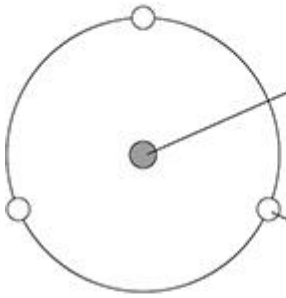
Q1.

This question is about atomic structure.

(a) The figure below is a model proposed by Rutherford to show the structure of an atom.



State **two** features of the current model that are not shown in the Rutherford model.

Feature 1 of the current model ___________________________________

____

____

Feature 2 of the current model ___________________________________

____

____

(2)

(b) A sample of tin is analysed in a time of flight mass spectrometer. The sample is ionised by electron impact to form 1+ ions.

The table below shows data about the four peaks in this spectrum.

m/z	Percentage abundance
112	22.41
114	11.78
117	34.97
120	To be determined

Give the symbol, including mass number, of the ion that reaches the detector first.

Calculate the relative atomic mass of tin in this sample. Give your answer to 1 decimal place.

Symbol of ion _______________

Relative atomic mass ______________________

(4)

(Total 6 marks)

Q2.

In a time of flight mass spectrometer, molecule X is ionised using electrospray ionisation.
What is the equation for this ionisation?

A $X(l) + e^- \rightarrow X^+(g) + 2\ e^-$ ⬭

B $X(g) + e^- \rightarrow X^+(g) + 2\ e^-$ ⬭

C $X(l) + H^+ \rightarrow XH^+(g)$ ⬭

D $X(g) + H^+ \rightarrow XH^+(g)$ ⬭

(Total 1 mark)

Q3.

What is the electron configuration of V^{2+} in the ground state?

A $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^3$ ⬭

B $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^1\ 4s^2$ ⬭

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

D $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^2$ ⬭

(Total 1 mark)

Q4.

Which atom has one more proton and two more neutrons than $^{31}_{15}P$?

A $^{33}_{16}P$ ⬭

B $^{34}_{16}P$ ⬭

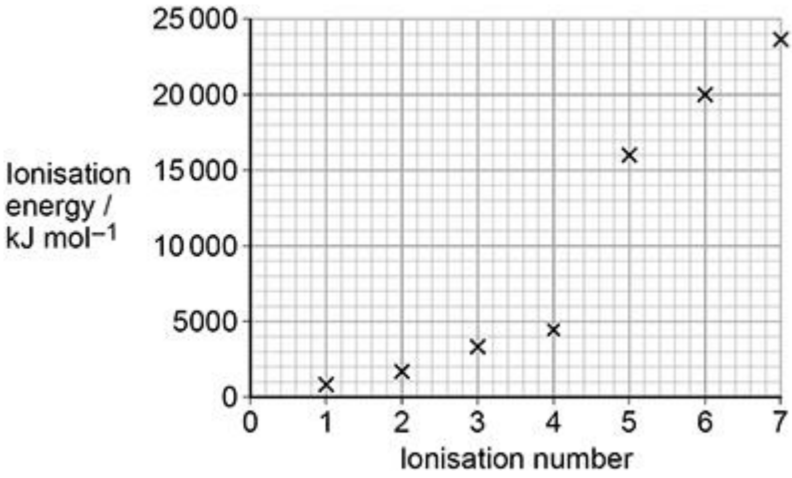
C $^{33}_{16}S$ ⬭

D $^{34}_{16}S$ ⬭

(Total 1 mark)

Q5.

The first seven successive ionisation energies for element Z are shown.



What is element Z?

A Carbon ⬭

B Nitrogen ⬭

C Silicon ⬭

D Phosphorus ⬭

(Total 1 mark)

Q6.

This question is about atomic structure.

(a) Define the mass number of an atom.

____

____

(1)

(b) Complete the table below to show the numbers of neutrons and electrons in the species shown.

	Number of protons	Number of neutrons	Number of electrons
^{46}Ti	22		
$^{49}Ti^{2+}$	22		

(2)

(c) A sample of titanium contains four isotopes, ^{46}Ti, ^{47}Ti, ^{48}Ti and ^{49}Ti
This sample has a relative atomic mass of 47.8
In this sample the ratio of abundance of isotopes ^{46}Ti, ^{47}Ti and ^{49}Ti is 2:2:1

Calculate the percentage abundance of ^{46}Ti in this sample.

Abundance of ^{46}Ti _______________ %

(3)

(Total 6 marks)

Q7.

Which has the electron configuration of a noble gas?

A H^+ ⬭

B O^- ⬭

C Se^{2-} ⬭

D Zn^{2+} ⬭

(Total 1 mark)

Q8.

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

(a) Define the term relative atomic mass.

____

____

____

____

(2)

(b) A sample of krypton is ionised using electron impact.

The mass spectrum of this sample of krypton has four peaks.

The table shows data from this spectrum.

m/z	82	83	84	86
Relative intensity	6	1	28	8

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

Give your answer to 1 decimal place.

A_r ________________

(2)

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

The kinetic energy of an ion is given by the equation $KE = \frac{1}{2}mv^2$

Where:
KE = kinetic energy / J
m = mass / kg
v = speed / m s^{-1}

In a TOF mass spectrometer, each $^{84}Kr^+$ ion is accelerated to a kinetic energy of 4.83×10^{-16} J and the time of flight is 1.72×10^{-5} s

Calculate the length, in metres, of the TOF flight tube.

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

Length of flight tube _______________ m

(4)

(Total 8 marks)

Q9.

Which atom has the smallest number of neutrons?

A ^{3}H ⬭

B ^{4}He ⬭

C ^{5}He ⬭

D ^{4}Li ⬭

(Total 1 mark)

Q10.

Which is the electron configuration of an atom with **only two** unpaired electrons?

A $1s^2\ 2s^2\ 2p^3$ ⬭

B $1s^2\ 2s^2\ 2p^4$ ⬭

C $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$ ⬭

D $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ 3d^5$ ⬭

(Total 1 mark)

Q11.

This question is about the isotopes of chromium.

(a) Give the meaning of the term relative atomic mass.

____

____

____

____

(2)

(b) A sample of chromium containing the isotopes ^{50}Cr, ^{52}Cr and ^{53}Cr has a relative atomic mass of 52.1

The sample contains 86.1% of the ^{52}Cr isotope.

Calculate the percentage abundance of each of the other two isotopes.

Abundance of ^{50}Cr _______________ %   Abundance of ^{53}Cr _______________ %

(4)

(c) State, in terms of the numbers of fundamental particles, **one** similarity and **one** difference between atoms of ^{50}Cr and ^{53}Cr

Similarity

____

____

Difference

____

____

____

(2)

The sample of chromium is analysed in a time of flight (TOF) mass spectrometer.

(d) Give **two** reasons why it is necessary to ionise the isotopes of chromium before they can be analysed in a TOF mass spectrometer.

1. ____

____

2. ____

____

(2)

(e) A $^{53}Cr^{+}$ ion travels along a flight tube of length 1.25 m
The ion has a constant kinetic energy (*KE*) of 1.102×10^{-13} J

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

m = mass of the ion / kg
v = speed of ion / m s^{-1}

Calculate the time, in s, for the $^{53}Cr^{+}$ ion to travel down the flight tube to reach the detector.

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

Time _______________ s

(5)

(Total 15 marks)

Q12.

Which shows the electron configuration of an atom of a transition metal?

A [Ar] $4s^2 3d^0$ ⬭

B [Ar] $4s^2 3d^8$ ⬭

C [Ar] $4s^2 3d^{10}$ ⬭

D [Ar] $4s^2 3d^{10} 4p^1$ ⬭

(Total 1 mark)

Q13.

Time of flight (TOF) mass spectrometry is an important analytical technique.

A mixture of three compounds is analysed using a TOF mass spectrometer.
The mixture is ionised using electrospray ionisation.
The three compounds are known to have the molecular formulas:

$C_3H_5O_2N$
$C_3H_7O_3N$
$C_3H_7O_2NS$

(a) Describe how the molecules are ionised using electrospray ionisation.

____

____

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____

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____

____

(3)

(b) Give the formula of the ion that reaches the detector first in the TOF mass spectrometer.

____

(1)

(c) A sample of germanium is analysed in a TOF mass spectrometer using electron impact ionisation.

Give an equation, including state symbols, for the process that occurs during the ionisation of a germanium atom.

____

(1)

(d) In the TOF mass spectrometer, a germanium ion reaches the detector in 4.654×10^{-6} s
The kinetic energy of this ion is 2.438×10^{-15} J
The length of the flight tube is 96.00 cm

The kinetic energy of an ion is given by the equation $KE = \frac{1}{2}mv^2$

where
m = mass / kg
v = speed / m s^{-1}

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

Use this information to calculate the mass, in g, of one mole of these germanium ions.
Use your answer to state the mass number of this germanium ion.

Mass of one mole of germanium ions ___________________________ g

Mass number of ion ______________________________

(5)
(Total 10 marks)

Q14.

The first ionisation energies of the elements in Period 2 change as the atomic number increases.

Explain the pattern in the first ionisation energies of the elements from lithium to neon.

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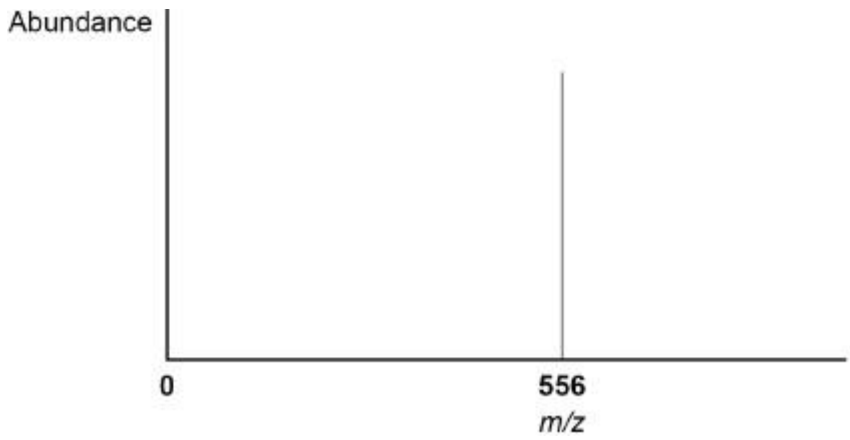
___

(Total 6 marks)

Q15.

Time of flight (TOF) mass spectrometry can be used to analyse large molecules such as the pentapeptide, leucine encephalin (**P**).

P is ionised by electrospray ionisation and its mass spectrum is shown in the diagram.



(a) Describe the process of electrospray ionisation.

Give an equation to represent the ionisation of **P** in this process.

Description ____

____

____

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____

____

____

____

____

Equation

____

(4)

(b) What is the relative molecular mass of **P**?
Tick (✓) **one** one box.

555 ☐ 556 ☐ 557 ☐

(1)

(c) A molecule **Q** is ionised by electron impact in a TOF mass spectrometer.
The Q^+ ion has a kinetic energy of 2.09×10^{-15} J
This ion takes 1.23×10^{-5}s to reach the detector.
The length of the flight tube is 1.50 m

Calculate the relative molecular mass of **Q**.

$KE = \frac{1}{2}mv^2$ where m = mass (kg) and v = speed (m s^{-1})
The Avogadro constant, $L = 6.022 \times 10^{23}$ mol^{-1}

Relative molecular mass ______________________________

(5)
(Total 10 marks)

Q16.

Which atom has the greatest first ionisation energy?

A H ☐

B He ☐

C Li ☐

D Ne ☐

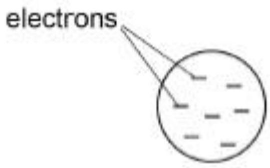
(Total 1 mark)

Q17.

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)

Q18.

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

Relative atomic mass ____

(3)
(Total 9 marks)

Q19.

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)

Q20.

Which of these has the highest first ionisation energy?

A	Na	○
B	Al	○
C	Si	○
D	Cl	○

(Total 1 mark)

Q21.

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)

(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 1.013×10^{-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)

Q22.

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.

____

____

____

(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)

Q23.

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]$3s^2 3p^1$ ○

D [Ne]$3s^1 3p^2$ ○

(Total 1 mark)

Q24.

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}**Q**$^{+}$ ion is 1.243×10^{-5} s.

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

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

(3)

(Total 6 marks)

Q25.

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)

Q26.

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)

Q27.

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

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

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

Mass number = ______________________

(4)

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

(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)

Q28.

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.

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____

____

(4)