**Q1.** Which of these atoms has the largest atomic radius?

**A** Ar ⬭

**B** Cl ⬭

**C** Mg ⬭

**D** Na ⬭

**(Total 1 mark)**

**Q2.** Which of these atoms has the smallest number of neutrons?

**A** $^{3}H$ ⬭

**B** $^{4}He$ ⬭

**C** $^{5}He$ ⬭

**D** $^{4}Li$ ⬭

**(Total 1 mark)**

**Q3.** Which change requires the largest amount of energy?

**A** $He^{+}(g) \longrightarrow He^{2+}(g) + e^{-}$ ⬭

**B** $Li(g) \longrightarrow Li^{+}(g) + e^{-}$ ⬭

**C** $Mg^{+}(g) \longrightarrow Mg^{2+}(g) + e^{-}$ ⬭

**D** $N(g) \longrightarrow N^{+}(g) + e^{-}$ ⬭

**(Total 1 mark)**

**Q4.** Photochromic glass contains silver ions and copper ions. A simplified version of a redox equilibrium is shown below. In bright sunlight the high energy u.v. light causes silver atoms to form and the glass darkens. When the intensity of the light is reduced the reaction is reversed and the glass lightens.

$$Cu^{+}(s) + Ag^{+}(s) \rightleftharpoons Cu^{2+}(s) + Ag(s)$$

clear glass dark glass

Which one of the following is a correct electron arrangement?

**A** $Cu^{+}$ is $[Ar]3d^{9}4s^{1}$

**B** Cu is $[Ar]3d^{10}4s^{2}$

**C** $Cu^{2+}$ is $[Ar]3d^{8}4s^{1}$

**D** $Cu^{+}$ is $[Ar]3d^{10}$

**(Total 1 mark)**

**Q5.** Chlorine has two isotopes, $^{35}Cl$ and $^{37}Cl$. The number of molecular ion peaks in the mass spectrum of a sample of $Cl_2$ is

**A** 2

**B** 3

**C** 4

**D** 5

**(Total 1 mark)**

**Q6.** Which one of the following statements is **not** correct?

**A** The first ionisation energy of iron is greater than its second ionisation energy.

**B** The magnitude of the lattice enthalpy of magnesium oxide is greater than that of barium oxide.

**C** The oxidation state of iron in $[Fe(CN)_6]^{3-}$ is greater than the oxidation state of copper in $[CuCl_2]^-$

**D** The boiling point of $C_3H_8$ is lower than that of $CH_3CH_2OH$

**(Total 1 mark)**

**Q7.** Which one of the following is the electronic configuration of the strongest reducing agent?

**A** $1s^2\ 2s^2\ 2p^5$

**B** $1s^2\ 2s^2\ 2p^6\ 3s^2$

**C** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

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

**(Total 1 mark)**

**Q8.** An atom in which the number of protons is greater than the number of neutrons is

**A** $^{234}U$

**B** $^{6}Li$

**C** $^{3}He$

**D** $^{2}H$

**(Total 1 mark)**

**Q9.** Assuming that chlorine exists as two isotopes, and that hydrogen and carbon exist as one isotope each, how many molecular ion peaks will be shown in the mass spectrum of $C_4H_6Cl_4$?

**A** 2

**B** 3

**C** 4

**D** 5

**(Total 1 mark)**

**Q10.** Which one of the following atoms has only two unpaired electrons in its ground (lowest energy) state?

**A** helium

**B** beryllium

**C** nitrogen

**D** oxygen

**(Total 1 mark)**

**Q11.** Which one of the following does **not** have a pair of s electrons in its highest filled electron energy sub-level?

**A** $H^-$

**B** Mg

**C** $P^{3+}$

**D** Ar

**(Total 1 mark)**

**Q12.** Which one of the following explains why boron has a lower first ionisation energy than beryllium?

**A** A boron atom is smaller than a beryllium atom.

**B** In beryllium all the electrons are paired in full sub-shells.

**C** A beryllium atom has fewer protons than a boron atom.

**D** In boron the 2*p* electron occupies a higher energy level than a 2*s* electron.

**(Total 1 mark)**

**Q13.** Which one of the following ionisations requires less energy than the first ionisation energy of oxygen?

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

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

**C** $N(g) \rightarrow N^{+}(g) + e^{-}$

**D** $F(g) \rightarrow F^{+}(g) + e^{-}$

**(Total 1 mark)**

**Q14.** Which atom has an incomplete sub-shell?

**A** Be

**B** Ca

**C** Ge

**D** Zn

**(Total 1 mark)**

**Q15.** In which one of the following pairs is the first ionisation energy of element **Y** greater than that of element **X**?

| | electronic configuration of element **X** | electronic configuration of element **Y** |
|---|---|---|
| **A** | $1s^1$ | $ls^2$ |
| **B** | $1s^2\ 2s^2$ | $ls^2 2s^2\ 2p^1$ |
| **C** | $1s^2\ 2s^2 2p^3$ | $ls^2 2s^2 2p^4$ |
| **D** | $1s^2\ 2s^2 2p^6$ | $ls^2 2s^2 2p^6\ 3s^1$ |

**(Total 1 mark)**

**Q16.** Which one of the following lists the first ionisation energies (in kJ $mol^{-1}$) of the elements Mg, Al, Si, P and S in this order?

| | | | | | |
|---|---|---|---|---|---|
| **A** | 577 | 786 | 1060 | 1000 | 1260 |
| **B** | 736 | 577 | 786 | 1060 | 1000 |
| **C** | 786 | 1060 | 1000 | 1260 | 1520 |
| **D** | 1060 | 1000 | 1260 | 1520 | 418 |

**(Total 1 mark)**

**Q17.** Which one of the following is the electronic configuration of an element with a maximum oxidation state of +5?

**A** $1s^2\ 2s^2\ 2p^5$

**B** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$

**C** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$

**D** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^7\ 4s^2$

**(Total 1 mark)**

**Q1.** This question is about the elements in Group 2 and their compounds.

(a) Use the Periodic Table to deduce the full electron configuration of calcium.

.....

**(1)**

(b) Write an ionic equation, with state symbols, to show the reaction of calcium with an excess of water.

.....

**(1)**

(c) State the role of water in the reaction with calcium.

.....

**(1)**

(d) Write an equation to show the process that occurs when the first ionisation energy of calcium is measured.

.....

**(1)**

(e) State and explain the trend in the first ionisation energies of the elements in Group 2 from magnesium to barium.

Trend .....

Explanation .....

.....

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**(3)**

**(Total 7 marks)**

**Q2.** This question is about the elements in Period 3 of the Periodic Table.

(a) State the element in Period 3 that has the highest melting point.
Explain your answer.

Element .....

Explanation .....

.....

.....

.....

.....

**(3)**

(b) State the element in Period 3 that has the highest first ionisation energy.
Explain your answer.

Element .....

Explanation .....

.....

.....

.....

.....

**(3)**

(c) Suggest the element in Period 3 that has the highest electronegativity value.

.....

**(1)**

(d) Chlorine is a Period 3 element.
Chlorine forms the molecules $ClF_3$ and $CCl_2$

(i) Use your understanding of electron pair repulsion to draw the shape of $ClF_3$ and the shape of $CCl_2$
Include any lone pairs of electrons that influence the shape.

Shape of $ClF_3$ Shape of $CCl_2$

**(2)**

(ii) Name the shape of $CCl_2$

.....

**(1)**

(iii) Write an equation to show the formation of one mole of $ClF_3$ from its elements.

.....

**(1)**

**(Total 11 marks)**

**Q3.**(a) **Table 1** shows some data about fundamental particles in an atom.

**Table 1**

| **Particle** | proton | neutron | electron |
|---|---|---|---|
| **Mass / g** | $1.6725 \times 10^{-24}$ | $1.6748 \times 10^{-24}$ | $0.0009 \times 10^{-24}$ |

(i) An atom of hydrogen can be represented as $^{1}H$

Use data from **Table 1** to calculate the mass of this hydrogen atom.

.....

**(1)**

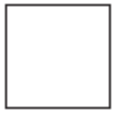
(ii) Which **one** of the following is a fundamental particle that would **not** be deflected by an electric field?

**A** electron

**B** neutron

**C** proton

Write the correct letter, **A**, **B** or **C**, in the box.



**(1)**

(b) A naturally occurring sample of the element boron has a relative atomic mass of 10.8.
In this sample, boron exists as two isotopes, $^{10}B$ and $^{11}B$

(i) Calculate the percentage abundance of $^{10}B$ in this naturally occurring sample of boron.

.....

.....

.....

.....

.....

**(2)**

(ii) State, in terms of fundamental particles, why the isotopes $^{10}B$ and $^{11}B$ have similar chemical reactions.

.....

.....

.....

**(1)**

(c) Complete **Table 2** by suggesting a value for the third ionisation energy of boron.

**Table 2**

| | **First** | **Second** | **Third** | **Fourth** | **Fifth** |
|---|---|---|---|---|---|
| **Ionisation energy / kJ mol$^{-1}$** | 799 | 2420 | | 25 000 | 32 800 |

**(1)**

(d) Write an equation to show the process that occurs when the **second** ionisation energy of boron is measured. Include state symbols in your equation.

.....

**(1)**

(e) Explain why the second ionisation energy of boron is higher than the first ionisation energy of boron.

.....

.....

**(1)**

**(Total 8 marks)**

**Q4.**(a) Nickel is a metal with a high melting point.

(i) State the block in the Periodic Table that contains nickel.

.....

**(1)**

(ii) Explain, in terms of its structure and bonding, why nickel has a high melting point.

.....

.....

.....

.....

.....

**(2)**

(iii) Draw a labelled diagram to show the arrangement of particles in a crystal of nickel.
In your answer, include at least six particles of each type.

**(2)**

(iv) Explain why nickel is ductile (can be stretched into wires).

.....

.....

.....

**(1)**

(b) Nickel forms the compound nickel(II) chloride ($NiCl_2$).

(i) Give the full electron configuration of the $Ni^{2+}$ ion.

.....

**(1)**

(ii) Balance the following equation to show how anhydrous nickel(II) chloride can be obtained from the hydrated salt using $SOCl_2$
Identify **one** substance that could react with both gaseous products.

.....$NiCl_2.6H_2O(s)$ + ..... $SOCl_2(g)$ ⟶ .....$NiCl_2(s)$ + .....$SO_2(g)$ + .....$HCl(g)$

Substance .....

**(2)**

**(Total 9 marks)**

**Q5.** Aluminium and thallium are elements in Group 3 of the Periodic Table.
Both elements form compounds and ions containing chlorine and bromine.

(a) Write an equation for the formation of aluminium chloride from its elements.

.....

**(1)**

(b) An aluminium chloride molecule reacts with a chloride ion to form the $AlCl_4^-$ ion.

Name the type of bond formed in this reaction. Explain how this type of bond is formed in the $AlCl_4^-$ ion.

Type of bond .....

Explanation .....

.....

.....

**(2)**

(c) Aluminium chloride has a relative molecular mass of 267 in the gas phase.

Deduce the formula of the aluminium compound that has a relative molecular mass of 267

.....

**(1)**

(d) Deduce the name or formula of a compound that has the same number of atoms, the same number of electrons and the same shape as the $AlCl_4^-$ ion.

.....

**(1)**

(e) Draw and name the shape of the $TlBr_5^{2-}$ ion.

Shape of the $TlBr_5^{2-}$ ion.

Name of shape .....

**(2)**

(f) (i) Draw the shape of the $TlCl_2^+$ ion.

**(1)**

(ii) Explain why the $TlCl_2^+$ ion has the shape that you have drawn in part (f)(i).

.....

.....

.....

**(1)**

(g) Which **one** of the first, second or third ionisations of thallium produces an ion with the electron configuration [Xe] $5d^{10}6s^1$?

Tick (✓) one box.

First ☐

Second ☐

Third ☐

**(1)**
**(Total 10 marks)**

**Q6.** Which change requires the largest amount of energy?

**A** $He^+(g) \longrightarrow He^{2+}(g) + e^-$ ⬭

**B** $Li(g) \longrightarrow Li^+(g) + e^-$ ⬭

**C** $Mg^+(g) \longrightarrow Mg^{2+}(g) + e^-$ ⬭

**D** $N(g) \longrightarrow N^+(g) + e^-$ ⬭

**(Total 1 mark)**

**Q7.** The table below shows some successive ionisation energy data for atoms of three different elements **X**, **Y** and **Z**.

Elements **X**, **Y** and **Z** are Ca, Sc and V but not in that order.

| | First | Second | Third | Fourth | Fifth | Sixth |
|---|---|---|---|---|---|---|
| **X** | 648 | 1370 | 2870 | 4600 | 6280 | 12 400 |
| **Y** | 590 | 1150 | 4940 | 6480 | 8120 | 10 496 |
| **Z** | 632 | 1240 | 2390 | 7110 | 8870 | 10 720 |

(a) Which element is calcium?

**X** ⬭

**Y** ⬭

**Z** ⬭

**(1)**

(b) Which element is vanadium?

**X** ⬭

**Y** ⬭

**Z** ⬭

**(1)**

(c) Justify your choice of vanadium in part (b)

.....

.....

.....

**(1)**

(d) An acidified solution of $NH_4VO_3$ reacts with zinc.

Explain how observations from this reaction show that vanadium exists in at least two different oxidation states.

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.....

.....

**(2)**

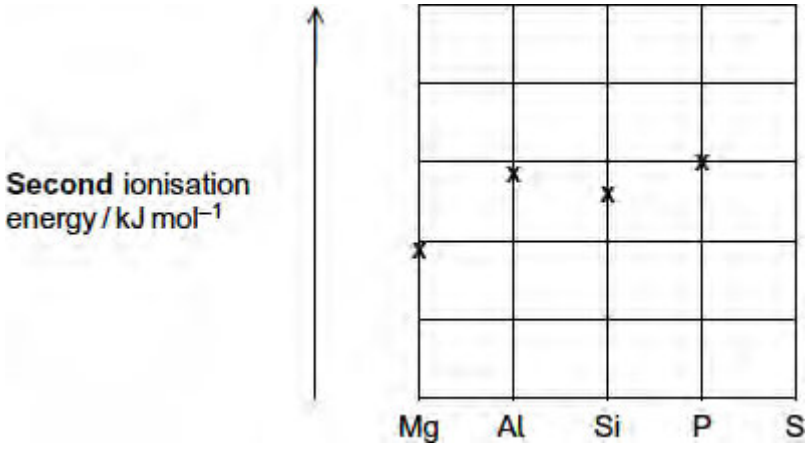
(e) The vanadium in 50.0 $cm^3$ of a 0.800 mol $dm^{-3}$ solution of $NH_4VO_3$ reacts with 506 $cm^3$ of sulfur(IV) oxide gas measured at 20.0 °C and 98.0 kPa.

Use this information to calculate the oxidation state of the vanadium in the solution after the reduction reaction with sulfur(IV) oxide.
Explain your working.
The gas constant $R$ = 8.31 J $K^{-1}$ $mol^{-1}$.

Oxidation state = .....

**(6)**
**(Total 11 marks)**

**Q1.**(a) Use your knowledge of electron configuration and ionisation energies to answer this question. The following diagram shows the **second** ionisation energies of some Period 3 elements.




(i) Draw an '**X**' on the diagram to show the **second** ionisation energy of sulfur.

**(1)**

(ii) Write the full electron configuration of the $Al^{2+}$ ion.

.....

**(1)**

(iii) Write an equation to show the process that occurs when the **second** ionisation energy of aluminium is measured.

.....

**(1)**

(iv) Give **one** reason why the **second** ionisation energy of silicon is lower than the **second** ionisation energy of aluminium.

.....

.....

.....

**(1)**

(b) Predict the element in Period 3 that has the highest **second** ionisation energy.

Give a reason for your answer.

Element .....

Reason .....

.....

.....

**(2)**

(c) The following table gives the successive ionisation energies of an element in Period 3.

| | First | Second | Third | Fourth | Fifth | Sixth |
|---|---|---|---|---|---|---|
| Ionisation energy / kJ $mol^{-1}$ | 786 | 1580 | 3230 | 4360 | 16100 | 19800 |

Identify this element.

.....

**(1)**

(d) Explain why the ionisation energy of every element is endothermic.

.....

.....

.....

*(Extra space)* .....

.....

**(1)**

**(Total 8 marks)**

**Q2.** The element rubidium exists as the isotopes $^{85}Rb$ and $^{87}Rb$

(a) State the number of protons and the number of neutrons in an atom of the isotope $^{85}Rb$

Number of protons .....

Number of neutrons .....

**(2)**

(b) (i) Explain how the gaseous atoms of rubidium are ionised in a mass spectrometer

.....

.....

.....

.....

**(2)**

(ii) Write an equation, including state symbols, to show the process that occurs when the **first** ionisation energy of rubidium is measured.

.....

**(1)**

(c) The table shows the first ionisation energies of rubidium and some other elements in the same group.

| **Element** | sodium | potassium | rubidium |
|---|---|---|---|
| **First ionisation energy / kJ mol$^{-1}$** | 494 | 418 | 402 |

State **one** reason why the first ionisation energy of rubidium is lower than the first ionisation energy of sodium.

.....

.....

.....

**(1)**

(d) (i) State the block of elements in the Periodic Table that contains rubidium.

.....

**(1)**

(ii) Deduce the full electron configuration of a rubidium atom.

.....

**(1)**

(e) A sample of rubidium contains the isotopes $^{85}Rb$ and $^{87}Rb$ only.
The isotope $^{85}Rb$ has an abundance 2.5 times greater than that of $^{87}Rb$

Calculate the relative atomic mass of rubidium in this sample.
Give your answer to one decimal place.

.....

.....

.....

.....

**(3)**

(f) By reference to the relevant part of the mass spectrometer, explain how the abundance of an isotope in a sample of rubidium is determined.

Name of relevant part .....

Explanation .....

.....

.....

**(2)**

(g) Predict whether an atom of $^{88}Sr$ will have an atomic radius that is larger than, smaller than or the same as the atomic radius of $^{87}Rb$. Explain your answer.

Atomic radius of $^{88}Sr$ compared to $^{87}Rb$ .....

Explanation .....

.....

.....

.....

**(3)**
**(Total 16 marks)**

**Q3.** The element nitrogen forms compounds with metals and non-metals.

(a) Nitrogen forms a nitride ion with the electron configuration $1s^2\ 2s^2\ 2p^6$
Write the formula of the nitride ion.

.....

**(1)**

(b) An element forms an ion **Q** with a single negative charge that has the same electron configuration as the nitride ion.
Identify the ion **Q**.

.....

**(1)**

(c) Use the Periodic Table and your knowledge of electron arrangement to write the formula of lithium nitride.

.....

**(1)**

(d) Calcium nitride contains 81.1% by mass of the metal.
Calculate the empirical formula of calcium nitride.
Show your working.

.....

.....

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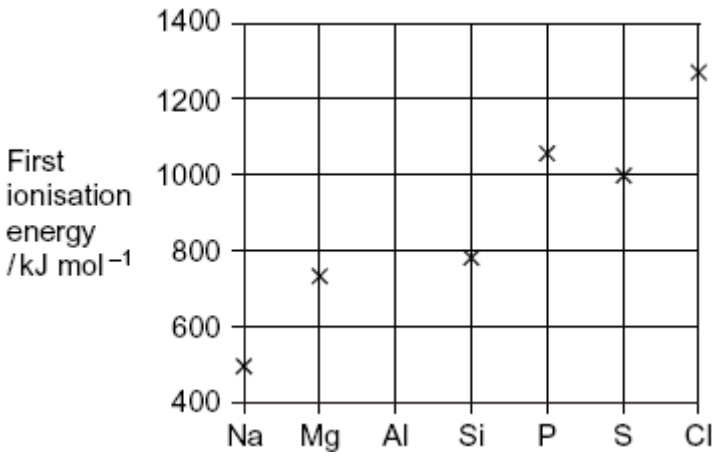
**(3)**

(e) Write an equation for the reaction between silicon and nitrogen to form silicon nitride, $Si_3N_4$

.....

**(1)**
**(Total 7 marks)**

**Q4.** The following diagram shows the first ionisation energies of some Period 3 elements.




(a) Draw a cross on the diagram to show the first ionisation energy of aluminium.

**(1)**

(b) Write an equation to show the process that occurs when the first ionisation energy of aluminium is measured.

.....

**(2)**

(c) State which of the first, second or third ionisations of aluminium would produce an ion with the electron configuration $1s^2\ 2s^2\ 2p^6\ 3s^1$

.....

**(1)**

(d) Explain why the value of the first ionisation energy of sulfur is less than the value of the first ionisation energy of phosphorus.

.....

.....

.....

.....

**(2)**

(e) Identify the element in Period 2 that has the highest first ionisation energy and give its electron configuration.

Element .....

Electron configuration .....

**(2)**

(f) State the trend in first ionisation energies in Group 2 from beryllium to barium. Explain your answer in terms of a suitable model of atomic structure.

Trend ….....

Explanation .....

.....

.....

.....

**(3)**
**(Total 11 marks)**

**Q5.** This question is about the first ionisation energies of some elements in the Periodic Table.

(a) Write an equation, including state symbols, to show the reaction that occurs when the first ionisation energy of lithium is measured.

.....

**(1)**

(b) State and explain the general trend in first ionisation energies for the Period 3 elements aluminium to argon.

Trend .....

Explanation .....

.....

.....

*(Extra space)*.....

.....

**(3)**

(c) There is a similar general trend in first ionisation energies for the Period 4 elements gallium to krypton.

State how selenium deviates from this general trend and explain your answer.

How selenium deviates from this trend .....

Explanation .....

.....

.....

*(Extra space)*.....

**(3)**

(d) Suggest why the first ionisation energy of krypton is lower than the first ionisation energy of argon.

.....

.....

.....

**(1)**

(e) The table below gives the successive ionisation energies of an element.

| | First | Second | Third | Fourth | Fifth |
|---|---|---|---|---|---|
| Ionisation energy / kJ $mol^{-1}$ | 590 | 1150 | 4940 | 6480 | 8120 |
| | | | | | |

Deduce the group in the Periodic Table that contains this element.

.....

**(1)**

(f) Identify the element that has a 5+ ion with an electron configuration of $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}$

.....

**(1)**
**(Total 10 marks)**

**Q1.** Ionisation energies provide evidence for the arrangement of electrons in atoms.

(a) Complete the electron configuration of the $Mg^+$ ion.

$1s^2$ .....

**(1)**

(b) (i) State the meaning of the term *first ionisation energy*.

.....

.....

.....

**(2)**

(ii) Write an equation, including state symbols, to show the reaction that occurs when the **second** ionisation energy of magnesium is measured.

.....

**(1)**

(iii) Explain why the second ionisation energy of magnesium is greater than the first ionisation energy of magnesium.

.....

.....

.....

**(1)**

(iv) Use your understanding of electron arrangement to complete the table by suggesting a value for the third ionisation energy of magnesium.

| | First | Second | Third | Fourth | Fifth |
|---|---|---|---|---|---|
| Ionisation energies of magnesium / kJ $mol^{-1}$ | 736 | 1450 | | 10 500 | 13 629 |
| | | | | | |

**(1)**

(c) State and explain the general trend in the first ionisation energies of the Period 3 elements sodium to chlorine.

Trend .....

Explanation .....

.....

.....

**(3)**

(d) State how the element sulfur deviates from the general trend in first ionisation energies across Period 3. Explain your answer.

How sulfur deviates from the trend .....

.....

Explanation .....

.....

.....

**(3)**

(e) A general trend exists in the first ionisation energies of the Period 2 elements lithium to fluorine. Identify **one** element which deviates from this general trend.

.....

**(1)**
**(Total 13 marks)**

**Q2.** (a) State the meaning of the term *first ionisation energy* of an atom.

.....

.....

**(2)**

(b) Complete the electron arrangement for the $Mg^{2+}$ ion.

*1s*$^2$ .....

**(1)**

(c) Identify the block in the Periodic Table to which magnesium belongs.

.....

**(1)**

(d) Write an equation to illustrate the process occurring when the **second** ionisation energy of magnesium is measured.

.....

**(1)**

(e) The Ne atom and the $Mg^{2+}$ ion have the same number of electrons. Give **two** reasons why the first ionisation energy of neon is lower than the third ionisation energy of magnesium.

*Reason 1* .....

*Reason 2* .....

**(2)**

(f) There is a general trend in the first ionisation energies of the Period 3 elements, Na – Ar

(i) State and explain this general trend.

*Trend* …….....

*Explanation* .....

.....

.....

(ii) Explain why the first ionisation energy of sulphur is lower than would be predicted from the general trend.

.....

.....

.....

**(5)**
**(Total 12 marks)**

**Q3.** Which one of the following statements is **not** correct?

**A** The first ionisation energy of iron is greater than its second ionisation energy.

**B** The magnitude of the lattice enthalpy of magnesium oxide is greater than that of barium oxide.

**C** The oxidation state of iron in $[Fe(CN)_6]^{3-}$ is greater than the oxidation state of copper in $[CuCl_2]^-$

**D** The boiling point of $C_3H_8$ is lower than that of $CH_3CH_2OH$

**(Total 1 mark)**

**Q4.** (a) When aluminium is added to an aqueous solution of copper(II) chloride, $CuCl_2$, copper metal and aluminium chloride, $AlCl_3$, are formed. Write an equation to represent this reaction.

.....

**(1)**

(b) (i) State the general trend in the first ionisation energy of the Period 3 elements from
Na to Ar.

.....

(ii) State how, and explain why, the first ionisation energy of aluminium does not follow this general trend.

.....

.....

.....

.....

**(4)**

(c) Give the equation, including state symbols, for the process which represents the second ionisation energy of aluminium.

.....

**(1)**

(d) State and explain the trend in the melting points of the Period 3 metals Na, Mg and Al.

*Trend* .....

*Explanation* .....

.....

.....

**(3)**
**(Total 9 marks)**

**Q5.** Photochromic glass contains silver ions and copper ions. A simplified version of a redox equilibrium is shown below. In bright sunlight the high energy u.v. light causes silver atoms to form and the glass darkens. When the intensity of the light is reduced the reaction is reversed and the glass lightens.

$$Cu^{+}(s) + Ag^{+}(s) \rightleftharpoons Cu^{2+}(s) + Ag(s)$$

clear glass dark glass

Which one of the following is a correct electron arrangement?

**A** $Cu^{+}$ is $[Ar]3d^{9}4s^{1}$

**B** Cu is $[Ar]3d^{10}4s^{2}$

**C** $Cu^{2+}$ is $[Ar]3d^{8}4s^{1}$

**D** $Cu^{+}$ is $[Ar]3d^{10}$

**(Total 1 mark)**

**Q6.** (a) Complete the electronic configuration for the sodium ion, $Na^{+}$

$1s^{2}$ .....

**(1)**

(b) (i) Write an equation, including state symbols, to represent the process for which the energy change is the second ionisation energy of sodium.

.....

**(2)**

(ii) Explain why the second ionisation energy of sodium is greater than the second ionisation energy of magnesium.

.....

.....

.....

.....

**(3)**

(iii) An element **X** in Period 3 of the Periodic Table has the following successive ionisation energies.

| | First | Second | Third | Fourth |
|---|---|---|---|---|
| Ionisation energies / kJ $mol^{-1}$ | 577 | 1820 | 2740 | 11600 |
| | | | | |

Deduce the identity of element **X**.

.....

**(1)**

(c) State and explain the trend in atomic radius of the Period 3 elements from sodium to chlorine.

Trend .....

Explanation .....

.....

.....

**(3)**

(d) Explain why sodium has a lower melting point than magnesium.

.....

.....

.....

.....

**(3)**

(e) Sodium reacts with ammonia to form the compound $NaNH_2$ which contains the $NH_2^-$ ion. Draw the shape of the $NH_2^-$ ion, including any lone pairs of electrons.
Name the shape made by the three atoms in the $NH_2^-$ ion.

Shape of $NH_2^-$

Name of shape .....

**(2)**

(f) In terms of its electronic configuration, give **one** reason why neon does not form compounds with sodium.

.....

**(1)**

**(Total 16 marks)**

**Q1.** The values of the first ionisation energies of neon, sodium and magnesium are 2080, 494 and 736 kJ $mol^{-1}$, respectively.

(a) Explain the meaning of the term *first ionisation* of an atom.

.....

.....

.....

**(2)**

(b) Write an equation to illustrate the process occurring when the **second** ionisation energy of magnesium is measured.

.....

.....

**(2)**

(c) Explain why the value of the first ionisation energy of magnesium is higher than that of sodium.

.....

.....

.....

**(2)**

(d) Explain why the value of the first ionisation energy of neon is higher than that of sodium.

.....

.....

.....

**(2)**
**(Total 8 marks)**

**Q2.** Lithium hydride, LiH, is an ionic compound containing the hydride ion, $H^-$
The reaction between LiH and aluminium chloride, $AlCl_3$, produces the ionic compound $LiAlH_4$

(a) Balance the equation below which represents the reaction between LiH and $AlCl_3$

$$LiH + AlCl_3 \rightarrow LiAlH_4 + LiCl$$

**(1)**

(b) Give the electronic configuration of the hydride ion, $H^-$

.....

**(1)**

(c) Predict the shape of the $AlH_4^-$ ion. Explain why it has this shape.

*Shape* .....

*Explanation* .....

.....

.....

**(3)**

(d) A bond in $AlH_4^-$ can be represented by H → Al

Name this type of bond and explain how it is formed.

*Type of bond* .....

*Explanation* .....

.....

.....

**(3)**
**(Total 8 marks)**

**Q3.** (a) State the meaning of the term *electronegativity*.

.....

.....

**(2)**

(b) State and explain the trend in electronegativity values across Period 3 from sodium to chlorine.

*Trend* .....

*Explanation* .....

**(3)**

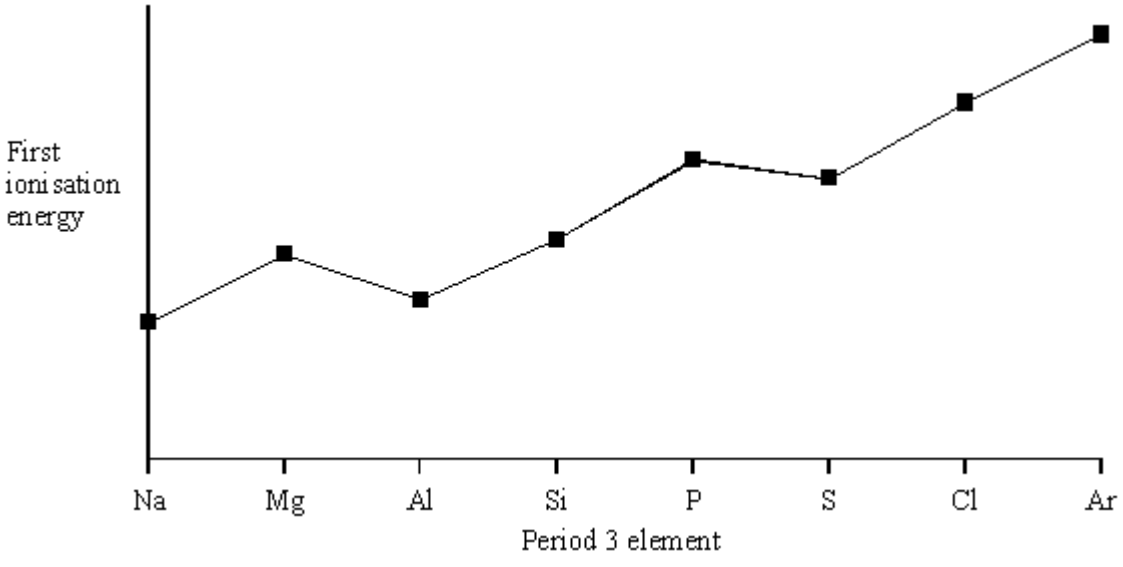
(c) What is meant by the term *first ionisation energy*?

.....

.....

**(2)**

(d) The diagram below shows the variation in first ionisation energy across Period 3.




(i) What is the maximum number of electrons that can be accommodated in an s sub-level?

.....

.....

(ii) What evidence from the diagram supports your answer to part (d)(i)?

.....

.....

(iii) What evidence from the diagram supports the fact that the 3p sub-level is higher in energy than the 3s?

.....

.....

(iv) What evidence from the diagram supports the fact that no more than three unpaired electrons can be accommodated in the 3p sub-level?

.....

.....

.....

**(5)**
**(Total 12 marks)**

**Q4.** Which one of the following is the electronic configuration of the strongest reducing agent?

**A** $1s^2\ 2s^2\ 2p^5$

**B** $1s^2\ 2s^2\ 2p^6\ 3s^2$

**C** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

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

**(Total 1 mark)**

**Q5.** There is a general trend in the values of the first ionisation energies of the elements Na to Ar. The first ionisation energies of the elements Al and S deviate from this trend.

(a) Write an equation, including state symbols, to represent the process for which the energy change is the first ionisation energy of Na.

.....

**(2)**

(b) State and explain the general trend in the values of the first ionisation energies of the elements Na to Ar.

*Trend* .....

*Explanation* .....

.....

.....

**(3)**

(c) State how, and explain why, the values of the first ionisation energies of the elements Al and S deviate from the general trend.

*How the values deviate from the trend* .....

*Explanation for Al* .....

.....

*Explanation for S* .....

.....

**(5)**
**(Total 10 marks)**

**Q6.** (a) One isotope of sodium has a relative mass of 23.

(i) Define, in terms of the fundamental particles present, the meaning of the term *isotopes*.

.....

.....

(ii) Explain why isotopes of the same element have the same chemical properties.

.....

.....

(iii) Calculate the mass, in grams, of a single atom of this isotope of sodium. (The Avogadro constant, $L$, is $6.023 \times 10^{23}$ $mol^{-1}$)

.....

.....

.....

**(5)**

(b) Give the electronic configuration, showing all sub-levels, for a sodium atom.

.....

**(1)**

(c) Explain why chromium is placed in the d block in the Periodic Table.

.....

.....

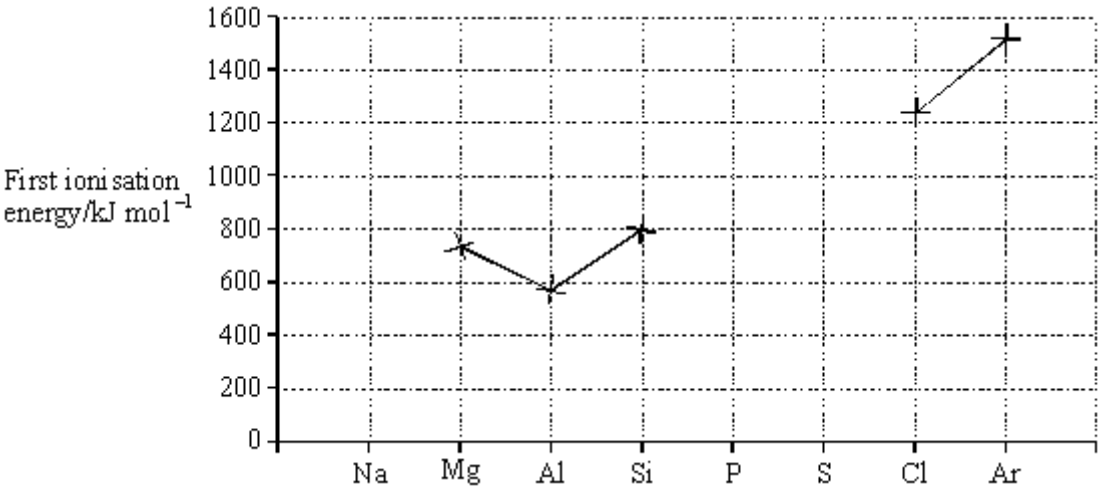
**(1)**

(d) An atom has half as many protons as an atom of $^{28}Si$ and also has six fewer neutrons than an atom of $^{28}Si$. Give the symbol, including the mass number and the atomic number, of this atom.

.....

**(2)**
**(Total 9 marks)**

**Q7.** The diagram below shows the values of the first ionisation energies of some of the elements in Period 3.




(a) On the above diagram, use crosses to mark the approximate positions of the values of the first ionisation energies for the elements Na, P and S. Complete the diagram by joining the crosses.

**(3)**

(b) Explain the general increase in the values of the first ionisation energies of the elements Na–Ar.

.....

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**(3)**

(c) In terms of the electron sub-levels involved, explain the position of aluminium and the position of sulphur in the diagram.

*Explanation for aluminium* .....

.....

.....

*Explanation for sulphur* .....

.....

.....

**(4)**
**(Total 10 marks)**

**Q1.**Which of these atoms has the largest atomic radius?

**A** Ar ⬭

**B** Cl ⬭

**C** Mg ⬭

**D** Na ⬭

**(Total 1 mark)**

**Q2.**(a) **Table 1** shows some data about fundamental particles in an atom.

**Table 1**

| **Particle** | proton | neutron | electron |
|---|---|---|---|
| **Mass / g** | $1.6725 \times 10^{-24}$ | $1.6748 \times 10^{-24}$ | $0.0009 \times 10^{-24}$ |

(i) An atom of hydrogen can be represented as H

Use data from **Table 1** to calculate the mass of this hydrogen atom.

.....

**(1)**

(ii) Which **one** of the following is a fundamental particle that would **not** be deflected by an electric field?

**A** electron

**B** neutron

**C** proton

Write the correct letter, **A**, **B** or **C**, in the box.

☐

**(1)**

(b) A naturally occurring sample of the element boron has a relative atomic mass of 10.8.
In this sample, boron exists as two isotopes, $^{0}$B and B

(i) Calculate the percentage abundance of $^{0}$B in this naturally occurring sample of boron.

.....

.....

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.....

.....

**(2)**

(ii) State, in terms of fundamental particles, why the isotopes $^{0}$B and B have similar chemical reactions.

.....

.....

.....

**(1)**

(c) Complete **Table 2** by suggesting a value for the third ionisation energy of boron.

**Table 2**

| | **First** | **Second** | **Third** | **Fourth** | **Fifth** |
|---|---|---|---|---|---|
| **Ionisation energy / kJ mol$^{-1}$** | 799 | 2420 | | 25 000 | 32 800 |

**(1)**

(d) Write an equation to show the process that occurs when the **second** ionisation energy of boron is measured. Include state symbols in your equation.

.....

**(1)**

(e) Explain why the second ionisation energy of boron is higher than the first ionisation energy of boron.

.....

.....

**(1)**
**(Total 8 marks)**

**Q3.** In 1913 Niels Bohr proposed a model of the atom with a central nucleus, made up of protons and neutrons, around which electrons moved in orbits. After further research, the model was refined when the existence of energy levels and sub-levels was recognised.

(a) Complete the following table for the particles in the nucleus.

| Particle | Relative charge | Relative mass |
|---|---|---|
| proton | | |
| neutron | | |

**(2)**

(b) State the block in the Periodic Table to which the element tungsten, W, belongs.

.....

**(1)**

(c) Isotopes of tungsten include $^{82}W$ and $^{86}W$

(i) Deduce the number of protons in $^{82}W$

.....

**(1)**

(ii) Deduce the number of neutrons in $^{86}W$

.....

**(1)**

(d) In order to detect the isotopes of tungsten using a mass spectrometer, a sample containing the isotopes must be vaporised and then ionised.

(i) Give **two** reasons why the sample must be ionised.

1 .....

2 .....

**(2)**

(ii) State what can be adjusted in the mass spectrometer to enable ions formed by the different isotopes to be directed onto the detector.

.....

**(1)**

(e) State and explain the difference, if any, between the chemical properties of the isotopes $^{82}W$ and $^{86}W$

Difference .....

Explanation .....

.....

**(2)**

(f) The table below gives the relative abundance of each isotope in the mass spectrum of a sample of tungsten.

| *m/z* | 182 | 183 | 184 | 186 |
|---|---|---|---|---|
| Relative abundance /% | 26.4 | 14.3 | 30.7 | 28.6 |

Use the data above to calculate a value for the relative atomic mass of this sample of tungsten. Give your answer to 2 decimal places.

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**(2)**
**(Total 12 marks)**

**Q4.** In one model of atomic structure, the atom has a nucleus surrounded by electrons in levels and sub-levels.

(a) Define the term *atomic number*.

.....

**(1)**

(b) Explain why atoms of an element may have different mass numbers.

.....

**(1)**

(c) The table below refers to a sample of krypton.

| Relative *m/z* | 82 | 83 | 84 | 86 |
|---|---|---|---|---|
| Relative abundance / % | 12 | 12 | 50 | 26 |

(i) Name an instrument which is used to measure the relative abundance of isotopes.

.....

(ii) Define the term *relative atomic mass*.

.....

(iii) Calculate the relative atomic mass of this sample of krypton.

.....

.....

.....

**(5)**

(d) Give the complete electronic configuration of krypton in terms of s, p and d sub-levels.

.....

**(1)**

(e) In 1963, krypton was found to react with fluorine. State why this discovery was unexpected.

.....

**(1)**

(f) Use a suitable model of atomic structure to explain the following experimental observations.

(i) The first ionisation energy of krypton is greater than that of bromine.

.....

.....

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

.....

.....

**(4)**
**(Total 13 marks)**

**Q5.** (a) Complete the following table.

| | Relative mass | Relative charge |
|---|---|---|
| Neutron | | |
| Electron | | |

**(2)**

(b) An atom has twice as many protons as, and four more neutrons than, an atom of $^{9}Be$. Deduce the symbol, including the mass number, of this atom.

.....

**(2)**

(c) Draw the shape of a molecule of $BeCl_2$ and the shape of a molecule of $Cl_2O$. Show any lone pairs of electrons on the central atom. Name the shape of each molecule.

*$BeCl_2$* *$Cl_2O$*

*Name of shape* ..... *Name of shape* .....

**(4)**

(d) The equation for the reaction between magnesium hydroxide and hydrochloric acid is shown below.

$$Mg(OH)_2(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + 2H_2O(l)$$

Calculate the volume, in $cm^3$, of 1.00 mol $dm^{-3}$ hydrochloric acid required to react completely with 1.00 g of magnesium hydroxide.

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**(4)**
**(Total 12 marks)**

**Q1.** (a) Complete the following table.

| | Relative mass | Relative charge |
|---|---|---|
| Proton | | |
| Electron | | |

**(2)**

(b) An atom of element **Q** contains the same number of neutrons as are found in an atom of $^{27}$A1. An atom of **Q** also contains 14 protons.

(i) Give the number of protons in an atom of $^{27}$A1.

.....

(ii) Deduce the symbol, including mass number and atomic number, for this atom of element **Q**.

.....

**(3)**

(c) Define the term *relative atomic mass* of an element.

.....

.....

**(2)**

(d) The table below gives the relative abundance of each isotope in a mass spectrum of a sample of magnesium.

| *m*/*z* | 24 | 25 | 26 |
|---|---|---|---|
| Relative abundance (%) | 73.5 | 10.1 | 16.4 |

Use the data above to calculate the relative atomic mass of this sample of magnesium.
Give your answer to one decimal place.

.....

.....

.....

**(2)**

(e) State how the relative molecular mass of a covalent compound is obtained from its mass spectrum.

.....

.....

**(1)**
**(Total 10 marks)**

**Q2.** (a) Complete the following table.

| Particle | Relative charge | Relative mass |
|---|---|---|
| Proton | | |
| Neutron | | |
| Electron | | |

**(3)**

(b) An atom of element **Z** has two more protons and two more neutrons than an atom of $^{34}_{16}S$. Give the symbol, including mass number and atomic number, for this atom of **Z.**

.....

**(2)**

(c) Complete the electronic configurations for the sulphur atom, S, and the sulphide ion, $S^{2-}$.

*S* $1s^2$ .....

$S^{2-}$ $1s^2$ .....

**(2)**

(d) State the block in the Periodic Table in which sulphur is placed and explain your answer.

*Block* .....

*Explanation* .....

**(2)**

(e) Sodium sulphide, $Na_2S$, is a high melting point solid which conducts electricity when molten. Carbon disulphide, $CS_2$, is a liquid which does not conduct electricity.

(i) Deduce the type of bonding present in $Na_2S$ and that present in $CS_2$

*Bonding in $Na_2S$* .....

*Bonding in $CS_2$*.....

(ii) By reference to all the atoms involved explain, in terms of electrons, how $Na_2S$ is formed from its atoms.

.....

.....

(iii) Draw a diagram, including all the outer electrons, to represent the bonding present in $CS_2$

(iv) When heated with steam, $CS_2$ reacts to form hydrogen sulphide, $H_2S$, and

carbon dioxide.
Write an equation for this reaction.

.....

**(7)**
**(Total 16 narks)**

**Q3.** (a) State the relative charge and relative mass of a proton, of a neutron and of an electron.
In terms of particles, explain the relationship between two isotopes of the same element.
Explain why these isotopes have identical chemical properties.

**(7)**

(b) Define the term *relative atomic mass*. An element exists as a mixture of three isotopes.
Explain, in detail, how the relative atomic mass of this element can be calculated from data obtained from the mass spectrum of the element.

**(7)**
**(Total 14 marks)**

**Q4.** An atom in which the number of protons is greater than the number of neutrons is

**A** $^{234}U$

**B** $^{6}Li$

**C** $^{3}He$

**D** $^{2}H$

**(Total 1 mark)**

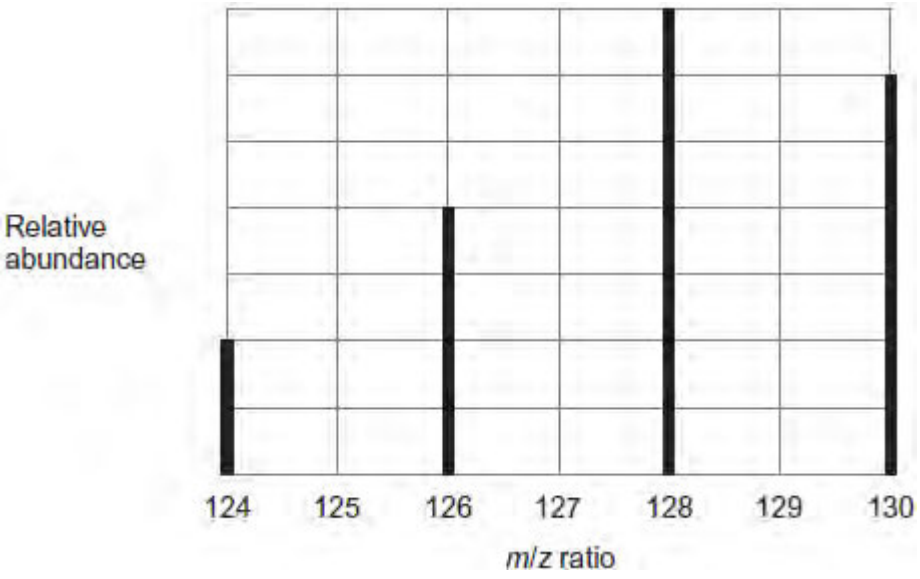
**Q1.** Tellurium is the element with atomic number of 52

(a) Using information from the Periodic Table, complete the electron configuration of tellurium.

[Kr] .....

**(1)**

(b) The mass spectrum of a sample of tellurium is shown in the graph.




(i) Use the graph to calculate the relative atomic mass of this sample of tellurium. Give your answer to one decimal place.

.....

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.....

**(3)**

(ii) Suggest what might cause the relative atomic mass of this sample to be different from the relative atomic mass given in the Periodic Table.

.....

.....

**(1)**

(c) Write an equation for the reaction that occurs when a tellurium ion hits the detector.

.....

**(1)**

(d) State the $m$ / $z$ value of the ions that produce the biggest current at the detector when the spectrum in the graph is recorded.
Give a reason for your answer.

$m$ / $z$ value .....

Reason .....

.....

.....

**(2)**

(e) The mass spectrum of tellurium also has a small peak at $m$ / $z$ = 64

Explain the existence of this peak.

.....

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.....

.....

**(2)**

(f) Predict whether the atomic radius of $^{124}Te$ is larger than, smaller than or the same as the atomic radius of $^{130}Te$
Explain your answer.

Atomic radius of $^{124}Te$ compared to $^{130}Te$ .....

Explanation .....

.....

.....

.....

**(2)**
**(Total 12 marks)**

**Q2.**(a) A sample of sulfur consisting of three isotopes has a relative atomic mass of 32.16. The following table gives the relative abundance of two of these isotopes.

| **Mass number of isotope** | 32 | 33 |
|---|---|---|
| **Relative abundance / %** | 91.0 | 1.8 |

Use this information to determine the relative abundance and hence the mass number of the third isotope.
Give your answer to the appropriate number of significant figures.

Mass number = .....

**(4)**

(b) Describe how ions are formed in a time of flight (TOF) mass spectrometer.

.....

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**(2)**

(c) A TOF mass spectrometer can be used to determine the relative molecular mass of molecular substances.

Explain why it is necessary to ionise molecules when measuring their mass in a TOF mass spectrometer.

.....

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.....

**(2)**
**(Total 8 marks)**

**Q3.**Which of these atoms has the smallest number of neutrons?

**A** $^{3}H$ ⬭

**B** $^{4}He$ ⬭

**C** $^{5}He$ ⬭

**D** $^{4}Li$ ⬭

**(Total 1 mark)**

**Q4.**(a) State the meaning of the term *mass number* of an isotope.

.....

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.....

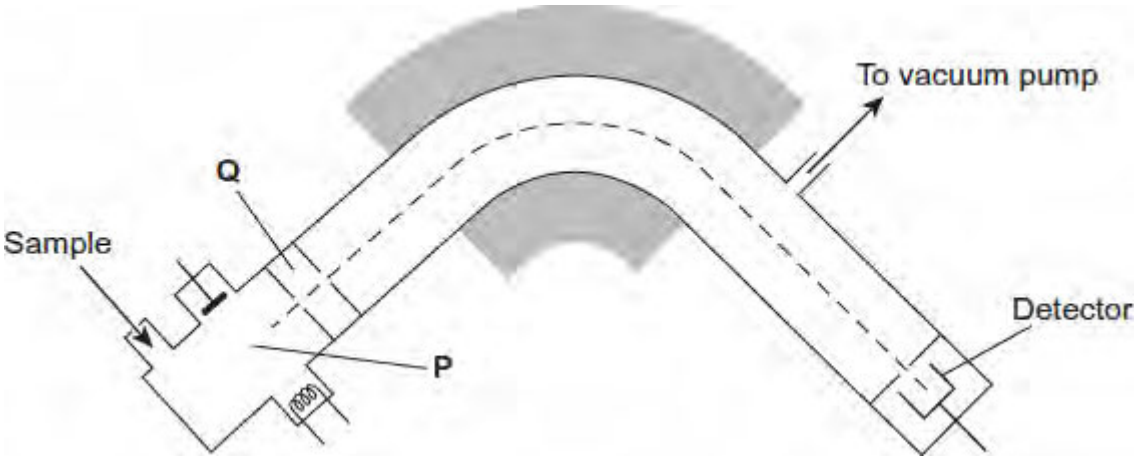
**(1)**

(b) Give the symbol of the element that has an isotope with a mass number of 68 and has 38 neutrons in its nucleus.

.....

**(1)**

(c) The following shows a simplified diagram of a mass spectrometer.




(i) State what happens to the sample in the parts labelled **P** and **Q**.

**P** .....

**Q** .....

**(2)**

(ii) In a mass spectrometer, the isotopes of an element are separated.
Two measurements for each isotope are recorded on the mass spectrum.

State the **two** measurements that are recorded for each isotope.

Measurement 1 .....

Measurement 2 .....

**(2)**

(d) A sample of element **R** contains isotopes with mass numbers of 206, 207 and 208 in a 1:1:2 ratio of abundance.

(i) Calculate the relative atomic mass of **R**. Give your answer to one decimal place.

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**(3)**

(ii) Identify **R**.

.....

**(1)**

(iii) All the isotopes of **R** react in the same way with concentrated nitric acid.

State why isotopes of an element have the same chemical properties.

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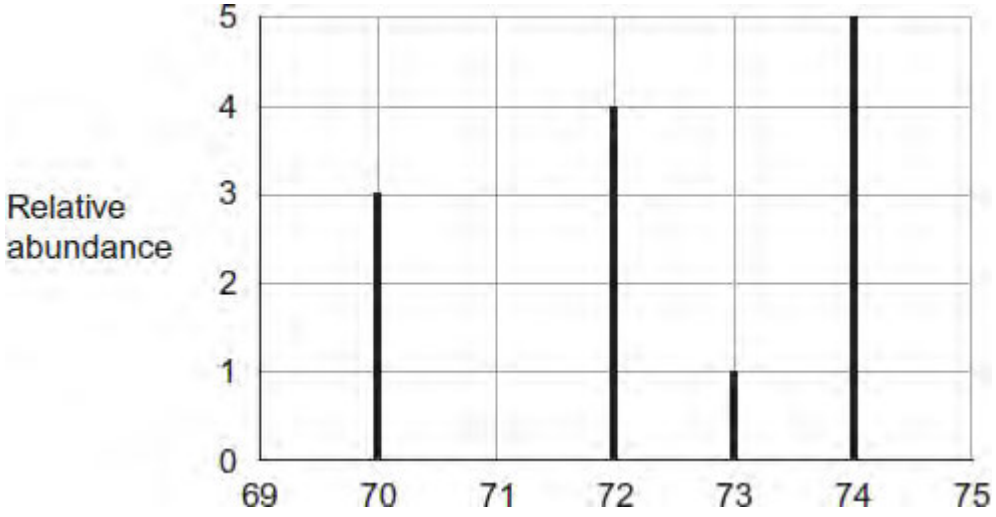
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*(Extra space)* .....

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**(1)**
**(Total 11 marks)**

**Q5.** The mass spectrum of the isotopes of element **X** is shown in the diagram.




(a) Define the term *relative atomic mass*.

.....

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.....

**(2)**

(b) Use data from the diagram to calculate the relative atomic mass of **X**.

Give your answer to one decimal place.

.....

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.....

**(3)**

(c) Identify the ion responsible for the peak at 72

.....

**(1)**

(d) Identify which one of the isotopes of **X** is deflected the most in the magnetic field of a mass spectrometer. Give a reason for your answer.

Isotope .....

Reason .....

**(2)**

(e) In a mass spectrometer, the relative abundance of each isotope is proportional to the current generated by that isotope at the detector.

Explain how this current is generated.

.....

.....

.....

.....

**(2)**

(f) **X** and **Zn** are different elements.

.....

.....

Explain why the chemical properties of $^{70}$**X** and $^{70}$**Zn** are different.

**(1)**
**(Total 11 marks)**

**Q6.** A sample of ethanedioic acid was treated with an excess of an unknown alcohol in the presence of a strong acid catalyst. The products of the reaction were separated and analysed in a time of flight (TOF) mass spectrometer. Two peaks were observed at $m / z$ = 104 and 118.

(a) Identify the species responsible for the two peaks.

.....

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.....

**(2)**

(b) Outline how the TOF mass spectrometer is able to separate these two species to give two peaks.

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**(4)**
**(Total 6 marks)**

**Q7.**(a) **Table 1** shows some data about fundamental particles in an atom.

**Table 1**

| **Particle** | proton | neutron | electron |
|---|---|---|---|
| **Mass / g** | $1.6725 \times 10^{-24}$ | $1.6748 \times 10^{-24}$ | $0.0009 \times 10^{-24}$ |

(i) An atom of hydrogen can be represented as $^{1}H$

Use data from **Table 1** to calculate the mass of this hydrogen atom.

.....

**(1)**

(ii) Which **one** of the following is a fundamental particle that would **not** be deflected by an electric field?

**A** electron

**B** neutron

**C** proton

Write the correct letter, **A**, **B** or **C**, in the box.

☐

**(1)**

(b) A naturally occurring sample of the element boron has a relative atomic mass of 10.8.
In this sample, boron exists as two isotopes, $^{10}B$ and $^{11}B$

(i) Calculate the percentage abundance of $^{10}B$ in this naturally occurring sample of boron.

.....

.....

.....

.....

.....

**(2)**

(ii) State, in terms of fundamental particles, why the isotopes $^{10}B$ and $^{11}B$ have similar chemical reactions.

.....

.....

.....

**(1)**

(c) Complete **Table 2** by suggesting a value for the third ionisation energy of boron.

**Table 2**

| | **First** | **Second** | **Third** | **Fourth** | **Fifth** |
|---|---|---|---|---|---|
| **Ionisation energy / kJ mol$^{-1}$** | 799 | 2420 | | 25 000 | 32 800 |

**(1)**

(d) Write an equation to show the process that occurs when the **second** ionisation energy of boron is measured. Include state symbols in your equation.

.....

**(1)**

(e) Explain why the second ionisation energy of boron is higher than the first ionisation energy of boron.

.....

.....

**(1)**

**(Total 8 marks)**

**Q1.** The element rubidium exists as the isotopes $^{85}Rb$ and $^{87}Rb$

(a) State the number of protons and the number of neutrons in an atom of the isotope $^{85}Rb$

Number of protons .....

Number of neutrons .....

**(2)**

(b) (i) Explain how the gaseous atoms of rubidium are ionised in a mass spectrometer

.....

.....

.....

.....

**(2)**

(ii) Write an equation, including state symbols, to show the process that occurs when the **first** ionisation energy of rubidium is measured.

.....

**(1)**

(c) The table shows the first ionisation energies of rubidium and some other elements in the same group.

| **Element** | sodium | potassium | rubidium |
|---|---|---|---|
| **First ionisation energy / kJ mol$^{-1}$** | 494 | 418 | 402 |

State **one** reason why the first ionisation energy of rubidium is lower than the first ionisation energy of sodium.

.....

.....

.....

**(1)**

(d) (i) State the block of elements in the Periodic Table that contains rubidium.

.....

**(1)**

(ii) Deduce the full electron configuration of a rubidium atom.

.....

**(1)**

(e) A sample of rubidium contains the isotopes $^{85}$Rb and $^{87}$Rb only.
The isotope $^{85}$Rb has an abundance 2.5 times greater than that of $^{87}$Rb

Calculate the relative atomic mass of rubidium in this sample.
Give your answer to one decimal place.

.....

.....

.....

.....

**(3)**

(f) By reference to the relevant part of the mass spectrometer, explain how the abundance of an isotope in a sample of rubidium is determined.

Name of relevant part .....

Explanation .....

.....

.....

**(2)**

(g) Predict whether an atom of $^{88}$Sr will have an atomic radius that is larger than, smaller than or the same as the atomic radius of $^{87}$Rb. Explain your answer.

Atomic radius of $^{88}Sr$ compared to $^{87}Rb$ .....

Explanation .....

.....

.....

.....

**(3)**
**(Total 16 marks)**

**Q2.** The manufacture of food grade phosphoric acid for use in cola drinks begins with the production of pure white phosphorus from the mineral fluoroapatite, $Ca_5F(PO_4)_3$

(a) Complete the following equation for the manufacture of phosphorus.

$$....Ca_5F(PO_4)_3 + 9SiO_2 + ....C \longrightarrow 9CaSiO_3 + CaF_2 + ....CO + ....P$$

**(1)**

(b) As the phosphorus cools, it forms white phosphorus, $P_4$

Give the oxidation state of phosphorus in each of the following.

$P_4$ .....

$H_3PO_4$ .....

**(2)**

(c) Fertiliser grade phosphoric acid is manufactured from sulfuric acid and calcium phosphate.
Use the following precise relative atomic mass data to show how mass spectrometry can be used to distinguish between pure sulfuric acid ($H_2SO_4$) and pure phosphoric acid ($H_3PO_4$) which both have $M_r$ = 98 to two significant figures.

| Atom | Precise relative atomic mass |
|---|---|
| $^{1}H$ | 1.00794 |
| $^{16}O$ | 15.99491 |

| | |
|---|---|
| $^{31}P$ | 30.97376 |
| $^{32}S$ | 32.06550 |

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**(1)**

(d) Concentrated phosphoric acid is used as a catalyst in the hydration of propene to form the alcohol $CH_3CH(OH)CH_3$ as the main organic product.
The industrial name for this alcohol is isopropyl alcohol.

(i) State the meaning of the term *catalyst*.

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*(Extra space)* .....

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**(1)**

(ii) State the meaning of the term *hydration*.

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*(Extra space)* .....

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**(1)**

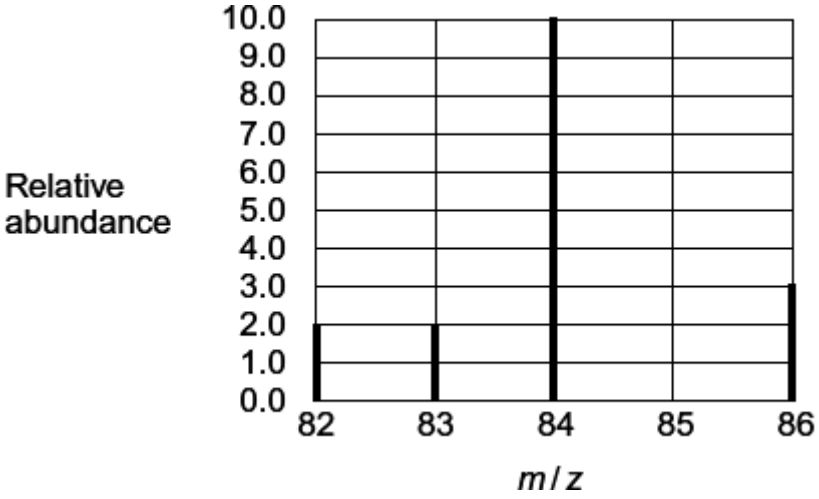
(iii) Write an equation for the hydration of propene to form isopropyl alcohol.
Give the IUPAC name for isopropyl alcohol.

Equation .....

IUPAC name .....

**(2)**
**(Total 8 marks)**

**Q3.**The mass spectrum of a sample of krypton taken from a meteorite is shown below.




(a) Use this spectrum to calculate the relative atomic mass of this sample of krypton. Give your answer to one decimal place.

Explain why the value you have calculated is slightly different from the relative atomic mass given in the Periodic Table.

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*(Extra space)* .....

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**(4)**

(b) State how krypton is ionised in the mass spectrometer.

Write an equation, including state symbols, to show the reaction that occurs when the **first** ionisation energy of Kr is measured.

Sometimes the mass spectrum of Kr has a very small peak with an *m/z* value of 42. Explain the occurrence of this peak.

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*(Extra space)* .....

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**(5)**
**(Total 9 marks)**

**Q4.** (a) Define the term *relative atomic mass*.

An organic fertiliser was analysed using a mass spectrometer. The spectrum showed that the nitrogen in the fertiliser was made up of 95.12% $^{14}N$ and 4.88% $^{15}N$

Calculate the relative atomic mass of the nitrogen found in this organic fertiliser. Give your answer to two decimal places.

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**(4)**

(b) In a mass spectrometer, under the same conditions, $^{14}N^{+}$ and $^{15}N^{+}$ ions follow different paths. State the property of these ions that causes them to follow different paths.

State **one** change in the operation of the mass spectrometer that will change the path of an ion.

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**(2)**

(c) Organic fertilisers contain a higher proportion of $^{15}N$ atoms than are found in synthetic fertilisers.

State and explain whether or not you would expect the chemical reactions of the nitrogen compounds in the synthetic fertiliser to be different from those in the organic fertiliser. Assume that the nitrogen compounds in each fertiliser are the same.

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**(2)**
**(Total 8 marks)**

**Q5.** Define the term *mass number* of an atom.

The mass number of an isotope of nitrogen is 15. Deduce the number of each of the fundamental particles in an atom of $^{15}N$

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**(Total 3 marks)**

**Q6.** Mass spectrometry can be used to identify isotopes of elements.

(a) (i) In terms of fundamental particles, state the difference between isotopes of an element.

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**(1)**

(ii) State why isotopes of an element have the same chemical properties.

.....

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**(1)**

(b) Give the meaning of the term *relative atomic mass.*

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*(Extra space)*.....

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**(2)**

(c) The mass spectrum of element **X** has four peaks. The table below gives the relative abundance of each isotope in a sample of element **X**.

| *m/z* | 64 | 66 | 67 | 68 |
|---|---|---|---|---|
| Relative abundance | 12 | 8 | 1 | 6 |

(i) Calculate the relative atomic mass of element **X**.
Give your answer to one decimal place.

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**(3)**

(ii) Use the Periodic Table to identify the species responsible for the peak at *m/z* = 64

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**(2)**

(d) Suggest **one** reason why particles with the same mass and velocity can be deflected by different amounts in the same magnetic field.

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**(1)**

(e) Explain how the detector in a mass spectrometer enables the abundance of an isotope to be measured.

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*(Extra space)* .....

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**(2)**
**(Total 12 marks)**

**Q1.** The manufacturer supplying concentrated ethanoic acid for the production of vinegar also supplied other acids. The label had come off a batch of one of these other acids.
A sample of this unknown acid was analysed and found to contain 54.5% of carbon and 9.10% of hydrogen by mass, the remainder being oxygen.

(a) Use these data to calculate the empirical formula of the unknown acid.
Show your working.

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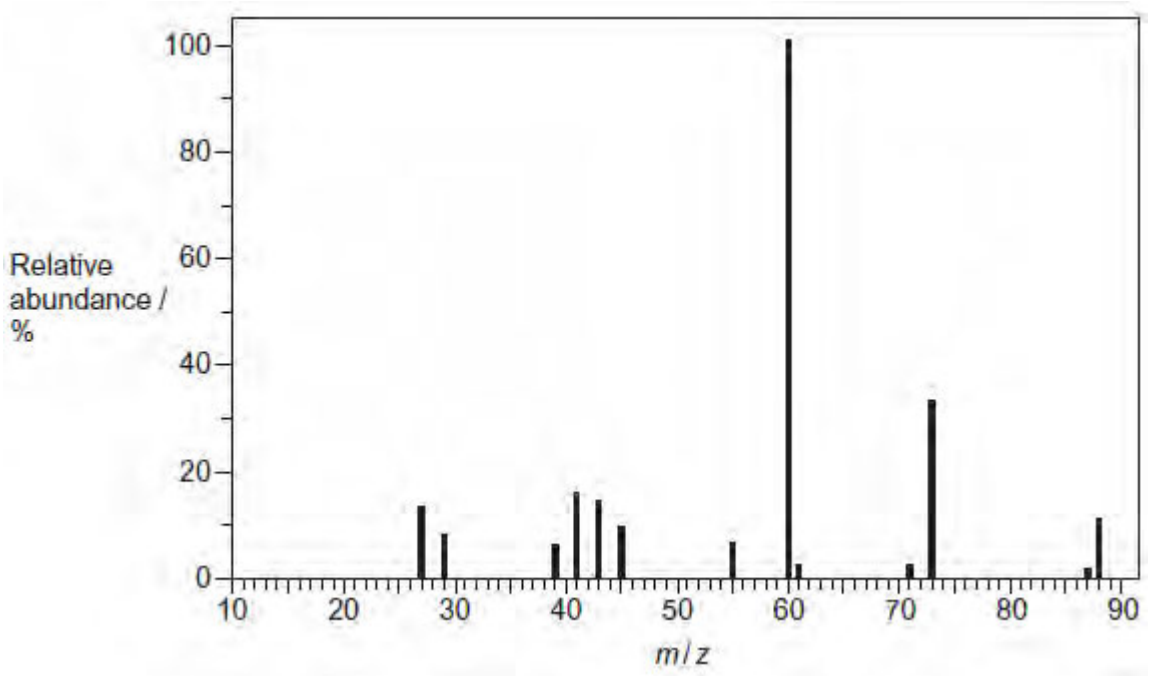
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**(3)**

(b) A sample of the unknown acid was analysed in a mass spectrometer. The mass spectrum obtained is shown below.




Use the mass spectrum to determine the $M_r$ of the unknown acid.

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**(1)**

(c) Use your answers from parts (a) and (b) to determine the molecular formula of the

unknown acid.
(If you could not answer part (b), you should assume that the $M_r$ of the acid is 132.0 but this is **not** the correct value.)
Show your working.

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**(2)**
**(Total 6 marks)**

**Q2.** A mass spectrometer can be used to investigate the isotopes in an element.

(a) Define the term *relative atomic mass* of an element.

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**(2)**

(b) Element **X** has a relative atomic mass of 47.9

Identify the block in the Periodic Table to which element **X** belongs and give the electron configuration of an atom of element **X**.

Calculate the number of neutrons in the isotope of **X** which has a mass number 49

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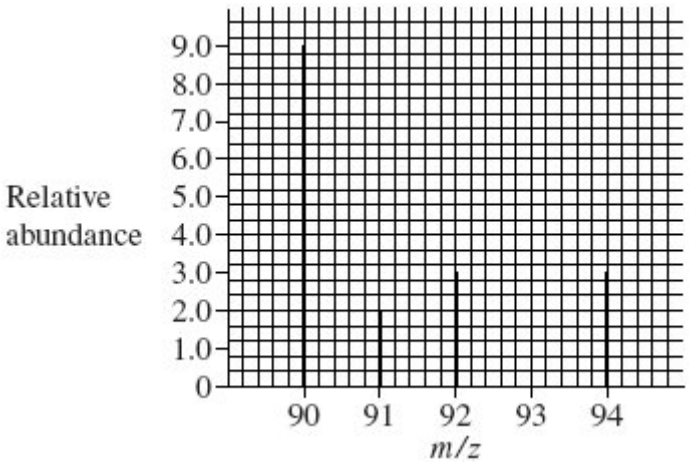
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**(3)**

(c) The mass spectrum of element **Z** is shown below.

Use this spectrum to calculate the relative atomic mass of **Z**, giving your answer to one decimal place.

Identify element **Z**.




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**(4)**

(d) State how vaporised atoms of **Z** are converted into $\mathbf{Z}^+$ ions in a mass spectrometer.

State and explain which of the $\mathbf{Z}^+$ ions formed from the isotopes of **Z** in part (c) will be deflected the most in a mass spectrometer.

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**(4)**

(e) Explain briefly how the relative abundance of an ion is measured in a mass spectrometer.

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**(2)**
**(Total 15 marks)**

**Q3.** In 1913 Niels Bohr proposed a model of the atom with a central nucleus, made up of protons and neutrons, around which electrons moved in orbits. After further research, the model was refined when the existence of energy levels and sub-levels was recognised.

(a) Complete the following table for the particles in the nucleus.

| Particle | Relative charge | Relative mass |
|---|---|---|
| proton | | |
| neutron | | |

**(2)**

(b) State the block in the Periodic Table to which the element tungsten, W, belongs.

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**(1)**

(c) Isotopes of tungsten include $^{182}W$ and $^{186}W$

(i) Deduce the number of protons in $^{182}W$

.....

**(1)**

(ii) Deduce the number of neutrons in $^{186}W$

.....

**(1)**

(d) In order to detect the isotopes of tungsten using a mass spectrometer, a sample containing the isotopes must be vaporised and then ionised.

(i) Give **two** reasons why the sample must be ionised.

1 .....

2 .....

**(2)**

(ii) State what can be adjusted in the mass spectrometer to enable ions formed by the different isotopes to be directed onto the detector.

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**(1)**

(e) State and explain the difference, if any, between the chemical properties of the isotopes $^{182}W$ and $^{186}W$

Difference .....

Explanation .....

.....

**(2)**

(f) The table below gives the relative abundance of each isotope in the mass spectrum of a sample of tungsten.

| *m/z* | 182 | 183 | 184 | 186 |
|---|---|---|---|---|
| Relative abundance /% | 26.4 | 14.3 | 30.7 | 28.6 |

Use the data above to calculate a value for the relative atomic mass of this sample of tungsten. Give your answer to 2 decimal places.

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**(2)**
**(Total 12 marks)**

**Q4.** (a) Complete the following table.

| | Relative mass | Relative charge |
|---|---|---|
| Proton | | |
| Electron | | |

**(2)**

(b) An atom of element **Q** contains the same number of neutrons as are found in an atom of $^{27}$A1. An atom of **Q** also contains 14 protons.

(i) Give the number of protons in an atom of $^{27}$A1.

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(ii) Deduce the symbol, including mass number and atomic number, for this atom of element **Q**.

.....

**(3)**

(c) Define the term *relative atomic mass* of an element.

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**(2)**

(d) The table below gives the relative abundance of each isotope in a mass spectrum

of a sample of magnesium.

| *m*/*z* | 24 | 25 | 26 |
|---|---|---|---|
| Relative abundance (%) | 73.5 | 10.1 | 16.4 |

Use the data above to calculate the relative atomic mass of this sample of magnesium.
Give your answer to one decimal place.

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**(2)**

(e) State how the relative molecular mass of a covalent compound is obtained from its mass spectrum.

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**(1)**
**(Total 10 marks)**

**Q5.** In one model of atomic structure, the atom has a nucleus surrounded by electrons in levels and sub-levels.

(a) Define the term *atomic number*.

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**(1)**

(b) Explain why atoms of an element may have different mass numbers.

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**(1)**

(c) The table below refers to a sample of krypton.

| Relative *m/z* | 82 | 83 | 84 | 86 |
|---|---|---|---|---|
| Relative abundance / % | 12 | 12 | 50 | 26 |

(i) Name an instrument which is used to measure the relative abundance of isotopes.

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(ii) Define the term *relative atomic mass*.

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(iii) Calculate the relative atomic mass of this sample of krypton.

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**(5)**

(d) Give the complete electronic configuration of krypton in terms of s, p and d sub-levels.

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**(1)**

(e) In 1963, krypton was found to react with fluorine. State why this discovery was unexpected.

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**(1)**

(f) Use a suitable model of atomic structure to explain the following experimental observations.

(i) The first ionisation energy of krypton is greater than that of bromine.

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

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**(4)**
**(Total 13 marks)**

**Q1.** (a) Complete the following table.

| | Relative mass | Relative charge |
|---|---|---|
| Neutron | | |
| Electron | | |

**(2)**

(b) An atom has twice as many protons as, and four more neutrons than, an atom of $^{9}Be$. Deduce the symbol, including the mass number, of this atom.

.....

**(2)**

(c) Draw the shape of a molecule of $BeCl_2$ and the shape of a molecule of $Cl_2O$. Show any lone pairs of electrons on the central atom. Name the shape of each molecule.

*$BeCl_2$* *$Cl_2O$*

*Name of shape* ..... *Name of shape* .....

**(4)**

(d) The equation for the reaction between magnesium hydroxide and hydrochloric acid is shown below.

$$Mg(OH)_2(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + 2H_2O(l)$$

Calculate the volume, in $cm^3$, of 1.00 mol $dm^{-3}$ hydrochloric acid required to react completely with 1.00 g of magnesium hydroxide.

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**(4)**
**(Total 12 marks)**

**Q2.** Chlorine has two isotopes, $^{35}Cl$ and $^{37}Cl$. The number of molecular ion peaks in the mass spectrum of a sample of $Cl_2$ is

**A** 2

**B** 3

**C** 4

**D** 5

**(Total 1 mark)**

**Q3.** (a) One isotope of sodium has a relative mass of 23.

(i) Define, in terms of the fundamental particles present, the meaning of the term *isotopes*.

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(ii) Explain why isotopes of the same element have the same chemical properties.

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(iii) Calculate the mass, in grams, of a single atom of this isotope of sodium. (The Avogadro constant, *L*, is $6.023 \times 10^{23}$ $mol^{-1}$)

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**(5)**

(b) Give the electronic configuration, showing all sub-levels, for a sodium atom.

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**(1)**

(c) Explain why chromium is placed in the d block in the Periodic Table.

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**(1)**

(d) An atom has half as many protons as an atom of $^{28}Si$ and also has six fewer neutrons than an atom of $^{28}Si$. Give the symbol, including the mass number and the atomic number, of this atom.

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**(2)**
**(Total 9 marks)**

**Q4.** Assuming that chlorine exists as two isotopes, and that hydrogen and carbon exist as one isotope each, how many molecular ion peaks will be shown in the mass spectrum of $C_4H_6Cl_4$?

**A** 2

**B** 3

**C** 4

**D** 5

**(Total 1 mark)**

**Q5.** (a) State the relative charge and relative mass of a proton, of a neutron and of an electron.
In terms of particles, explain the relationship between two isotopes of the same element.
Explain why these isotopes have identical chemical properties.

**(7)**

(b) Define the term *relative atomic mass*. An element exists as a mixture of three isotopes.
Explain, in detail, how the relative atomic mass of this element can be calculated from data obtained from the mass spectrum of the element.

**(7)**
**(Total 14 marks)**