AQA A-LEVEL CHEMISTRY · 7405

CHEMISTRY



EXAM QUESTION PACK

3.1.1 ATOMIC STRUCTURE

SCORE	PERCENTAGE
/749	%

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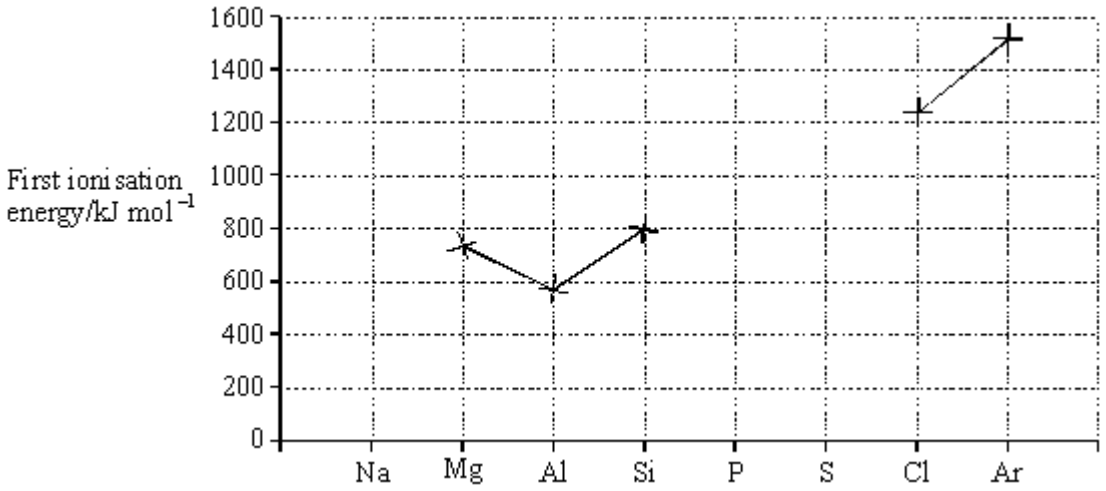
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Q1.

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.

_____

_____

_____

_____

(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)

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Q2.

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)

Q3.

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)

Q4.

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

_____

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_____

(2)

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

Trend _____

Explanation _____

(3)

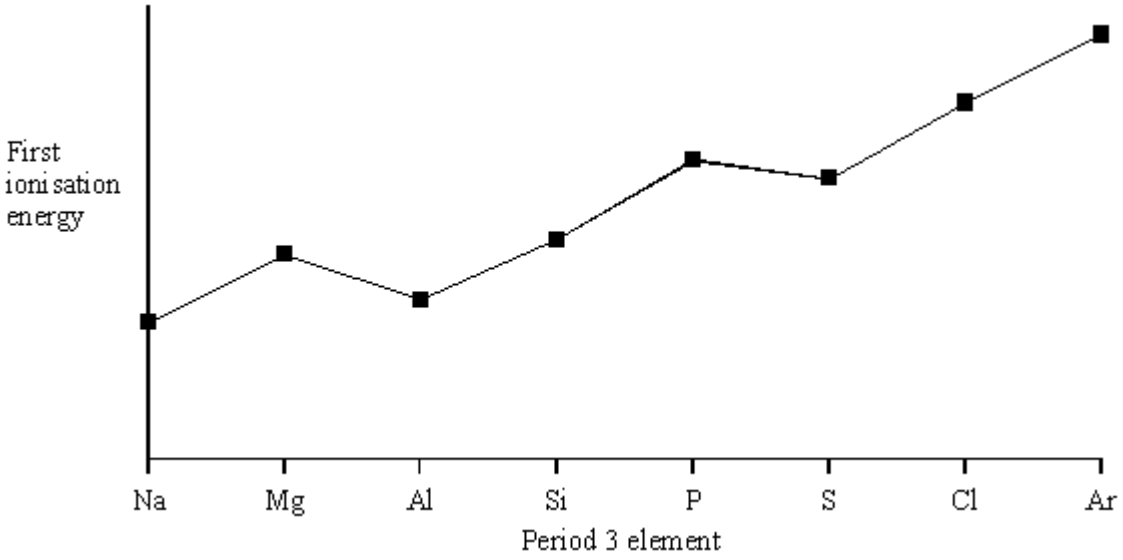
(c) What is meant by the term *first ionisation energy*?

_____

_____

(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?

_____

_____

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(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)

Q5.

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)

Q6.

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)

Q7.

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 $2p$ electron occupies a higher energy level than a $2s$ electron.

(Total 1 mark)

Q8.

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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)

Q9.

Which atom has an incomplete sub-shell?

A Be

B Ca

C Ge

D Zn

(Total 1 mark)

Q10.

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)

Q11.

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

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(Total 1 mark)

Q12.

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)

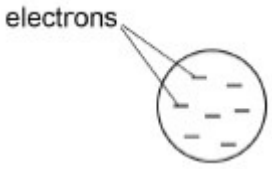
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Q1.

This question is about atomic structure.

In the nineteenth century JJ Thomson discovered the electron. He suggested that negative electrons were found throughout an atom like 'plums in a pudding of positive charge'.

The diagram shows an atom of element **R** using the 'plum pudding' model.
An atom of **R** contains seven electrons.



(a) State **two** differences between the 'plum pudding' model and the model of atomic structure used today.

1. _____

_____

2. _____

_____

(2)

(b) Deduce the full electron configuration of an atom of element **R**.

_____

(1)

(c) Identify **R** and deduce the formula of the compound formed when **R** reacts with the Group 2 metal in the same period as **R**.

_____

(1)

(Total 4 marks)

Q2.

This question is about sodium fluoride (NaF).

Some toothpastes contain sodium fluoride.
The concentration of sodium fluoride can be expressed in parts per million (ppm).
1 ppm represents a concentration of 1 mg in every 1 kg of toothpaste.

(a) A 1.00 g sample of toothpaste was found to contain 2.88×10^{-5} mol of sodium fluoride.

Calculate the concentration of sodium fluoride, in ppm, for the sample of toothpaste.
Give your answer to 3 significant figures.

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Concentration of sodium fluoride _____ ppm

(4)

(b) Sodium fluoride is toxic in high concentrations.
Major health problems can occur if concentrations of sodium fluoride are greater than 3.19×10^{-2} g per kilogram of body mass.

Deduce the maximum mass of sodium fluoride, in mg, that a 75.0 kg person could swallow without reaching the toxic concentration.

Mass of sodium fluoride _____ mg

(1)

(c) The concentration of sodium fluoride in a prescription toothpaste is 2800 ppm.

Use your answer to Question (b) to deduce the mass of toothpaste, in kg, that a 75.0 kg person could swallow without reaching the toxic concentration.

Mass of toothpaste _____ kg

(1)

(d) Identify the diagram in the figure below that shows the correct relative sizes of the ions in sodium fluoride.
Justify your answer.

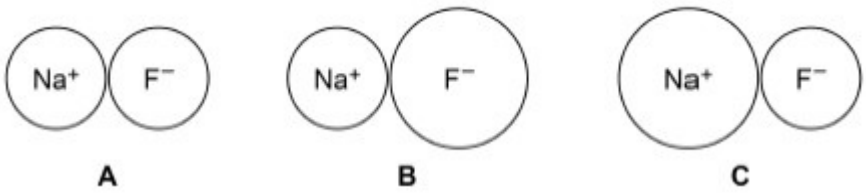


Diagram _____

Justification _____

_____

_____

_____

_____

_____

_____

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(3)
(Total 9 marks)

Q3.

This question is about s-block metals.

(a) Give the full electron configuration for the calcium ion, Ca^{2+}

_____

(1)

(b) Explain why the second ionisation energy of calcium is lower than the second ionisation energy of potassium.

_____

_____

_____

_____

_____

(2)

(c) Identify the s-block metal that has the highest first ionisation energy.

_____

(1)

(d) Give the formula of the hydroxide of the element in Group 2, from Mg to Ba, that is least soluble in water.

_____

(1)

(e) A student added 6 cm^3 of 0.25 mol dm^{-3} barium chloride solution to 8 cm^3 of 0.15 mol dm^{-3} sodium sulfate solution.
The student filtered off the precipitate and collected the filtrate.

Give an ionic equation for the formation of the precipitate.
Show by calculation which reagent is in excess.
Calculate the total volume of the other reagent which should be used by the student so that the filtrate contains only one solute.

Ionic equation _____

Reagent in excess _____

Total volume of other reagent _____

_____

_____

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_____

_____

(3)

(f) A sample of strontium has a relative atomic mass of 87.7 and consists of three isotopes, ^{86}Sr, ^{87}Sr and ^{88}Sr
In this sample, the ratio of abundances of the isotopes ^{86}Sr :^{87}Sr is 1:1

State why the isotopes of strontium have identical chemical properties.
Calculate the percentage abundance of the ^{88}Sr isotope in this sample.

Why isotopes of strontium have identical chemical properties

_____

_____

_____

Percentage abundance of ^{88}Sr _____ %

(4)

(g) A time of flight (TOF) mass spectrum was obtained for a sample of barium that contains the isotopes ^{136}Ba, ^{137}Ba and ^{138}Ba

The sample of barium was ionised by electron impact.

Identify the ion with the longest time of flight.

_____

(1)

(h) A $^{137}Ba^{+}$ ion travels through the flight tube of a TOF mass spectrometer with a kinetic energy of 3.65×10^{-16} J
This ion takes 2.71×10^{-5} s to reach the detector.

$KE = \frac{1}{2} mv^2$ where m = mass (kg) and v = speed (m s^{-1})

The Avogadro constant, $L = 6.022 \times 10^{23}$ mol^{-1}

Calculate the length of the flight tube in metres.

Give your answer to the appropriate number of significant figures.

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Length of flight tube _____ m

(5)

(Total 18 marks)

Q4.

This question is about atomic structure.

(a) Write the full electron configuration for each of the following species.

Cl^-_____

Fe^{2+}_____

(2)

(b) Write an equation, including state symbols, to represent the process that occurs when the third ionisation energy of manganese is measured.

_____

_____

(1)

(c) State which of the elements magnesium and aluminium has the lower first ionisation energy.

Explain your answer.

_____

_____

_____

_____

_____

_____

_____

(3)

(d) A sample of nickel was analysed in a time of flight (TOF) mass spectrometer. The sample was ionised by electron impact ionisation. The spectrum produced showed three peaks with abundances as set out in the table.

m/z	Abundance / %
58	61.0
60	29.1
61	9.9

Give the symbol, including mass number, of the ion that would reach the detector first in the sample.

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Calculate the relative atomic mass of the nickel in the sample.

Give your answer to one decimal place.

Symbol of ion _____

Relative atomic mass _____

(3)

(Total 9 marks)

Q5.

Which of these has the highest first ionisation energy?

A Na ○

B Al ○

C Si ○

D Cl ○

(Total 1 mark)

Q6.

A sample of titanium was ionised by electron impact in a time of flight (TOF) mass spectrometer. Information from the mass spectrum about the isotopes of titanium in the sample is shown in the table.

m/z	46	47	48	49
Abundance / %	9.1	7.8	74.6	8.5

(a) Calculate the relative atomic mass of titanium in this sample.

Give your answer to one decimal place.

Relative atomic mass of titanium in this sample _____

(2)

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(b) Write an equation, including state symbols, to show how an atom of titanium is ionised by electron impact and give the m/z value of the ion that would reach the detector first.

Equation _____

m/z value _____

(2)

(c) Calculate the mass, in kg, of one atom of ^{49}Ti

The Avogadro constant $L = 6.022 \times 10^{23}\,mol^{-1}$

Mass _____ kg

(1)

(d) In a TOF mass spectrometer the time of flight, t, of an ion is shown by the equation

$$t = d\sqrt{\frac{m}{2E}}$$

In this equation *d* is the length of the flight tube, m is the mass, in kg, of an ion and *E* is the kinetic energy of the ions.

In this spectrometer, the kinetic energy of an ion in the flight tube is $1.013 \times 10^{-13}\,J$

The time of flight of a $^{49}Ti^{+}$ ion is 9.816×10^{-7} s

Calculate the time of flight of the $^{47}Ti^{+}$ ion.

Give your answer to the appropriate number of significant figures.

Time of flight _____ s

(3)

(Total 8 marks)

Q7.

Element Q forms a sulfate with formula QSO_4

Which of these could represent the electronic configuration of an atom of Q?

A $[Ne]3s^1$ ⬭

B $[Ne]3s^2$ ⬭

C $[Ne]3s^23p^1$ ⬭

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D $[Ne]3s^1 3p^2$ ⬭

(Total 1 mark)

Q8.

Bromine exists as two isotopes ^{79}Br and ^{81}Br, which are found in almost equal abundance.

Which of the statements is correct?

A The first ionisation energy of ^{79}Br is less than the first ionisation energy of ^{81}Br ⬭

B The atomic radius of ^{79}Br is less than the atomic radius of ^{81}Br ⬭

C The mass spectrum of C_3H_7Br has two molecular ion peaks at 122 and 124 ⬭

D ^{79}Br is more reactive than ^{81}Br ⬭

(Total 1 mark)

Q9.

This question is about the element iodine and its compounds.

(a) Iodine is in Group 7 of the Periodic Table.

Complete the electron configuration of an iodine atom.

[Kr] _____

(1)

(b) Part of the structure of an iodine crystal is shown in the diagram.



Use your knowledge of structure and bonding to explain why the melting point of iodine is low (113.5 °C) and why that of hydrogen iodide is very low (–50.8 °C).

(6)

(c) State why iodine does **not** conduct electricity.

_____

_____

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_____

(1)

(d) Deduce an equation for the formation of hydrogen iodide from its elements.

_____

(1)

(e) The triiodide ion is formed when an iodine molecule is bonded to an iodide ion.

What is the formula of ammonium triiodide?

Tick (✔) **one** box.

NH_3I_3 ☐

NH_3I_4 ☐

NH_4I ☐

NH_4I_3 ☐

(1)

(f) Draw the shape of the IF_3 molecule and the shape of the IF_4^- ion.
Include any lone pairs of electrons that influence each shape.

(2)

(g) Deduce the oxidation state of iodine in the following species.

$Ba(IO_3)_2$

_____

$[H_4IO_6]^-$

_____

(2)

(Total 14 marks)

Q10.

What is the electron configuration of Cu^{2+}?

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A $[Ar]3d^9 4s^2$ ⬭

B $[Ar]3d^{10} 4s^1$ ⬭

C $[Ar]3d^9$ ⬭

D $[Ar]3d^{10}$ ⬭

(Total 1 mark)

Q11.

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 _____

_____

_____

_____

_____

_____

(3)

(Total 7 marks)

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Q12.

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)

Q13.

This question is about electron configuration.

(a) Give the full electron configuration of an Al atom and of a Cr^{3+} ion.

Al atom _____

Cr^{3+} ion _____

(2)

(b) Deduce the formula of the ion that has a charge of 2+ with the same electron configuration as krypton.

_____

(1)

(c) Deduce the formula of the compound that contains 2+ ions and 3− ions that both have the same electron configuration as argon.

_____

(1)

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(Total 4 marks)

Q14.

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)

Q15.

This question is about Period 3 of the Periodic Table.

(a) Deduce which of Na^+ and Mg^{2+} is the smaller ion.
Explain your answer.

Smaller ion _____

Explanation _____

_____

_____

_____

(2)

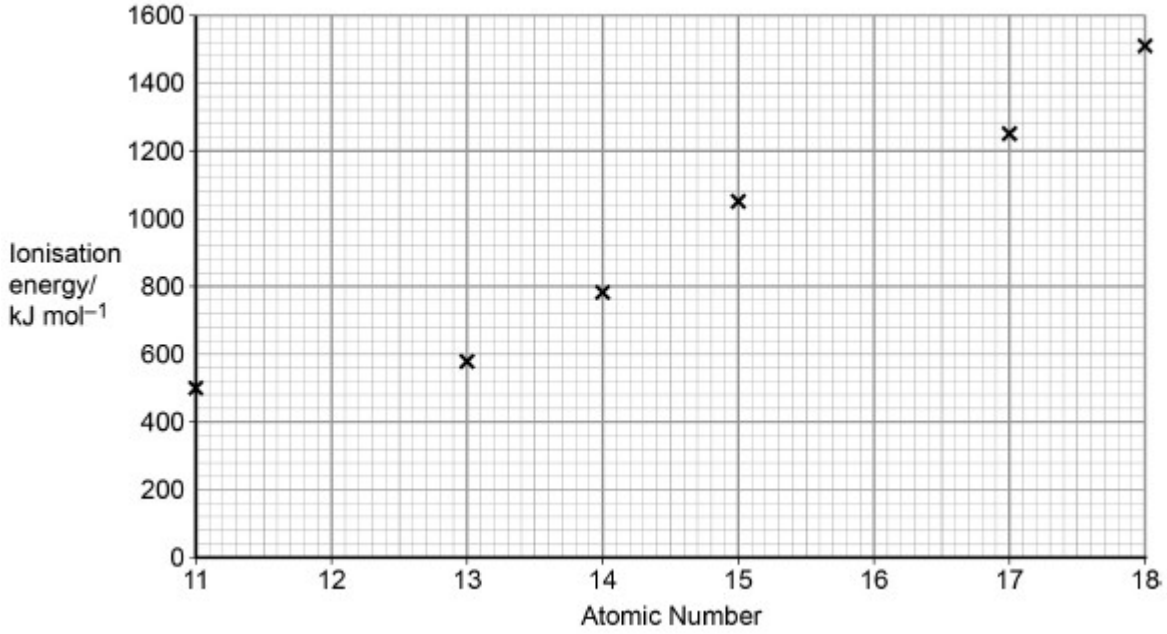
(b) Write an equation to represent the process that occurs when the first ionisation energy for sodium is measured.

_____

(1)

(c) The first ionisation energies of some Period 3 elements are shown in the following graph.

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Complete the graph by plotting the approximate first ionisation energy values for magnesium and sulfur.

Explain why the first ionisation energy of sulfur is different from that of phosphorus.

(4)

(Total 7 marks)

Q16.

This question is about the periodicity of the Period 3 elements.

(a) State and explain the general trend in first ionisation energy across Period 3.

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(4)

(b) Give one example of an element which deviates from the general trend in first ionisation energy across Period 3.

Explain why this deviation occurs.

(3)

(c) The table shows successive ionisation energies of an element **Y** in Period 3.

Ionisation number	1	2	3	4	5	6	7	8
Ionisation energy / kJ mol^{-1}	1000	2260	3390	4540	6990	8490	27 100	31 700

Identify element **Y**.

Explain your answer using data from the table.

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_____

(2)

(d) Identify the Period 3 element that has the highest melting point.

Explain your answer by reference to structure and bonding.

_____

_____

_____

_____

_____

_____

_____

_____

(4)

(Total 13 marks)

Q17.

Ions of two isotopes of iron are

$^{53}Fe^{2+}$ $^{56}Fe^{2+}$

Which statement is correct?

A The ions of both the isotopes have the electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$ ⬭

B The ions of both the isotopes contains 26 neutrons ⬭

C $^{53}Fe^{2+}$ has fewer protons than $^{56}Fe^{2+}$ ⬭

D After acceleration to the same kinetic energy $^{56}Fe^{2+}$ will move more slowly than $^{53}Fe^{2+}$ ⬭

(Total 1 mark)

Q18.

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 _____

_____

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_____

_____

_____

(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.

_____

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(1)

(Total 11 marks)

Q19.

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

Table 1

Particle	proton	neutron	electron
Mass / g	1.6725×10^{-24}	1.6748×10^{-24}	0.0009×10^{-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.

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_____

_____

_____

(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)

Q20.

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.

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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 ☐

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Second ☐

Third ☐

(1)

(Total 10 marks)

Q21.

(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 ($NiCl_2$).

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(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.

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

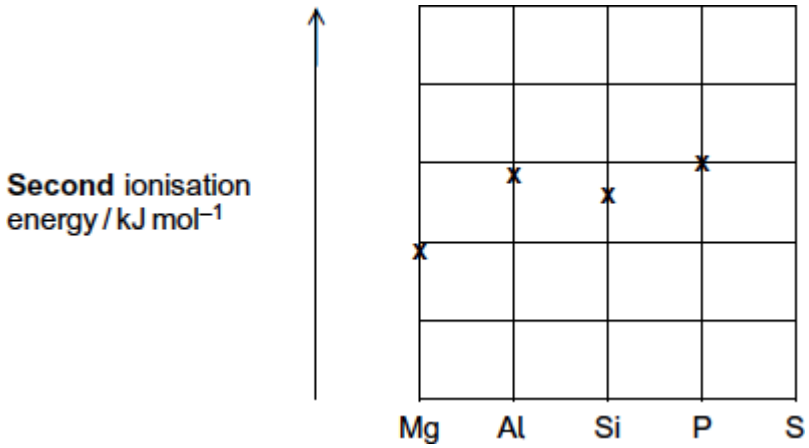
Substance _____

(2)

(Total 9 marks)

Q22.

(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.

_____

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_____

_____

(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.

_____

_____

_____

(1)

(Total 8 marks)

Q23.

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**.

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_____

(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.

_____

_____

_____

_____

_____

_____

(3)

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

_____

(1)

(Total 7 marks)

Q24.

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

_____

_____

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_____

_____

(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)

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(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)

Q25.

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 _____

_____

_____

(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 _____

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_____

_____

(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 $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}$

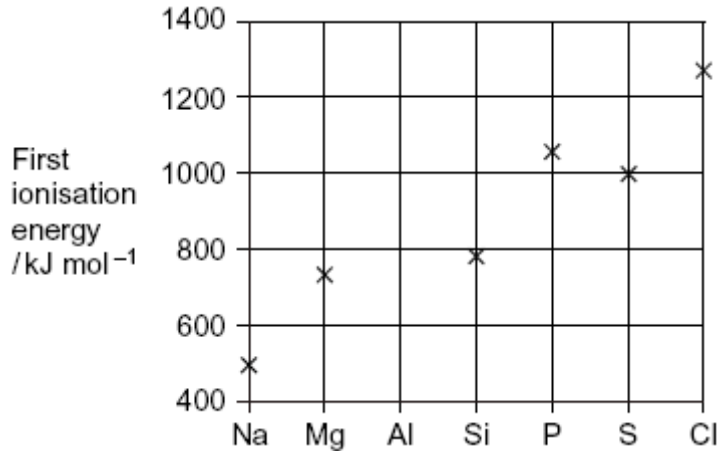
_____

(1)

(Total 10 marks)

Q26.

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)

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(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)

Q27.

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*.

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_____

_____

_____

(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 _____

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_____

_____

(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)

Q28.

(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 _____

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_____

_____

(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)

Q29.

(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.

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_____

(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)

Q30.

(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.

_____

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(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)

Q31.

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)

Q32.

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

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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)

Q33.

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)

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Q34.

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)

Q35.

(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.

_____

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(iii) Calculate the mass, in grams, of a single atom of this isotope of sodium.
(The Avogadro constant, L, is 6.023×10^{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)

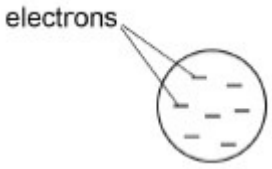
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Q1.

This question is about atomic structure.

In the nineteenth century JJ Thomson discovered the electron. He suggested that negative electrons were found throughout an atom like 'plums in a pudding of positive charge'.

The diagram shows an atom of element **R** using the 'plum pudding' model.
An atom of **R** contains seven electrons.



(a) State **two** differences between the 'plum pudding' model and the model of atomic structure used today.

1. _____

_____

2. _____

_____

(2)

(b) Deduce the full electron configuration of an atom of element **R**.

_____

(1)

(c) Identify **R** and deduce the formula of the compound formed when **R** reacts with the Group 2 metal in the same period as **R**.

_____

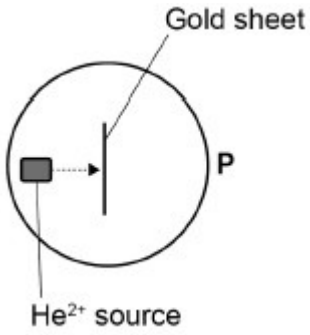
(1)

(Total 4 marks)

Q2.

In the early twentieth century the apparatus shown in the diagram was used to investigate atomic structure. When He^{2+} particles were fired at a thin sheet of gold, most of the particles were detected at point **P**.

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What conclusion can be drawn from the detection of He^{2+} particles at point **P**?

A Gold atoms contain electrons. ⬭

B Gold atoms contain protons. ⬭

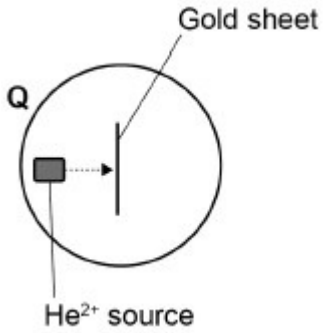
C Gold atoms contain neutrons. ⬭

D Gold atoms are mainly empty space. ⬭

(Total 1 mark)

Q3.

When He^{2+} particles were fired at a thin sheet of gold, about 1 in 8000 of the particles were detected at point **Q**.



What conclusion can be drawn from the detection of He^{2+} particles at point **Q**?

A Gold atoms have a small, positive nucleus. ⬭

B Gold atoms have electrons in orbitals. ⬭

C Gold consists of ions in a sea of delocalised electrons. ⬭

D Gold atoms have more protons than He^{2+} particles. ⬭

(Total 1 mark)

Q4.

Magnesium exists as three isotopes: ^{24}Mg, ^{25}Mg and ^{26}Mg

(a) In terms of sub-atomic particles, state the difference between the three isotopes of magnesium.

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_____

_____

_____

(1)

(b) State how, if at all, the chemical properties of these isotopes differ.

Give a reason for your answer.

Chemical properties _____

_____

Reason _____

_____

_____

(2)

(c) ^{25}Mg atoms make up 10.0% by mass in a sample of magnesium.

Magnesium has A_r = 24.3

Use this information to deduce the percentages of the other two magnesium isotopes present in the sample.

^{24}Mg percentage = _____ % ^{26}Mg percentage = _____ %

(4)

(d) In a TOF mass spectrometer, ions are accelerated to the same kinetic energy (KE).

$KE = \frac{1}{2}mv^2$ where m = mass (kg) and v = velocity (m s^{-1})

$v = \frac{d}{t}$ where d = distance (m) and t = time (s)

In a TOF mass spectrometer, each $^{25}Mg^+$ ion is accelerated to a kinetic energy of 4.52×10^{-16} J and the time of flight is 1.44×10^{-5} s.
Calculate the distance travelled, in metres, in the TOF drift region.
(The Avogadro constant L = 6.022×10^{23} mol^{-1})

Distance = _____ m

(4)

(Total 11 marks)

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Q5.

Which of these correctly shows the numbers of sub-atomic particles in a $^{41}K^{+}$ ion?

	Number of electrons	Number of protons	Number of neutrons	
A	19	19	20	○
B	18	20	21	○
C	18	19	22	○
D	19	18	23	○

(Total 1 mark)

Q6.

Which species has the same number of electrons as the radical $\bullet CH_3$?

A CH_2 ○

B CH_3^+ ○

C CH_3^- ○

D CH_4^+ ○

(Total 1 mark)

Q7.

What are the numbers of neutrons and electrons in the $^{57}Fe^{2+}$ ion?

	Neutrons	Electrons	
A	31	24	○
B	57	24	○
C	31	26	○
D	57	28	○

(Total 1 mark)

Q8.

Which of these atoms has the largest atomic radius?

A Ar ○

B Cl ○

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C Mg ⬭

D Na ⬭

(Total 1 mark)

Q9.

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

Table 1

Particle	proton	neutron	electron
Mass / g	1.6725×10^{-24}	1.6748×10^{-24}	0.0009×10^{-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)

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(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)

Q10.

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)

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(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.

_____

(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.

_____

_____

_____

(2)

(Total 12 marks)

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Q11.

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.

_____

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

(4)

(Total 13 marks)

Q12.

(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)

Q13.

(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)

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

_____

_____

(1)

(Total 10 marks)

Q14.

(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 _____

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(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)

Q15.

(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.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

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(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)

Q16.

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)

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Q1.

A sample of bromine was analysed in a time of flight (TOF) mass spectrometer and found to contain two isotopes, ^{79}Br and ^{81}Br

After electron impact ionisation, all of the ions were accelerated to the same kinetic energy (KE) and then travelled through a flight tube that was 0.950 m long.

(a) The $^{79}Br^+$ ions took 6.69×10^{-4} s to travel through the flight tube.

Calculate the mass, in kg, of one ion of $^{79}Br^+$

Calculate the time taken for the $^{81}Br^+$ ions to travel through the same flight tube.

The Avogadro constant, $L = 6.022 \times 10^{23}$ mol^{-1}

$KE = \frac{1}{2} mv^2$ where m = mass (kg) and v = speed (m s^{-1})

$v = \frac{d}{t}$ where d = distance (m) and t = time (s)

Mass of one ion of $^{79}Br^+$ _____ kg

Time taken by $^{81}Br^+$ ions _____ s

(5)

(b) Explain how ions are detected and relative abundance is measured in a TOF mass spectrometer.

_____

_____

_____

_____

_____

_____

(2)

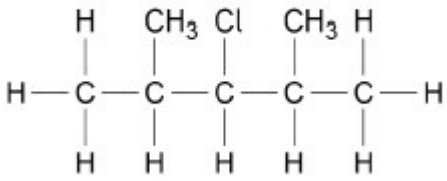
(Total 7 marks)

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Q2.

Compound **A** is a halogenoalkane.

Compound A



(a) Name Compound **A**.

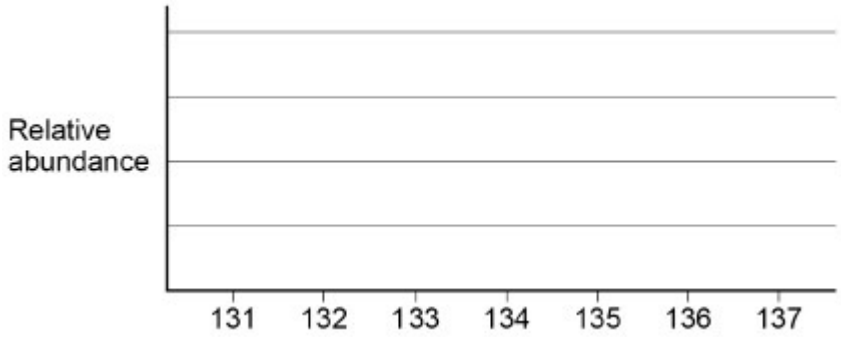
_____

(1)

(b) Compound **A** has a relative molecular mass (Mr) of 134.5
The main isotope of hydrogen is ^{1}H
The main isotope of carbon is ^{12}C
Chlorine consists of two common isotopes, ^{35}Cl and ^{37}Cl, of which 75% is ^{35}Cl
The mass spectrum of **A** was recorded when **A** was ionised by electron impact to form $\mathbf{A}^{+}$ ions.

Draw, on **Figure 1**, the peaks for the main molecular ions in the mass spectrum of **A**.

Figure 1



(2)

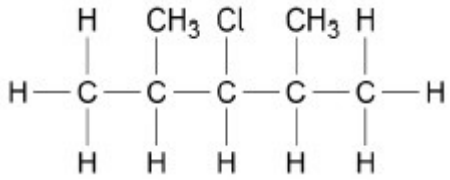
(c) Reaction of **A** with warm, dilute aqueous sodium hydroxide forms alcohol **B**.

Name the mechanism for this reaction.

Outline the mechanism using the structure of **A** shown.
Include the structure of the product, alcohol **B**.

Mechanism _____

Outline of mechanism



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(4)

(d) Reaction of **A** with hot, ethanolic potassium hydroxide gives alkene **C**.

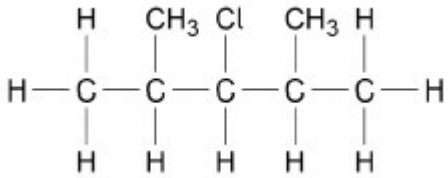
Name the mechanism for this reaction.
State the role of the hydroxide ions.

Outline the mechanism using the structure of **A** shown.
Include the structure of the product, alkene **C**.

Mechanism _____

Role of hydroxide ions _____

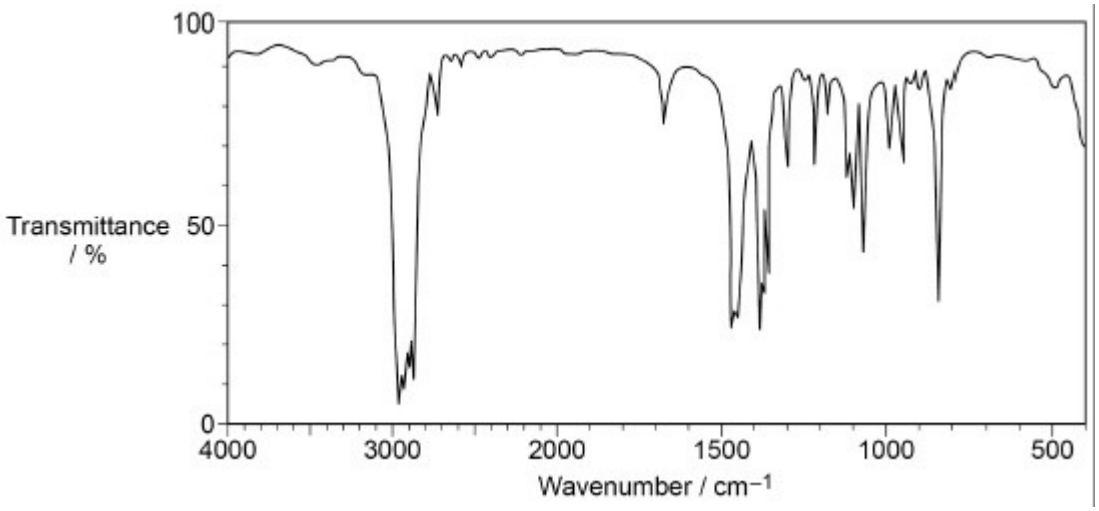
Outline of mechanism



(6)

(e) The infrared spectrum in **Figure 2** is that of either alcohol **B** or alkene **C**.

Figure 2



Tick the box that shows the correct compound.
Explain your answer with reference to a bond and the wavenumber of its absorption.

Alcohol **B** ☐ Alkene **C** ☐

Explanation _____

_____

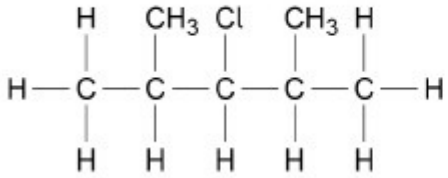
_____

(1)

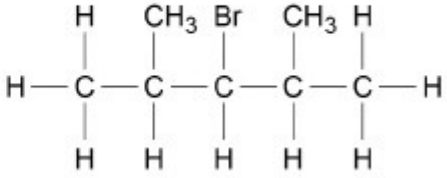
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(f) Compound **D** reacts with dilute aqueous sodium hydroxide in a similar way to **A** to form alcohol **B**.

Compound A



Compound D



Explain why **D** reacts more quickly than **A** with dilute aqueous sodium hydroxide at the same temperature.

_____

_____

_____

_____

_____

(1)

(Total 15 marks)

Q3.

A student has a 10 cm^3 sample of 1.00×10^{-2} mol dm^{-3} methanoic acid solution. The student is asked to dilute the methanoic acid solution to a concentration of 2.00×10^{-4} mol dm^{-3} by adding distilled water.

Which volume of water should be added?

A 200 cm^3 ⬭

B 490 cm^3 ⬭

C 500 cm^3 ⬭

D 510 cm^3 ⬭

(Total 1 mark)

Q4.

This question is about s-block metals.

(a) Give the full electron configuration for the calcium ion, Ca^{2+}

_____

(1)

(b) Explain why the second ionisation energy of calcium is lower than the second ionisation energy of potassium.

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_____

_____

_____

_____

_____

(2)

(c) Identify the s-block metal that has the highest first ionisation energy.

_____

(1)

(d) Give the formula of the hydroxide of the element in Group 2, from Mg to Ba, that is least soluble in water.

_____

(1)

(e) A student added 6 cm^3 of 0.25 mol dm^{-3} barium chloride solution to 8 cm^3 of 0.15 mol dm^{-3} sodium sulfate solution.
The student filtered off the precipitate and collected the filtrate.

Give an ionic equation for the formation of the precipitate.
Show by calculation which reagent is in excess.
Calculate the total volume of the other reagent which should be used by the student so that the filtrate contains only one solute.

Ionic equation _____

Reagent in excess _____

Total volume of other reagent _____

_____

_____

_____

_____

(3)

(f) A sample of strontium has a relative atomic mass of 87.7 and consists of three isotopes, ^{86}Sr, ^{87}Sr and ^{88}Sr
In this sample, the ratio of abundances of the isotopes ^{86}Sr :^{87}Sr is 1:1

State why the isotopes of strontium have identical chemical properties.
Calculate the percentage abundance of the ^{88}Sr isotope in this sample.

Why isotopes of strontium have identical chemical properties

_____

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_____

_____

Percentage abundance of ^{88}Sr _____ %

(4)

(g) A time of flight (TOF) mass spectrum was obtained for a sample of barium that contains the isotopes ^{136}Ba, ^{137}Ba and ^{138}Ba

The sample of barium was ionised by electron impact.

Identify the ion with the longest time of flight.

_____

(1)

(h) A $^{137}Ba^{+}$ ion travels through the flight tube of a TOF mass spectrometer with a kinetic energy of 3.65×10^{-16} J
This ion takes 2.71×10^{-5} s to reach the detector.

$KE = \frac{1}{2} mv^2$ where m = mass (kg) and v = speed (m s^{-1})

The Avogadro constant, $L = 6.022 \times 10^{23}$ mol^{-1}

Calculate the length of the flight tube in metres.

Give your answer to the appropriate number of significant figures.

Length of flight tube _____ m

(5)

(Total 18 marks)

Q5.

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This question is about atomic structure.

(a) Write the full electron configuration for each of the following species.

Cl^- _____

Fe^{2+} _____

(2)

(b) Write an equation, including state symbols, to represent the process that occurs when the third ionisation energy of manganese is measured.

_____

_____

(1)

(c) State which of the elements magnesium and aluminium has the lower first ionisation energy.

Explain your answer.

_____

_____

_____

_____

_____

_____

_____

(3)

(d) A sample of nickel was analysed in a time of flight (TOF) mass spectrometer. The sample was ionised by electron impact ionisation. The spectrum produced showed three peaks with abundances as set out in the table.

m/z	Abundance / %
58	61.0
60	29.1
61	9.9

Give the symbol, including mass number, of the ion that would reach the detector first in the sample.

Calculate the relative atomic mass of the nickel in the sample.

Give your answer to one decimal place.

Symbol of ion _____

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Relative atomic mass _____

(3)

(Total 9 marks)

Q6.

Which statement about time of flight mass spectrometry is correct?

A	The current in the detector is proportional to the ion abundance	○
B	Sample particles gain electrons to form positive ions	○
C	Particles are detected in the order of their kinetic energies	○
D	Ions are accelerated by a magnetic field	○

(Total 1 mark)

Q7.

Chlorine exists as two isotopes ^{35}Cl and ^{37}Cl in the ratio 3:1

Which statement about peaks in the mass spectrum of Cl_2 is correct?

A	Peaks at m/z = 70 and 74 in the ratio 3:1	○
B	Peaks at m/z = 70, 72 and 74 in the ratio 9:6:1	○
C	Peaks at m/z = 70, 72 and 74 in the ratio 9:3:1	○
D	Peaks at m/z = 70 and 72 in the ratio 3:1	○

(Total 1 mark)

Q8.

A sample of titanium was ionised by electron impact in a time of flight (TOF) mass spectrometer. Information from the mass spectrum about the isotopes of titanium in the sample is shown in the table.

m/z	46	47	48	49
Abundance / %	9.1	7.8	74.6	8.5

(a) Calculate the relative atomic mass of titanium in this sample.

Give your answer to one decimal place.

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Relative atomic mass of titanium in this sample _____

(2)

(b) Write an equation, including state symbols, to show how an atom of titanium is ionised by electron impact and give the m/z value of the ion that would reach the detector first.

Equation _____

m/z value _____

(2)

(c) Calculate the mass, in kg, of one atom of ^{49}Ti

The Avogadro constant $L = 6.022 \times 10^{23}\ mol^{-1}$

Mass _____ kg

(1)

(d) In a TOF mass spectrometer the time of flight, t, of an ion is shown by the equation

$$t = d\sqrt{\frac{m}{2E}}$$

In this equation *d* is the length of the flight tube, m is the mass, in kg, of an ion and *E* is the kinetic energy of the ions.

In this spectrometer, the kinetic energy of an ion in the flight tube is $1.013 \times 10^{-13}\ J$

The time of flight of a $^{49}Ti^{+}$ ion is $9.816 \times 10^{-7}\ s$

Calculate the time of flight of the $^{47}Ti^{+}$ ion.

Give your answer to the appropriate number of significant figures.

Time of flight _____ s

(3)

(Total 8 marks)

Q9.

Magnesium exists as three isotopes: ^{24}Mg, ^{25}Mg and ^{26}Mg

(a) In terms of sub-atomic particles, state the difference between the three isotopes of magnesium.

_____

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_____

_____

(1)

(b) State how, if at all, the chemical properties of these isotopes differ.

Give a reason for your answer.

Chemical properties _____

_____

Reason _____

_____

_____

(2)

(c) ^{25}Mg atoms make up 10.0% by mass in a sample of magnesium.

Magnesium has A_r = 24.3

Use this information to deduce the percentages of the other two magnesium isotopes present in the sample.

^{24}Mg percentage = _____ % ^{26}Mg percentage = _____ %

(4)

(d) In a TOF mass spectrometer, ions are accelerated to the same kinetic energy (KE).

$KE = \frac{1}{2}mv^2$ where m = mass (kg) and v = velocity (m s^{-1})

$v = \frac{d}{t}$ where d = distance (m) and t = time (s)

In a TOF mass spectrometer, each $^{25}Mg^+$ ion is accelerated to a kinetic energy of 4.52×10^{-16} J and the time of flight is 1.44×10^{-5} s.
Calculate the distance travelled, in metres, in the TOF drift region.
(The Avogadro constant L = 6.022×10^{23} mol^{-1})

Distance = _____ m

(4)

(Total 11 marks)

Q10.

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Bromine exists as two isotopes ^{79}Br and ^{81}Br, which are found in almost equal abundance.

Which of the statements is correct?

A The first ionisation energy of ^{79}Br is less than the first ionisation energy of ^{81}Br ⬭

B The atomic radius of ^{79}Br is less than the atomic radius of ^{81}Br ⬭

C The mass spectrum of C_3H_7Br has two molecular ion peaks at 122 and 124 ⬭

D ^{79}Br is more reactive than ^{81}Br ⬭

(Total 1 mark)

Q11.

This question is about time of flight (TOF) mass spectrometry.

(a) The mass spectrum of element **Q** has peaks with *m*/*z* values shown in the table.

m*/*z	82	83	84	86
Relative intensity	5	3	26	7

Calculate the relative atomic mass of **Q** and give your answer to one decimal place. Identify the element **Q**.

Relative atomic mass of **Q** _____

Element **Q** _____

(3)

(b) A sample of the element **Q** consists of several isotopes. All of the **Q**+ ions in the sample of **Q** that has been ionised in a TOF mass spectrometer have the same kinetic energy.

kinetic energy of each ion = $\frac{1}{2}mv^2$

where *m* is the mass, in kg, of one ion of an isotope and *v* is the velocity of an ion in m s^{-1}

$$v = \frac{d}{t}$$

where *d* is the length, in m, of the flight tube and *t* is the time taken, in s, for an ion to reach the detector

The time of flight of a $^{82}\mathbf{Q}^+$ ion is 1.243×10^{-5} s.

Calculate the time of flight of the $^{86}\mathbf{Q}^+$ ion.

Time of flight of the $^{86}\mathbf{Q}^+$ ion _____ s

(3)

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(Total 6 marks)

Q12.

This question is about halogenoalkanes.

(a) Chlorine atoms are formed in the upper atmosphere when ultraviolet radiation causes C–Cl bonds in chlorofluorocarbons (CFCs) to break.

Write **two** equations to show how chlorine atoms catalyse the decomposition of ozone.

1. _____

_____

2. _____

_____

(2)

(b) Chloroethane reacts with potassium hydroxide in the presence of propan-1-ol to form ethene.

State the role of potassium hydroxide and the role of propan-1-ol in the reaction.

Role of potassium hydroxide _____

Role of propan-1-ol _____

(2)

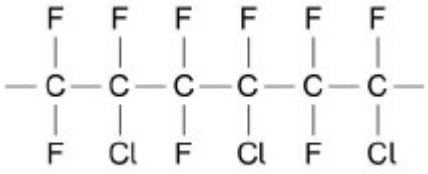
(c) Name and outline a mechanism for the reaction in part **(b)** between chloroethane and potassium hydroxide to produce ethene.

Name of mechanism _____

Mechanism

(4)

(d) The structure of polymer **A** is shown.



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Draw the structure of the monomer used to form polymer **A**.

(1)

(e) Chemical analysis shows that a chlorofluoroalkane, **B**, contains by mass 51.6% fluorine, 32.1% chlorine and no hydrogen.

Chlorine exists as two isotopes, ^{35}Cl and $3^{37}Cl$, in the ratio 3:1
Fluorine only exists as one isotope, ^{19}F.

A mass spectrum of **B** is obtained using electron impact ionisation. The mass spectrum shows three molecular ion peaks at *m/z* = 220, 222 and 224.

Determine the formula of each of the three molecular ions of **B**.

Predict and explain the ratio of the relative abundancies of each of the three molecular ion peaks at *m/z* = 220, 222 and 224.

To gain full marks you must show all your working.

(6)

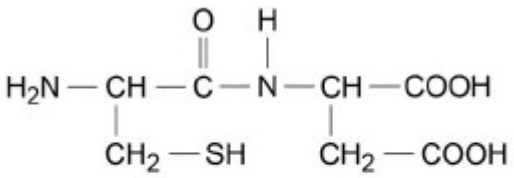
(Total 15 marks)

Q13.

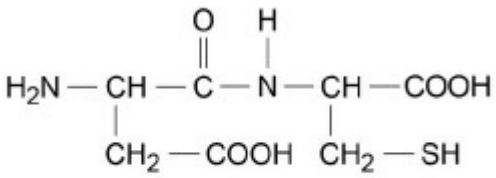
Chromatography is used to identify amino acid sequences in compounds.

The dipeptide cysteine-aspartic acid (cys-asp), **J**, and the dipeptide aspartic acid-cysteine (asp-cys), **K**, are shown.

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J (cys – asp)



K (asp – cys)

(a) A mixture of the two dipeptides **J** and **K** is analysed by gas chromatography followed by mass spectrometry (GC-MS).

Explain why **J** and **K** can be separated by gas chromatography and why mass spectrometry using electrospray ionisation does **not** enable you to identify them.

Gas chromatography explanation _____

_____

_____

_____

_____

_____

_____

Mass spectrometry explanation _____

_____

_____

_____

_____

_____

_____

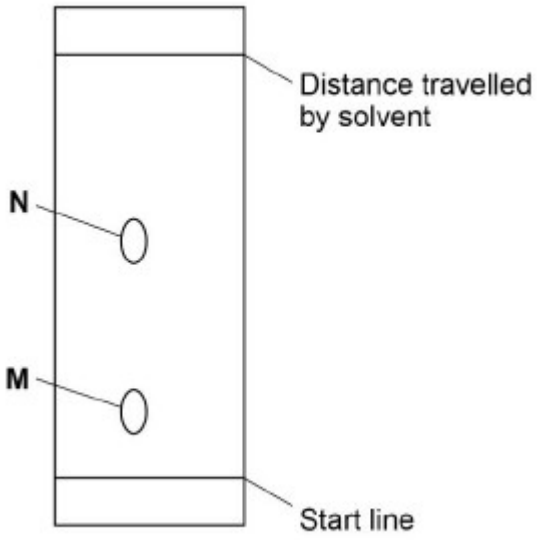
_____

(4)

(b) A tripeptide, **L**, is partially hydrolysed with concentrated hydrochloric acid to produce two dipeptides and the amino acids alanine (ala), lysine (lys) and serine (ser).

The two dipeptides are separated by chromatography. The diagram below shows the chromatogram.

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The table below contains the R_f values of some dipeptides.

Dipeptide	ala-lys	ala-ser	lys-ser	lys-ala	ser-ala	ser-lys
R_f value	0.55	0.85	0.10	0.20	0.15	0.45

Use the chromatogram in the diagram above and the R_f values in the table to identify the two dipeptides present in spots **M** and **N**.

Use your answers to deduce the order of the amino acids in the tripeptide **L**.

Dipeptide responsible for spot **M** _____

_____

Dipeptide responsible for spot **N** _____

_____

Order of amino acids in tripeptide **L** _____

_____

(3)

(Total 7 marks)

Q14.

(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

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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.

_____

_____

_____

_____

_____

(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.

_____

_____

_____

_____

_____

(2)

(Total 8 marks)

Q15.

Which of these atoms has the smallest number of neutrons?

A ^{3}H ⬭

B ^{4}He ⬭

C ^{5}He ⬭

D ^{4}Li ⬭

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(Total 1 mark)

Q16.

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.

_____

_____

_____

_____

(2)

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

_____

_____

_____

_____

_____

_____

_____

_____

(4)

(Total 6 marks)

Q17.

This question is about electron configuration.

(a) Give the full electron configuration of an Al atom and of a Cr^{3+} ion.

Al atom _____

Cr^{3+} ion _____

(2)

(b) Deduce the formula of the ion that has a charge of 2+ with the same electron configuration as krypton.

_____

(1)

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(c) Deduce the formula of the compound that contains 2+ ions and 3− ions that both have the same electron configuration as argon.

_____

(1)

(Total 4 marks)

Q18.

(a) Explain how ions are accelerated, detected and have their abundance determined in a time of flight (TOF) mass spectrometer.

_____

_____

_____

_____

_____

(3)

(b) Calculate the mass, in kg, of a single $^{52}Cr^{+}$ ion.
Assume that the mass of a $^{52}Cr^{+}$ ion is the same as that of a ^{52}Cr atom.

(The Avogadro constant L = 6.022×10^{23} mol^{-1})

_____

_____

(1)

(c) In a TOF mass spectrometer the kinetic energy (KE) of a $^{52}Cr^{+}$ ion was 1.269×10^{-13} J

Calculate the velocity of the ion using the equation.

$$KE = \frac{1}{2}mv^2$$

(m = mass/kg and v = velocity/ms^{-1})

_____

_____

_____

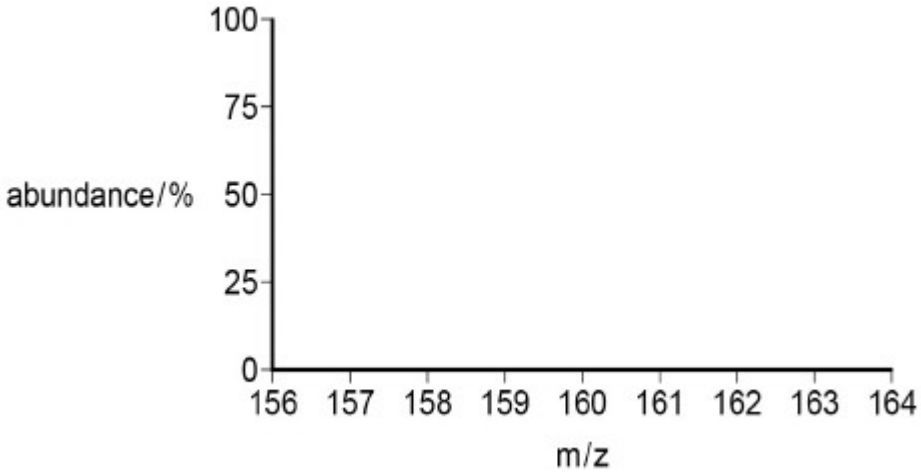
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(2)

(d) Bromine has two isotopes, ^{79}Br and ^{81}Br, in approximately equal abundance. In a TOF mass spectrometer bromine forms ions with formula $[Br_2]^{+}$

Sketch the pattern of peaks you would expect to see in the mass spectrum of a sample of bromine.

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(2)

(e) A sample of xenon has A_r = 131.31. The sample consists of four isotopes. The abundances of three of the isotopes are shown in the table below. The data for one of the isotopes, ^{m}Xe, is missing.

Isotope	**^{129}Xe**	**^{131}Xe**	**^{132}Xe**	**^{m}Xe**
% abundance	28.0	25.0	27.0	To be calculated

Use the data to calculate the abundance of isotope ^{m}Xe and calculate m, the mass number of ^{m}Xe. Show your working.

_____

_____

_____

_____

_____

_____

_____

(4)

(Total 12 marks)

Q19.

Ions of two isotopes of iron are

$^{53}Fe^{2+}$ $^{56}Fe^{2+}$

Which statement is correct?

A The ions of both the isotopes have the electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$ ⬭

B The ions of both the isotopes contains 26 neutrons ⬭

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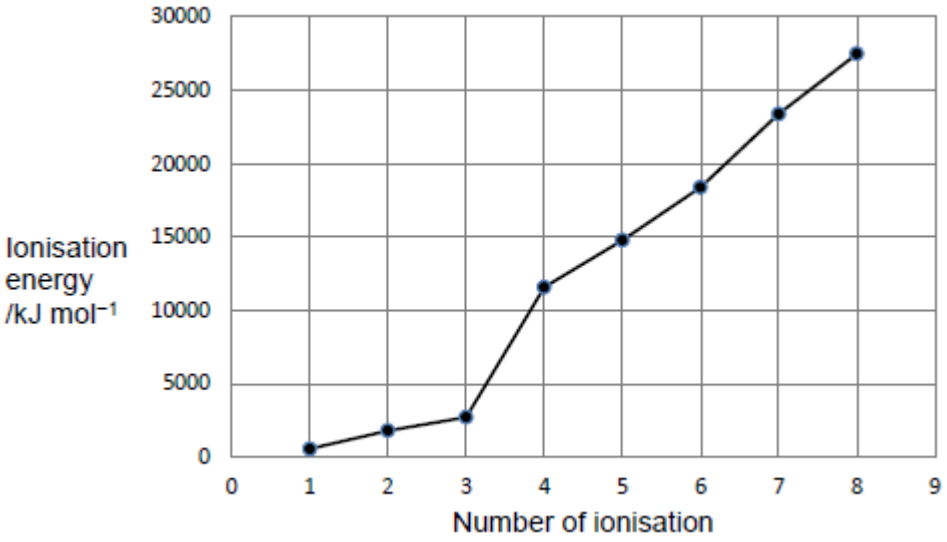
C $^{53}Fe^{2+}$ has fewer protons than $^{56}Fe^{2+}$ ⬭

D After acceleration to the same kinetic energy $^{56}Fe^{2+}$ will move more slowly than $^{53}Fe^{2+}$ ⬭

(Total 1 mark)

Q20.

The successive ionisation energies for element X are shown in the following graph.



Which element is X?

A Nitrogen ⬭

B Phosphorus ⬭

C Aluminium ⬭

D Boron ⬭

(Total 1 mark)

Q21.

Tellurium is the element with atomic number of 52

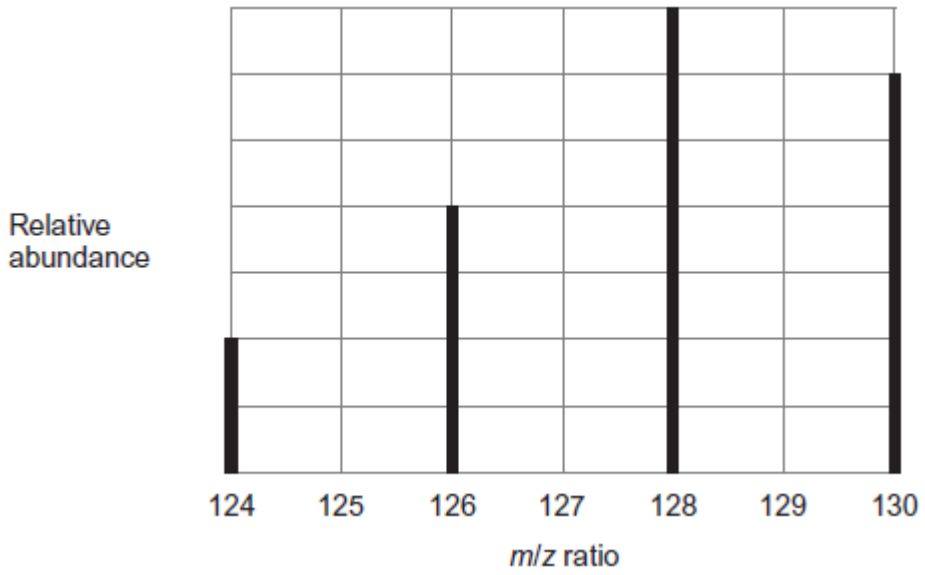
(a) Using information from the Periodic Table, complete the electron configuration of tellurium.

[Kr] _____

(1)

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

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

_____

_____

_____

_____

_____

(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 _____

_____

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_____

(2)

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

Explain the existence of this peak.

_____

_____

_____

_____

(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)

Q22.

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

Table 1

Particle	proton	neutron	electron
Mass / g	1.6725×10^{-24}	1.6748×10^{-24}	0.0009×10^{-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

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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.

_____

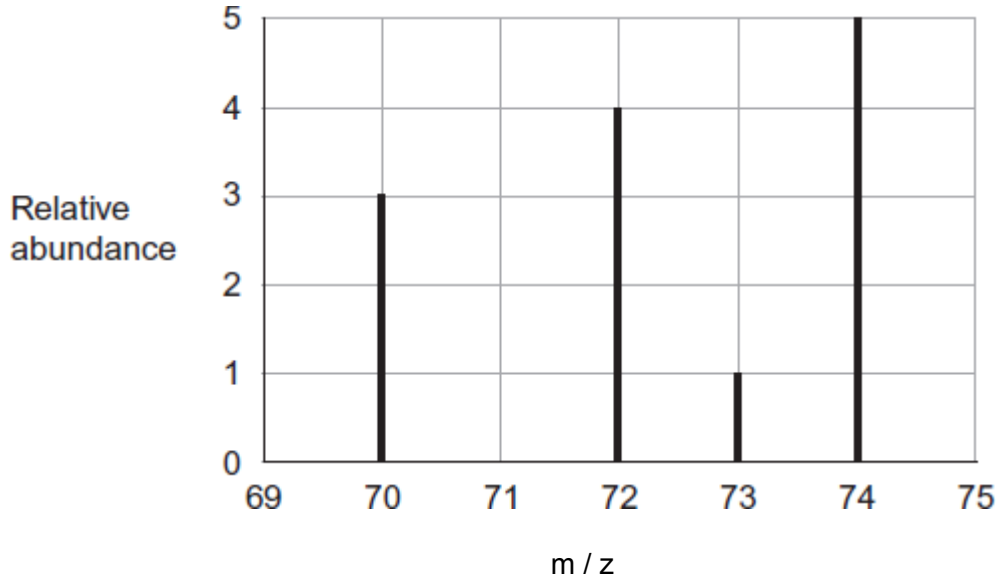
_____

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(1)
(Total 8 marks)

Q23.

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



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

_____

_____

_____

_____

(2)

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

Give your answer to one decimal place.

_____

_____

_____

_____

_____

_____

(3)

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

_____

(1)

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(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)

Q24.

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

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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 _____

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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)

Q25.

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

_____

_____

_____

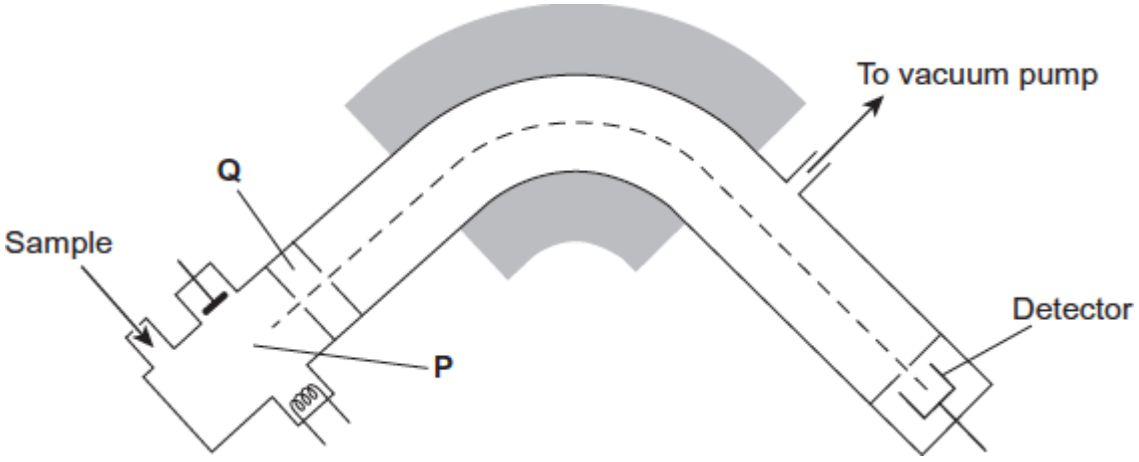
(1)

(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**.

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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.

_____

_____

_____

_____

_____

(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.

_____

_____

(1)

(Total 11 marks)

Q26.

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)

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(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

_____

_____

_____

_____

(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*.

_____

_____

_____

(1)

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

_____

_____

_____

(1)

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

Equation _____

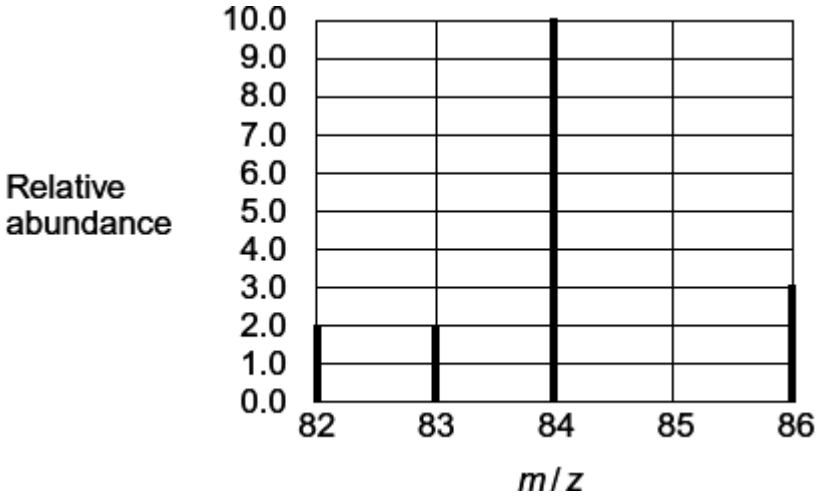
IUPAC name _____

(2)

(Total 8 marks)

Q27.

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.

_____

_____

_____

_____

_____

_____

_____

_____

(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.

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

(5)

(Total 9 marks)

Q28.

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.

(1)

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

(1)

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

(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

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

_____

_____

_____

_____

_____

(3)

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

_____

(2)

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

_____

_____

(1)

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

_____

_____

_____

(2)

(Total 12 marks)

Q29.

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)

Q30.

(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.

(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.

(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)

Q31.

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.

_____

_____

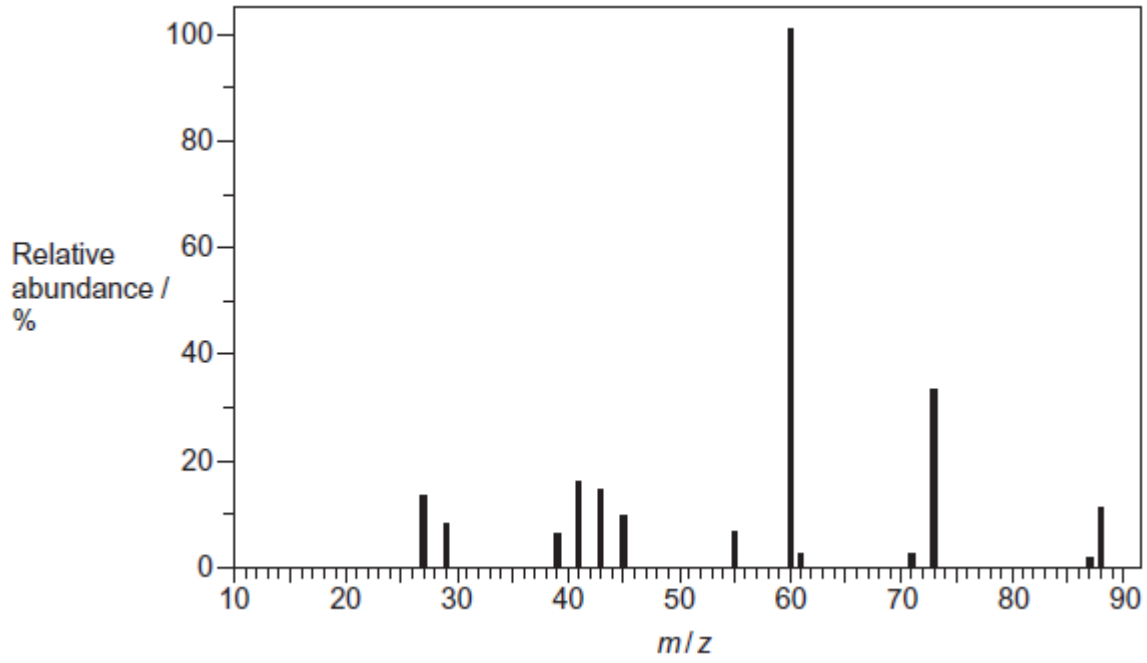
_____

_____

_____

(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.

_____

(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.)

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Show your working.

_____

_____

_____

(2)

(Total 6 marks)

Q32.

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

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

_____

_____

_____

_____

(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

_____

_____

_____

_____

_____

_____

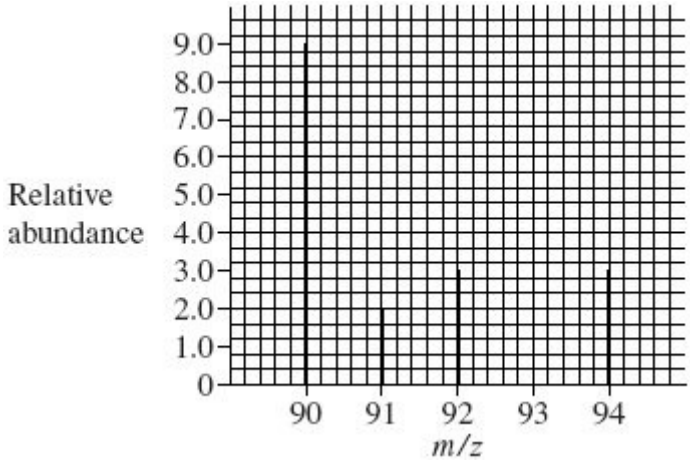
(3)

(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.

(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)

Q33.

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 ^{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.

_____

(1)

(e) State and explain the difference, if any, between the chemical properties of the

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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.

_____

_____

_____

(2)

(Total 12 marks)

Q34.

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*.

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_____

(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)

Q35.

(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.

_____

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(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.

_____

_____

_____

_____

_____

_____

(4)

(Total 12 marks)

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Q1.

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)

Q2.

(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

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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)

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*.

_____

_____

(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 6.023×10^{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.

_____

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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.

_____

(2)

(Total 9 marks)

Q4.

(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.

_____

_____

_____

_____

_____

_____

_____

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_____

_____

_____

_____

(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.

_____

_____

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(7)

(Total 14 marks)

Q5.

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)

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