removed from a (3)p orbital/subshell in aluminium/ (3)s orbital/subshell from magnesium **(1)** **(1)** • p electron(s) shielded by the s electrons (so requires less energy)/ p energy level is higher than s energy level	Do not award 2p/2s	**(2)**

Question Number	Answer	Additional Guidance	Mark
(c)(i)	An answer that makes reference to • delocalised /free (to move) electrons /sea of electrons **(1)** • attracted to (a lattice of) metal/aluminium/positive **ions/cations** **(1)**	Allow charges up to 3+ Correct fully labelled diagram scores 2 marks Ignore attraction of electrons to nuclei	**(2)**

Question Number	Answer	Additional Guidance	Mark
(c)(ii)	An answer that makes reference to **two** of the following: • (delocalised) electrons can move/carry charge **(1)** • aluminium has low density/light (weight) **(1)** • aluminium is ductile/can be drawn into wires **(1)** • aluminium forms an inert/oxide layer **(1)**	Allow good conductor of **electricity** Ignore malleable, strong, heat resistant, high melting temperature.	**(2)**

Question Number	Answer	Additional Guidance	Mark
(d)(i)	**2** Al + **3** H_2O → **Al_2O_3** + **$3H_2$**	Allow multiples Ignore state symbols even if incorrect	**(1)**

Question Number	Answer	Additional Guidance	Mark
(d)(ii)	An answer that makes reference to **two** of the following: • reduces greenhouse gas emissions / carbon dioxide **and** which affects climate change / global warming **(1)** **(1)** • the production of hydrogen is portable **(1)** • fossil fuels are non-renewable (unlike water) **(1)** • aluminium can be recycled	Allow reduces sulfur dioxide emissions **and** which reduces acid rain Do not award references to ozone depletion, carbon neutral Ignore renewable Ignore landfill, atom economy, references to cost	**(2)**

Q3.

Q	Answer	Mark
	The only correct answer is D (Y and Z) ***A*** *is incorrect because W and X both have the same number of neutrons* ***B*** *is incorrect because W and Y have different numbers of protons so are different elements* ***C*** *is incorrect because X and Y have different numbers of protons so are different elements*	**1**

Q4.

Q	Answer	Mark
	The only correct answer is B (3 quantum shells and 5 electrons in the outer shell) ***A*** *is incorrect because the outer five electrons require the least amount of energy to remove* ***C*** *is incorrect because there are two large jumps between the 3 quantum shells and the outer five electrons require the least amount of energy to remove* ***D*** *is incorrect because there are two large jumps between the 3 quantum shells*	**1**

Q5.

Q	Answer	Mark
	The only correct answer is C (4) ***A*** *is incorrect because the ICl_3^+ ion can have* *3 x ^{35}Cl, 2 x ^{35}Cl + 1 x ^{37}Cl, 1 x ^{35}Cl + 2 x ^{37}Cl or 3 x ^{37}Cl* ***B*** *is incorrect because the ICl_3^+ ion can have* *3 x ^{35}Cl, 2 x ^{35}Cl + 1 x ^{37}Cl, 1 x ^{35}Cl + 2 x ^{37}Cl or 3 x ^{37}Cl* ***D*** *is incorrect because the ICl_3^+ ion can have* *3 x ^{35}Cl, 2 x ^{35}Cl + 1 x ^{37}Cl, 1 x ^{35}Cl + 2 x ^{37}Cl or 3 x ^{37}Cl*	**1**

Q6.

Question Number	Answer	Mark
(a)	**The only correct answer is B** (electrons are removed from molecules or atoms and positive ions are formed) ***A*** *is incorrect because the sample has been vaporised previously* ***C*** *is incorrect because electrons are not added to atoms (in this mass spectrometer)* ***D*** *is incorrect because acceleration occurs in region* ***S***	**(1)**

Question Number	Answer	Mark
(b)	**The only correct answer is A** (ions with a greater mass have a smaller deflection) ***B*** *is incorrect because ions with a greater mass have a smaller deflection* ***C*** *is incorrect because ions with a greater charge have a greater deflection* ***D*** *is incorrect because ions are not speeded up in a magnetic field*	**(1)**

Q7.

Question Number	Correct Answer	Mark
(a)	**The only correct answer is B** (*region* Q) *A is incorrect because region P denotes where ionisation takes place* *C is incorrect because region R denotes where deflection takes place* *D is incorrect because region S denotes where detection takes place*	1

Question Number	Correct Answer	Mark
(b)	**The only correct answer is B** ($^{54}Fe^{2+}$) *A is incorrect because it has the same mass but a smaller charge than* $^{54}Fe^{2+}$ *C is incorrect because it has a larger mass and a smaller charge than* $^{54}Fe^{2+}$ *D is incorrect because it has a larger mass than* $^{54}Fe^{2+}$	1

Question Number	Correct Answer	Mark
(c)	**The only correct answer is C** (3) *A is incorrect because it assumes that all chlorine molecular ions have the same mass* *B is incorrect because it assumes that all chlorine molecules only form between atoms of the same mass* *D is incorrect because it assumes that* $^{35}Cl-^{37}Cl$ *and* $^{37}Cl-^{35}Cl$ *are not identical*	1

Q8.

Q	Answer	Mark
	The only correct answer is C (192.5) ***A*** *is incorrect because this is the relative atomic mass with the abundances reversed* ***B*** *is incorrect because this would be the relative atomic mass if there were equal amounts of the two isotopes* ***D*** *is incorrect because this is the relative atomic mass of the most abundant isotope*	**1**

Q9.

Question number	Answer	Mark
	B $^{56}Fe^{2+}$	1

Q10.

Question number	Answer	Mark
	The only correct answer is C (carbon) ***A*** *is incorrect because Al is in Period 3* ***B*** *is incorrect because the element with the highest melting temperature is in Group 4* ***D*** *is incorrect because Si is in Period 3*	**1**

Q11.

Question number	Answer	Mark
	The only correct answer is B ($^{124}_{50}Sn$) ***A*** *is incorrect because* $^{115}_{49}In$ *has 66 neutrons* ***C*** *is incorrect because* $^{123}_{51}Sb$ *has 72neutrons* ***D*** *is incorrect because* $^{124}_{52}Te$ *has 72neutrons*	1

Q12.

Question number	Answer	Mark
	The only correct answer is B (8, 12, 5) ***A*** *is not correct because the 4s electrons have been placed in the 3d subshell* ***C*** *is not correct because the 4p subshell has been filled and 1 electron placed in 3d and 0 electron in 4s* ***D*** *is not correct because the 4p subshell has been occupied before the 3d*	1

Q13.

Question number	Answer	Mark
	The only correct answer is B ($1s^2 2s^2 2p^6 3s^2 3p^6$) ***A*** *is incorrect because this is the electronic configuration of an s-block element* ***C*** *is incorrect because this could not be the electronic configuration of the ion of a p-block element* ***D*** *is incorrect because this could not be the electronic configuration of the ion of a Period 3 element*	1

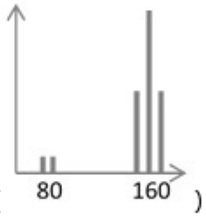
Q14.

Question number	Answer	Mark
(a)	A R and U	1

Question number	Answer	Mark
(b)	C Y	1

Question number	Answer	Mark
(c)	C U^{2+} and T^{2-}	1

Q15.

Question Number	Answer	Mark
	 **The only correct answer is D** ( ) **A** *is not correct because this shows only one molecular ion peak* **B** *is not correct because this shows only one molecular ion peak* **C** *is not correct because this shows three molecular ion peaks in the wrong relative abundances*	**(1)**

Q16.

Question number	Answer	Additional guidance	Mark
(a)(i)	• correct electronic configuration	Example of electronic configuration:  Allow half-arrow heads Allow three arrows pointing downwards in 3p orbitals Ignore numbers in the boxes e.g. 2	(1)

Question number	Answer	Additional guidance	Mark
(a)(ii)	An explanation that makes reference to the following points: **Phosphorus** • phosphorus has a half-filled p (sub)shell / one electron in each p orbital / the p orbitals are singly occupied (1) • more energy is required to remove an unpaired electron (than a paired electron) **or** an unpaired electron / electron removed has a lower energy (1) OR **Sulfur** • the outermost / 3p electron or the electron being removed in sulfur is paired (1) • less energy is required to remove a paired electron (than an unpaired electron) **or** repulsion between paired electrons (reduces the ionisation energy needed to remove it) **or** the paired electron has a higher energy (1)	**Both marks must come from the same pair** Allow 'electrons-in-boxes' / $3p_x3p_y3p_z$ to show electronic configurations Allow 'box' for orbital as this is in (i) Ignore references to shielding / nuclear charge / lone pairs Penalise 3 or more electrons in a p **orbital** once only Allow '(electron removed is from) a half-filled p orbital' Do not award just $3p^3$ Allow a half-filled subshell is (more) stable Allow sulfur is $3p^4$ Allow sulfur forms a half-filled p (sub)shell when it loses 1 electron Note – paired only needs to be mentioned once in M1 or M2 Do not award M2 if answer states more energy needed to remove electron in sulfur	(2)

Question number	Answer	Additional guidance	Mark
(b)	An explanation that makes reference to the following points: • there are intermolecular forces between P_4 / phosphorus (molecules) **or** phosphorus is made up of small molecules / discrete molecules / is simple molecular (1) • there are covalent bonds between the silicon atoms **or** silicon is a giant (covalent) structure / giant lattice (1) • (much) more energy is needed to break the (covalent) bonds in silicon than overcome the intermolecular forces in phosphorus **or** the (covalent) bonds in silicon are (much) stronger than the (intermolecular) forces in phosphorus (1)	Allow London / dispersion / van der Waals' forces for intermolecular forces Allow macromolecular / giant molecule Do not award ionic / metallic Do not award breaking bonds between phosphorus **atoms**	(3)

Question number	Answer	Additional guidance	Mark
(c)(i)	• number of bonding pairs **and** number of lone pairs (1) • shape (1) • **both** bond angles (1)	Example of table: Number of bonding pairs of electrons on phosphorus: 5 Number of lone pairs on electrons on phosphorus: 0 Shape of molecule: trigonal bipyramidal Cl-P-Cl bond angles: 90° 120° Mark independently Allow bond angles in either order Ignore 180°	(3)

Question number	Answer	Additional guidance	Mark
(c)(ii)	• PCl_4^+ (1) • PCl_6^- (1)	Ions can be in any order If no charges are shown or charges are incorrect, allow (1) for PCl_4 and PCl_6	(2)

Question number	Answer	Additional guidance	Mark
(d)	• calculation of mol of H_3PO_4 **and** calculation of mol of NaOH (1) • mol ratio (1) • balanced equation (1)	Example of calculation: mol H_3PO_4 = $\frac{10.0 \times 0.100}{1000}$ = 0.00100 / 1.00 x 10^{-3} **and** mol NaOH = $\frac{8.0 \times 0.250}{1000}$ = 0.00200 / 2.00 x 10^{-3} mol ratio H_3PO_4 : NaOH = 1 : 2 Mol ratio mark can be awarded from equation TE on mol H_3PO_4 and NaOH Do not award M2 if the mol ratio in the balanced equation contradicts the mol ratio from the mol calculations $H_3PO_4 + 2NaOH \rightarrow Na_2HPO_4 + 2H_2O$ Allow HNa_2PO_4 Allow $H_3PO_4 + 2OH^- \rightarrow HPO_4^{2-} + 2H_2O$ Allow multiples Ignore state symbols, even if incorrect Equation TE on mol ratio provided it is 1:1 or 1:3 $H_3PO_4 + NaOH \rightarrow NaH_2PO_4 + H_2O$ $H_3PO_4 + 3NaOH \rightarrow Na_3PO_4 + 3H_2O$	(3)

Question number	Answer	Additional guidance	Mark
(e)	• calculation of molar mass of hydrated magnesium phosphate (1) • calculation of **y** (1)	Examples of calculation: **Method 1** molar mass = 262.9 x $\frac{100}{78.5}$ = 334.9 (g) mass of water = 334.9 – 262.9 = 72 moles of water = $\frac{72}{18}$ = 4 so **y** = 4 Allow alternative methods, for example **Method 2** in 100 g of salt: mol $Mg_3(PO_4)_2$ = $\frac{78.5}{262.9}$ = 0.29859 (mol) **and** mol H_2O = $\frac{21.5}{18}$ = 1.1944(mol) (1) ratio $Mg_3(PO_4)_2$: H_2O = 0.29859 : 1.1944 = 1 : 4 so **y** = 4 (1) This could also be done using 0.785 g and 0.215 g **Method 3** $\frac{262.9}{262.9 + 18y}$ = 0.785 or $\frac{262.9}{262.9 + 18y}$ x 100 = 78.5(1) 262.9 = 206.4 + 14.13 **y** so **y** = 4 (1) Correct answer with no working or working that does not involve A_r or M_r or moles scores (0) Allow TE for **y** from correct working but an incorrect number used for one of the values	(2)

Q17.

Question number	Answer	Mark
	A P^{3-}	1

Q18.

Question Number	Answer	Mark
	The only correct answer is C (d) ***A*** *is incorrect because the s block elements don't form stable 3+ ions* ***B*** *is incorrect because the elements which form stable 3+ ions do not have 21 electrons* ***D*** *is incorrect because elements in the f block have more than 21 electrons*	**(1)**

Q19.

Question number	Answer	Mark
	C 20.18	1

Q20.

Question Number	Answer	Additional Guidance	Mark
(a)(i)	• expression for calculation of RAM of silicon **(1)** • answer to two decimal places **(1)**	Example of calculation: $\frac{(28x92.17)+(29x4.71)+(30x3.12)}{100}$ =28.1095 =28.11 Allow units g mol^{-1}/a.m.u only Correct answer scores 2 Allow TE from incorrect expression if answer lies between 28 and 30.	**(2)**

Question Number	Answer	Additional Guidance	Mark
(a)(ii)	Some silicon atoms (of mass 28) lose two electrons/have a charge of 2+	Allow (formation of) Si^{2+} Do not award "atoms of mass 14"	(1)

Question Number	Answer	Additional Guidance	Mark
(a)(iii)	^{28}Si 14 14 ^{29}Si 14 15 ^{30}Si 14 16		(1)

Question Number	Answer	Additional Guidance	Mark
(b)	• **all** atoms are joined together by covalent bonds/giant covalent(structure) (1) • these are strong / take a lot of energy to break (so melting temperature is very high) (1) • no electrons are free (to move)/ mobile/delocalised/ (so charge cannot be carried) (1)	Allow correct description of covalent bond Do not award intermolecular forces/ ionic bonds/ double covalent bonds. Ignore stoichiometry even if incorrect. Ignore high boiling temperature Ignore no free moving ions	(3)

Question Number	Answer	Additional Guidance	Mark
(c)	• calculation of number of moles (1) • calculation of whole number mole ratio (1) • empirical formula	Example of calculation $\frac{12}{40.1}$: $\frac{8.43}{28.1}$: $\frac{14.47}{16}$ OR 0.299 : 0.30 : 0.904 1 : 1 : 3 $CaSiO_3$ Correct formula with no working scores 1 mark only TE on use of atomic numbers Incorrect symbol(s) in formula loses M3	(3)

Question Number	Answer	Additional Guidance	Mark
(d)	• calculation of moles carbon dioxide **(1)** • conversion of temperature to K **(1)** • rearrangement of expression **(1)** • evaluation of answer in cm^3	Example of calculation: 3÷44 = 0.06818 273 + 5 = 278 $V=\frac{0.06818 \times 8.31 \times 278}{1.3 \times 10^5}$ $(=1.2116 \times 10^{-3} m^3)$ $=1211.6/1212/1210/1200\ (cm^3)$ TE throughout but do not award M4 for negative volume Ignore SF except 1 SF Correct answer with no working scores 4 marks	**(4)**

Q21.

Question number	Answer	Mark
(a)	**The only correct answer is A** (20) ***B*** *is not correct because this is the number of electrons in a Sc atom* ***C*** *is not correct because this is the number of electrons in a* Sc^- *ion* ***D*** *is not correct because this is calculated by taking Z = 45 − 21 and then removing an electron.*	**1**

Question number	Answer	Mark
(b)	**The only correct answer is A** (22.5) ***B*** *is not correct because this is 0.5 x (mass number + atomic number)* ***C*** *is not correct because this is the m/z value for an* Sc^+ *ion* ***D*** *is not correct because this is mass number x2*	**1**

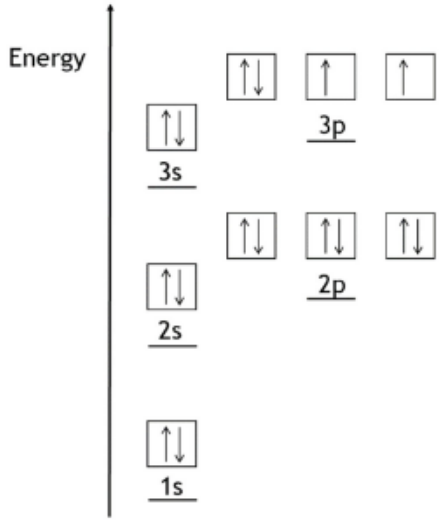
Q22.

Question Number	Answer	Mark
	The only correct answer is D ($Cl^{+}(g) \rightarrow Cl^{2+}(g) + e^{-}$) ***A*** *is incorrect because the equation represents an electron is added to an ion rather than being removed* ***B*** *is incorrect because the equation represents electrons being added to an atom* ***C*** *is incorrect because one electron is being removed from each of two atoms*	**(1)**

Q23.

Question Number	Answer	Mark
	The only correct answer is A (atoms always contain the same number of protons and electrons) **B** *is not correct because many atoms have different numbers of protons and neutrons* **C** *is not correct because electrons do not have a relative mass of 1* **D** *is not correct because protons have a charge of +1*	**(1)**

Q24.

Question Number	Answer	Additional guidance	Mark
(a)	A completed diagram showing: • correctly labelled subshells (1) • correctly filled boxes/orbitals (1)	 Allow p subshell labelled as orbitals eg $2p_x$, $2p_y$, $2p_z$ Ignore specified number of electrons, even if incorrect eg $3p^5$ Allow paired 3p electrons in any 3p orbital Allow unpaired 3p electrons as spin down Allow half-headed arrows Do not award vertical lines for arrows Do not award paired electrons with parallel spin Example of completed diagram: 	2

Question Number	Answer	Additional guidance	Mark
(b)	 • species and balancing (1) • correct state symbols (1)	Example of equation: $S(g) \rightarrow S^+(g) + e^{(-)}$ or $S(g) - e^{(-)} \rightarrow S^+(g)$ Do not award multiples **M2 dependent on S/S_8 on one side of equation and charged $S^+/S_8^+/S^-/S_8^-$ on the other (does not need to be balanced)** Ignore (g) state symbol on electron $S(g) + e^{(-)} \rightarrow S^+(g) + 2e^{(-)}$ scores (1)	2

Question Number	Answer	Additional guidance	Mark
(c)	An explanation that makes reference to the following points: • outermost electrons in same subshell / (quantum) shell (1) • Cl contains the greatest number of protons / more protons than S (1) • repulsion between (paired) electrons in (3)p orbital in S (1)	Accept similar/same (electron) shielding Allow same number of shells Allow correct reference to full or partial electronic configurations for two/three elements Do not award incorrect electronic configurations Accept Cl has the greatest nuclear charge Ignore Cl has the greatest nuclear attraction Ignore Cl has the greatest atomic number Do not award just Cl has the greatest charge Do not award S has the smallest nuclear charge Allow Cl has the smallest atomic radius / smaller atomic radius than S Do not award S had the greatest atomic radius Do not award same/similar atomic radius Do not award outer electron same/similar distance from nucleus Do not award ionic/molecular radius There must be a mention of **p** (orbital) Allow subshell for orbital Do not award shell for orbital Allow spin-spin repulsion in p orbital/subshell Allow correct reference to stable half-full p subshell: eg stable half-full p subshell in P eg removing electron from S gives stable half-full p subshell Do not award reference to bonding electrons	3

Question Number	Answer	Additional guidance	Mark
(d)(i)	• (atoms with the) same number of protons (1) • (and) different number of neutrons (1)	Penalise use of species/particles/molecules for atoms once only Allow same atomic number Allow amount for number Ignore atoms of the same element Ignore electrons Ignore different mass number Do not award different number of electrons	2

Question Number	Answer	Additional guidance	Mark
(d)(ii)	• Expression for relative atomic mass (1) • Calculation and answer to two decimal places (1)	Example of calculation: $(A_r =) \frac{32 \times 94.88 + 33 \times 0.83 + 34 \times 4.27 + 36 \times 0.02}{100}$ $(A_r =)$ 32.09 TE on transcription errors only (ie no TE on incorrect expression) Ignore units of amu / g / g mol^{-1} Do not award any other unit 32.09 scores (2) provided there is evidence of all four isotopes having been used in the calculation 32.09 with no working scores (1) 32.10 with no working scores (0) 33.75 scores (0)	2

Question Number	Answer	Additional guidance	Mark
(e)(i)	• $\frac{256}{32}$ = 8 (atoms)	Allow working shown on mass spectrum Ignore calculations involving the Avogadro constant, even if incorrect Do not award just 8 (with no working)	1

Question Number	Answer	Additional guidance	Mark
(e)(ii)	An answer that makes reference to the following points: • (species containing) two sulfur atoms (1) • (ion with) 1+ charge (1)	Penalise isotopes other than ^{32}S once only eg S_2 / S—S Allow SS / S,S Ignore incorrect charge, including negative charge **M2 dependent on an ion containing sulfur only** S_2^+ / $[S—S]^+$ / SS^+ / S,S^+ scores (2) S_4^{2+} / $[S_2—S_2]^{2+}$ / $S_2S_2^{2+}$ / $S_2^+S_2^+$ / S_2^+,S_2^+ scores (1)	2

Q25.

Question Number	Answer	Mark
	The only correct answer is A (of giant covalent structures are the highest in Period 2 and Period 3) **B** *is not correct because the giant covalent structures have the highest melting temperatures* **C** *is not correct because there is not a regular pattern in each group* **D** *is not correct because melting temperatures increase then decrease within each Period*	**(1)**

Q26.

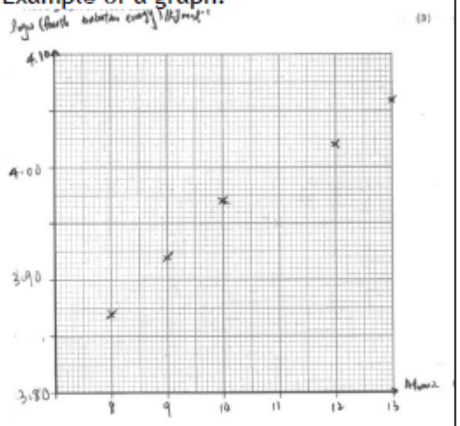
Question Number	Correct Answer	Mark
	The only correct answer is C (7,8,10) *A is incorrect because this is the number of protons, electrons and neutrons in the* $^{15}_{7}N$ *atom* *B is incorrect because this is the number of protons, electrons and neutrons in the* $^{15}_{7}N^{3+}$ *ion* *D is incorrect because it the numbers of protons and neutrons have been reversed*	1

Q27.

Question Number	Answer	Additional guidance	Mark
(a)	A statement that makes reference to the following points: • a region within an atom (1) • can hold (up to) **two** electrons (with opposing spins) **or** where there is a **high** probability of finding an electron (1)	Allow A region around the nucleus Allow area/place/space for region Ignore path/track/orbiting Do not award in the nucleus Allow a percentage between 90 and 95 Allow a **greater** chance of finding / **most** likely to find Do not award just likely Marks are standalone	**(2)**

Question Number	Answer	Additional guidance	Mark
(b)	• s-orbitals are spherical / ball shaped **and** p-orbitals are dumbbell shaped	IGNORE the words circular or figure of eight or pear shaped Accept labelled diagrams e.g.  s-orbital p-orbital Accept a p-orbital on any axis Allow correct unlabelled diagrams or descriptions in the correct order Allow 3 p-orbitals overlapping if they are specifically labelled as 3 p-orbitals Ignore references to numbers of electrons Ignore has two lobes for p-orbital	(1)

Question Number	Answer		Additional guidance	Mark
(c)	A description that makes reference to: • three (quantum) shells • 2, 8, 1 • Indication of which electrons are in which (quantum) shell	(1) (1) (1)	Accept energy levels Accept the numbers in the reverse order Allow descriptions of the large jumps between IE1 & IE2 **and** IE9 & IE10 e.g. • It has one electron in its outermost shell or • First electron removed is in the third shell / 3s or • 8 electrons in 2nd quantum shell or • Two electrons are on the innermost shell Allow one electron in valence shell Ignore one valence electron Ignore spd notation	(3)

Question Number	Answer	Additional guidance	Mark
(d)(i)	• axes correct way round and both suitably labelled (1) • suitable choice of linear scale so that the points cover at least 50% of the grid in both directions (1) • all 5 points plotted correctly (1)	Example of a graph:  Do not award log as an axis label Ignore units and brackets on the y-axis Accept atomic numbers on the x-axis **Allow element symbols Al to O** Allow MP3 for bar charts Allow half square tolerance on plotted points Ignore any lines joining the points	(3)

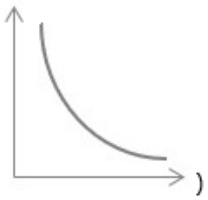
Question Number	Answer	Additional guidance	Mark
(d)(ii)	• ($10^{(3.99)}$=) 9772 (kJ mol^{-1})	Accept answers given in standard form Accept answers given in the grid for (d)(i) Allow 9544 – 10000 (kJ mol^{-1}) TE from graph in 18(d)(i) Allow any SF Ignore units even if incorrect	(1)

Question Number	Answer	Additional guidance	Mark
(d)(iii)	The fourth electron is removed from the same / second (quantum) shell	Allow both electrons are removed from 2p orbitals / the 2p subshell Allow same energy level Do not award same electronic structure / same orbital in place of same shell Ignore shielding Ignore nuclear charge Ignore references to electron pairs repelling	(1)

Q28.

Question number	Answer	Mark
	The only correct answer is A ($J^{2+}(g) \rightarrow J^{3+}(g) + e^-$) *B is incorrect because this is the fourth ionisation energy* *C is incorrect because the equation is unbalanced and begins with the uncharged atom* *D is incorrect because it begins with the uncharged atom*	**(1)**

Q29.

Question Number	Answer	Mark
	The only correct answer is A () **B** *is not correct because first ionisation energies decrease down Group 1* **C** *is not correct because first ionisation energies decrease more quickly at the start* **D** *is not correct because first ionisation energies decrease down Group 1, with no increases*	**(1)**

Q30.

Question Number	Answer	Mark
	The only correct answer is B (Li< Be< B< C) ***A** is incorrect because the melting temperatures of Group 7 elements increase going down the group* ***C** is incorrect because the melting temperatures of Group 1 elements decrease going down the group* ***D** is incorrect because silicon has the **highest** melting temperature in Period 3*	**(1)**