Q1.

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)

Q2.

Which atom has two more protons and two more neutrons than $^{52}_{24}Cr$?

A $^{54}_{26}Cr$ ☐

B $^{56}_{26}Cr$ ☐

C $^{54}_{26}Fe$ ☐

D $^{56}_{26}Fe$ ☐

(Total 1 mark)

Q3.

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)

Q4.

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)

Q5.

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)

Q6.

Which atom has the smallest number of neutrons?

A ^{3}H ⬭

B ^{4}He ⬭

C ^{5}He ⬭

D ^{4}Li ⬭

(Total 1 mark)

Q7.

This question is about s-block metals.

(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.

Length of flight tube ____________________ m

(5)

Q8.

This question is about chromium and its compounds.

(b) An atom has 2 more protons and 3 more neutrons than an atom of ^{52}Cr.

Deduce the symbol, including the mass number and the atomic number, for this atom.

____

(1)

(c) A sample of chromium contains four isotopes and has a relative atomic mass of 52.09

The table shows the mass number and the percentage abundance of three of these isotopes.

Mass number	52	53	54
Abundance (%)	82.8	10.9	2.7

Determine the percentage abundance of the fourth isotope.
Show by calculation that the mass number of this isotope is 50

Percentage abundance ____________________________

Calculation

(3)

Q9.

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.

(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)

Q10.

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.

____

____

____

____

____

____

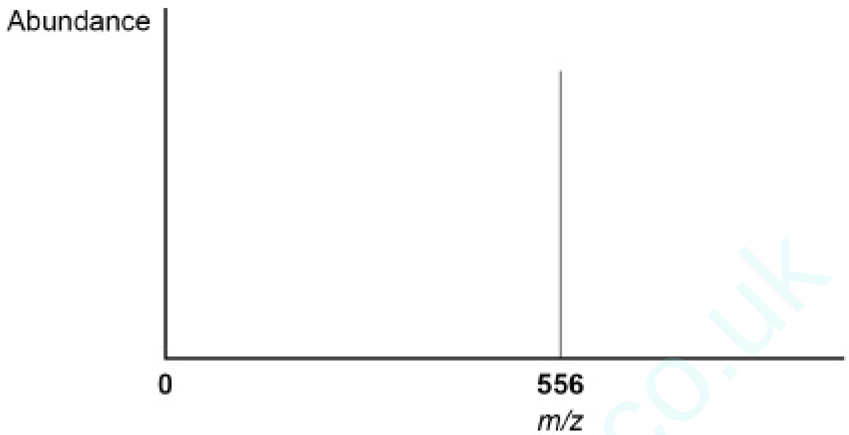
(2)

(Total 7 marks)

Q11.

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 ____

____

____

____

____

____

____

____

____

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 $\mathbf{Q}^+$ ion has a kinetic energy of 2.09 x 10^{-15} J
This ion takes 1.23 x 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 x 10^{23} mol^{-1}

Relative molecular mass ______________________________

(5)
(Total 10 marks)

Q12.

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 × 10^{23} mol^{-1}

Time _______________ s

(5)

(Total 15 marks)

Q13.

This question is about atomic structure.

(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)

Q14.

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)

Q15.

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)

Q16.

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

(a) Compound **X** is dissolved in a polar, volatile solvent and is ionised by electrospray ionisation.
Each ion is accelerated so that it has a kinetic energy of 1.36×10^{-16} J

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}

The time of flight along the 0.750 m flight tube is 2.48×10^{-5} s

Determine the mass, in g, of one mole of **X**.

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

Mass of one mole of **X** ____________________ g

(5)

A mixture of gases is analysed using TOF mass spectrometry.
The mixture contains argon, carbon dioxide, nitrogen and oxygen.
The mixture is ionised by electron impact.

(b) State the meaning of the term electron impact ionisation.

____

____

(1)

(c) Identify the ion formed from this mixture that reaches the detector last.

Justify your answer.

Ion that reaches detector last ________________________________

Justification ____

____

____

(2)

(d) State how the ions are detected, and how the abundance of each ion is measured, in a TOF mass spectrometer.

How ions are detected ____

____

How abundance is measured ____________________________________

____

(2)

(Total 10 marks)

Q17.

(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)

Q18.

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

(a) Give the equation, including state symbols, for the formation of Sr^+ ions from Sr atoms by electron impact.

____

(1)

(b) A sample of strontium is analysed by TOF mass spectrometry. The sample is ionised using electron impact.

The ions are accelerated to have a kinetic energy (*KE*) of 7.02×10^{-20} J. An ion takes 9.47×10^{-4} s to travel along a 95.0 cm flight tube.

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

where m = mass (kg) and v = speed (m s^{-1})

Use the information given to deduce the mass number of this ion.

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

Mass number ____________________

(5)

(c) Explain how the ions are detected in the TOF mass spectrometer.

State how the relative abundance of the ions is determined.

How ions are detected ____

____

How relative abundance is determined ____

____

____

(2)

(d) A sample of strontium contains three isotopes, ^{86}Sr, ^{87}Sr and ^{88}Sr
82% of the sample is ^{88}Sr
The other isotopes are in a 1:2 ratio of ^{86}Sr : ^{87}Sr

Calculate the percentage abundance of ^{87}Sr in this sample.

Use your answer to deduce the relative atomic mass (A_r) of the sample.
Give your answer to 1 decimal place.

Abundance of ^{87}Sr ____________________ %

A_r ____________________

(3)

(e) Electrospray ionisation is used instead of electron impact for the ionisation of a protein in a mass spectrometry experiment.

Suggest why.

____

____

____

(1)

(Total 12 marks)

Q19.

Rhenium has an atomic number of 75

(a) Define the term relative atomic mass.

____

____

____

(2)

(b) The relative atomic mass of a sample of rhenium is 186.3

The table below shows information about the two isotopes of rhenium in this sample.

Relative isotopic mass	**Relative abundance**
185	10
To be calculated	17

Calculate the relative isotopic mass of the other rhenium isotope. Show your working.

Relative isotopic mass ________________

(2)

(c) State why the isotopes of rhenium have the same chemical properties.

____

____

(1)

A sample of rhenium is ionised by electron impact in a time of flight (TOF) mass spectrometer.

(d) A $^{185}Re^{+}$ ion with a kinetic energy of 1.153×10^{-13} J travels through a 1.450 m flight tube.

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

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

Calculate the time, in seconds, for the ion to reach the detector.

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

Time _______________ s

(5)

(e) State how the relative abundance of $^{185}Re^{+}$ is determined in a TOF mass spectrometer.

___

___

___

___

(2)

(Total 12 marks)

Q20.

(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)

Q21.

The element rubidium exists as the isotopes ^{85}Rb and ^{87}Rb

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

Number of protons ____

Number of neutrons ____

(2)

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

____

____

____

____

(2)

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

____

(1)

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

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

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

____

____

____

(1)

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

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

____

____

____

____

(3)

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

Name of relevant part ____

Explanation ____

____

____

(2)

Q22.

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

(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)

Q23.

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.

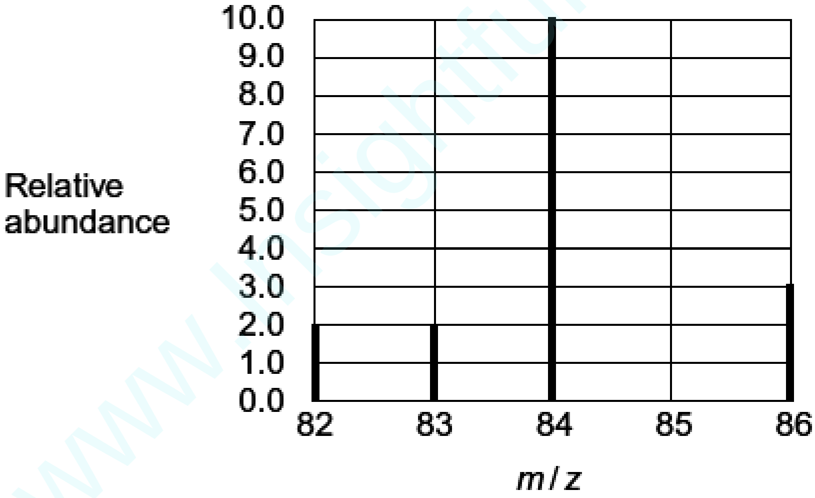
Time of flight ____________________ s

(3)

(Total 8 marks)

Q24.

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.

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)

Q25.

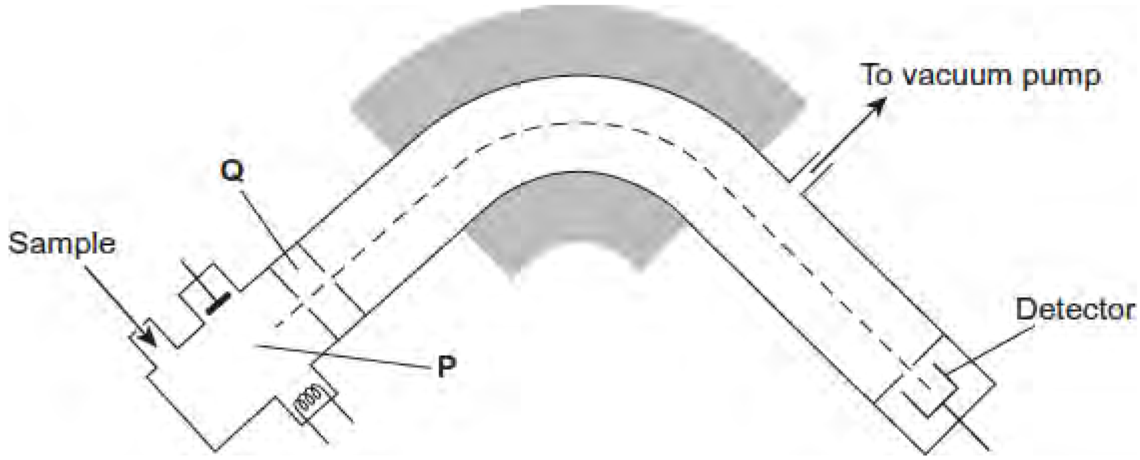
(a) State the meaning of the term *mass number* of an isotope.

(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**.

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.

(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})

___

___

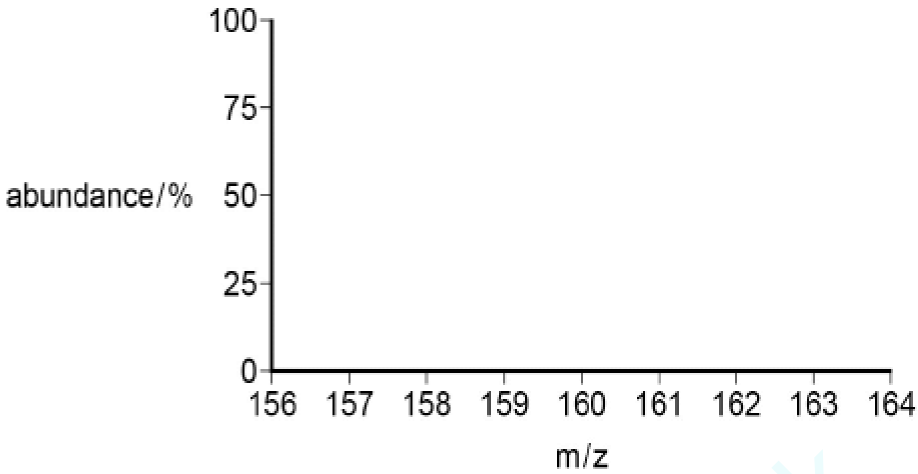
___

___

(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.



(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.

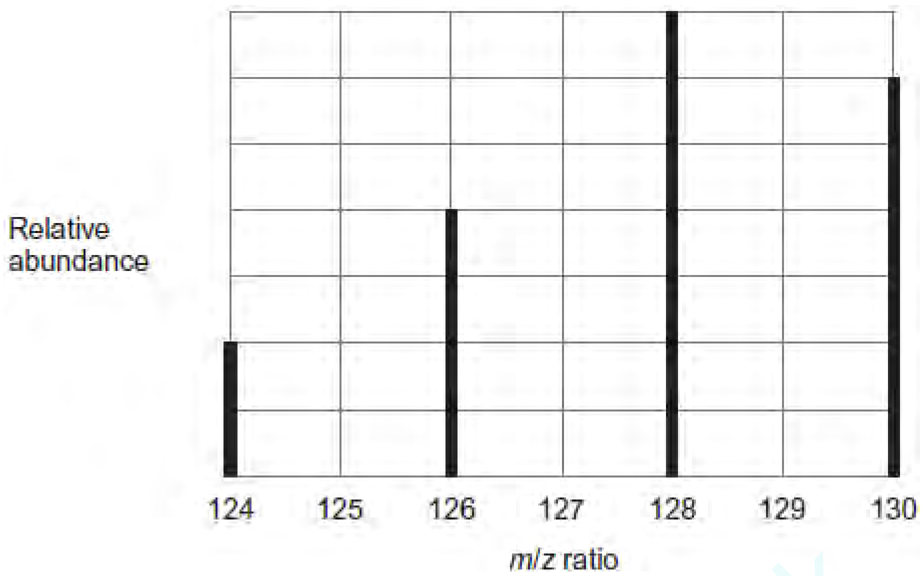
(4)

(Total 12 marks)

Q27.

Tellurium is the element with atomic number of 52

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



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

___

___

___

___

___

(3)

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

___

___

(1)

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

___

(1)

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

m / *z* value ___

Reason ___

___

(2)

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

Explain the existence of this peak.

(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)

Q28.

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)

Q29.

(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.

____

____

(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)

Mark schemes

Q1.

D

$^{34}_{16}S$

[1]

Q2.

D

$^{56}_{26}Fe$

[1]

Q3.

B

[1]

Q4.

D

X(g) + H⁺ → XH⁺(g)

[1]

Q5.

A

[1]

Q6.

D

^{4}Li

[1]

Q7.

(f) **M1** Same electronic configuration / same number of electrons (in outer shell) / all have 37 electrons (1)

Ignore protons and neutrons unless incorrect numbers

Not just electrons determine chemical properties

1

M2 $\frac{86x + 87x + 88(100-2x)}{100} = 87.7$ = 87.7

Alternative M2:

$\frac{86 + 87 + 88y}{1 + 1 + y} = 87.7$

1

M3 x = 10% (or × = 0.1)

M3 y = 8

1

M4 (% abundance of 88 isotope is 100 – 2x10) = 80(.0)%

M4 % of 88 isotope is 100 – 10y = 80(.0) %

Allow other alternative methods

1

(g) $^{138}Ba^+$

1

(h) **M1** $\text{mass} = \frac{137 \times 10^{-3}}{6.022 \times 10^{23}}$ $= 2.275 \times 10^{-25}$ (kg)

Calculation of m in kg

If not converted to kg, max 4

If not divided by L lose M1 and M5, max 3

1

M2 $v^2 = \frac{2KE}{m} = \frac{2 \times 3.65 \times 10^{-16}}{2.275 \times 10^{-25}}$ $= 3.2088 \times 10^9$

For re-arrangement

1

M3 $v = \sqrt{2KE/m}$ ($v = 5.6646 \times 10^4$)

For expression with square root

1

M4 v = d/t or d = vt or with numbers

1

M5 $d = (5.6646 \times 10^4 \times 2.71 \times 10^{-5}) = 1.53 - 1.54$ (m)

M5 must be to 3sf

If not converted to kg, answer = 0.0485-0.0486 (3sf). This scores 4 marks

1

Alternative method

M1 $m = \frac{137 \times 10^{-3}}{6.022 \times 10^{23}}$ $= 2.275 \times 10^{-25}$

M1 Calculation of m in kg

1

M2 v = d/t

M2, M3 and M4 are for algebraic expressions or correct expressions with numbers

1

M3 $d^2 = \frac{KE \times 2t^2}{m}$

1

M4 d = $\sqrt{\frac{KE \times 2t^2}{m}}$ (= √ ($3.65 \times 10^{-16} \times 2 \times (2.71 \times 10^{-5})^2 / 2.275 \times 10^{-25}$))

1

M5 d = 1.53 – 1.54 (m)

M5 must be to 3sf

1

[18]

Q8.

(b) $^{57}_{26}Fe$

Allow mass number and atomic number on RHS of Fe

1

(c) % of 4th isotope = 3.6

1

M2:

$$\frac{(52 \times 82.8) + (53 \times 10.9) + (54 \times 2.7) + (3.6x)}{100} = 52.09$$

1

M3:

x = 49.97 OR

179.9 = 3.6 x and x = 50

(evidence of working)

1

Allow alternative methods

M2 *(52 × 82.8) + (53 × 10.9) + (54 × 2.7) + (50 × 3.6) =5209*

M3 *A_r = 5209/100 = 52.09*

Or

M2

$$\frac{(52 \times 82.8) + (53 \times 10.9) + (54 \times 2.7) + (50x)}{100} = 52.09$$

M3 *awarded for 50.. = 179.9 and then .. = 3.6*

(evidence of working)

[9]

Q9.

(a) (Sample is) dissolved (in a volatile solvent)

Allow named solvent (eg water/methanol)

1

(Injected through) needle/nozzle/capillary at high voltage/positively charged

Ignore pressure

1

Each molecule/particle gains a proton/H^+

Allow M3 from a suitable equation (ignore state symbols)

Do not allow atoms gain a proton for M3
Ignore references to electron gun ionisation
Mark each point independently

1

(b) $C_3H_6O_2N^+$ / $C_3H_5O_2NH^+$

Must be charged

1

(c) $Ge(g) + e^- \rightarrow Ge^+(g) + 2\,e^-$

OR

$Ge(g) \rightarrow Ge^+(g) + e^-$

State symbols essential

(d) **M1** v = length/t = $0.96 / 4.654 \times 10^{-6}$

v = 206274 m s^{-1}

m = $2KE/v^2$

M1 *= working (or answer)*

1

M2 mass of one ion = 1.146×10^{-25} kg

M2 *= answer conseq on* ***M1***

1

M3 mass of 1 mole ions = $1.146 \times 10^{-25} \times 6.022 \times 10^{23}$ = (0.06901 kg)

M3 *=* ***M2*** *× 6.022 ×* 10^{23}

1

M4 = 69(.01) g

M4 *=* ***M3*** *× 1000*
M3/M4 *could be in either order*

1

M5 mass number = 69

M5 *must have whole number for mass no*

1

[10]

Q10.

(a) = $79 / (1000 \times 6.022 \times 10^{23}) = 1.31 \times 10^{-25}$ kg

1

Then either follow **method 1** (or **method 2** below)

Do not mix and match methods

Method 1

$V_{79} = \frac{d}{t}$ = $0.950 / 6.69 \times 10^{-4}$

= 1420 ms^{-1}

In method 1, M2 can be awarded in M3

1

KE = ½ mv^2

= ½ × 1.312 × 10^{-25} × $(1420)^2$

= 1.32 × 10^{-19} J

Mark consequential to their velocity and mass. Allow mass of 79 etc.

1

$V_{81} = \sqrt{\left(\frac{2KE}{m}\right)}$

= √ 1.963 × 10^6

= 1.40 × 10^3 ms^{-1}

(allow 1.398 × 10^3 - 1.402 × 10^3)

Mark consequential to their velocity and mass. Allow mass of 81 etc.

1

$t = \frac{d}{v} = \frac{0.950}{v_{81}}$

= 6.80 × 10^{-4} s

Mark consequential to their M4

Accept 6.77 – 6.80 × 10^{-4} s

1

Method 2

$m_1(d/t_1)^2 = m_2\ (d/t_1)^2$
or
$m_1 / t_1^2 = m_2 / t_2^2$

1

$t_2^2 = t_1^2\ (m_2/m_1)$
Or
t_2^2 = (6.69 × 10^{-4})2 × (81/79)

1

t_2^2 = 4.59 × 10^{-7}

Mark consequential to their M3

1

t = 6.77 × 10^{-4} s

Mark consequential to their M4

Accept 6.77 – 6.80 × 10^{-4} s

1

(b) ion hits the detector / negative plate <u>and</u> gains an electron

1

Not positive plate

(relative) abundance is proportional to (the size of) the current

1

[7]

Q11.

(a) **M1**: P dissolved or put in/added to a solvent

__M1__: Allow named solvent eg water or methanol

1

M2: (injected through) a needle or nozzle or capillary <u>and</u> at high voltage/4000 volts or high potential

__M2__: Allow needle is positively charged

1

M3: Gains a proton / H^+

__M3__: Not atoms gain a proton

__M3__: Could be scored from equation

1

M4: $P + H^+ \rightarrow PH^+$

Correct equation gains __M3__ and __M4__

Ignore state symbols

1

(b) 555

1

(c) **M1** $V = d/t$ or $= 1.22 \times 10^5\ ms^{-1}$

Recall this equation

1

M2 $m = \dfrac{2KE}{v^2}$ or $\dfrac{2 \times 2.09 \times 10^{-15}}{(1.22 \times 10^5)^2}$

or

M2 $m = \dfrac{2KE \times t^2}{d^2}$ or $\dfrac{2 \times 2.09 \times 10^{-15} \times (1.23 \times 10^{-5})^2}{1.50^2}$

Rearrangement to give m

1

M3 $m = \underline{2.8(1) \times 10^{-25}}$ (kg)

__M3__: Calculation of m.

1

M4 $= 2.81 \times 10^{-25}\ \underline{\times L} = 0.169$

__M4__: Allow __M3__ × L

1

M5 $0.169\ \underline{\times 1000} = 169.(2)$

__M5__: Allow __M4__ × 1000

169 only scores 5 marks

Allow answers to 2 significant figures or more ignore units

1

[10]

Q12.

(a) Average / mean mass of 1 atom (of an element)

1

1/12 mass of one atom of ^{12}C

1

If moles and atoms mixed, max = 1

Mark top and bottom line independently. All key terms must be present for each mark.

OR

Average / mean mass of atoms of an element
1/12 mass of one atom of ^{12}C

OR

Average / mean mass of atoms of an element × 12
mass of one atom of ^{12}C

OR

(Average) mass of one mole of atoms
1/12 mass of one mole of ^{12}C

OR

(Weighted) average mass of all the isotopes
1/12 mass of one atom of ^{12}C

OR

Average mass of an atom/isotope compared to/relative to C−12 on a scale in which an atom of C−12 has a mass of 12

This expression = 2 marks

(b) **M1** % of ^{50}Cr and ^{53}Cr = 13.9%

Let % of ^{53}Cr = x% and Let % of ^{50}Cr = (13.9 - x)%

If x used for ^{50}Cr and ^{53}Cr or x and y, max 2 marks = ***M1*** *and* ***M4***

Alternative ***M2***

Let % of ^{53}Cr = (13.9%-x)% and % of ^{50}Cr = x%

1

M2 $52.1 = \frac{50(13.9 - x) + (52 \times 86.1) + 53(x)}{100}$

OR

3x = 37.8

M2 $52.1 = \frac{53(13.9 - x)+(52 \times 86.1)+50x}{100}$

OR

3x = 3.9

1

M3 x = % of ^{53}Cr = 12.6%

1

M4 % of ^{50}Cr = 1.3%

M4** = **M1**- **M3

1

(c) **M1** (Same) number of protons OR electrons

*Do not allow same electronic configuration for **M1***

1

M2 (Different) number of neutrons

1

(d) **M1** (Ions will interact with and) be accelerated (by an electric field)

Allow (ions) accelerated to a negative plate

Do not allow magnetic field

1

M2 Ions create a current when hitting the detector OR ions create a current in the detector/electron multiplier.

Allow (ions) can be detected

1

(e) **M1** Mass of ion = 8.8. x 10^{-26} kg

***M1** Mass of ion in kg*

1

M2 $v^2 = \frac{2KE}{m} = v^2 = \frac{2 \times 1.102 \times 10^{-13}}{8.8. \times 10^{-26}}$ $(= 2.504 \times 10^{12})$

***M2** Rearrangement*

*Alternative **M2*** $v = \sqrt{\frac{2KE}{m}}$

1

M3 $v = \sqrt{\left(\frac{2 \times 1.102 \times 10^{-13}}{8.8. \times 10^{-26}}\right)} = 1.58 \times 10^6\ (ms^{-1})$

***M3**: Calculating v by taking* $\sqrt{v}$

1

M4 $v = \frac{d}{t}$

***M4**: Recall of v = d/t*

1

M5 t = 7.9(0) x 10^{-7} (s) (2sf or more)

***M5**: Calculating t*

1

Alternative

M1 Mass of ion = <u>8.8. x 10</u>$^{-26}$ kg

Alternative

***M1** Mass of ion in kg*

1

M2 $KE = \frac{md^2}{2t^2}$ or $v = \frac{d}{t}$

***M2** Recall of v = d/t*

1

M3 $t^2 = \frac{md^2}{2KE}$ OR $\frac{8.8. \times 10^{-26} \times 1.25^2}{2 \times 1.102 \times 10^{-13}}$

***M3** Rearrangement*

1

M4 t^2 = 6.24 x 10−13

***M4**: Correct calculation to get t^2*

1

M5 *t* = 7.9(0) x 10^{-7} (s) (2sf or more)

M5**: Calculating t by taking square root of **M4

*Allow answers consequential on incorrect **M1** If mass in g calculated = 8.8. x 10^{-23} , then t = 2.5 x 10^{-5} s (4 marks)*

1

[15]

Q13.

1

Ignore shielding

(d) $^{58}Ni^{+}$

M1 needs mass and charge – allow subscripts

1

A_r= [(58 × 61.0) + (60 × 29.1) + (61 × 9.9)] / 100

1

A_r= 58.<u>9</u> must be to 1dp

1

[9]

Q14.

(a) <u>Number</u> of protons + neutrons (in the nucleus of the atom)

Do not allow reference to mass or average

Ignore references to C-12 being 12

1

(b)

	Number of protons	**Number of neutrons**	**Number of electrons**
^{46}Ti	22	**24**	**22**
$^{49}Ti^{2+}$	22	**27**	**20**

Mark as rows

1
1

(c) Let ^{49}Ti be y

M1 $47.8 = \frac{(46 \times 2y) + (47 \times 2y) + (48 \times (100 - 5y)) + (49 \times y)}{100}$

$47.8 = \frac{235y + 4800 - 240y}{100}$

Allow

M1 $47.8 = \frac{(46 \times 2) + (47 \times 2) + (48 \times n) + 49}{(5 + n)}$

1

M2 5y = 20 OR y = 4

M2 0.2n =4 or n=20

1

M3 abundance of ^{46}Ti = 8%

M3 % $^{46}Ti = \frac{2}{25} \times 100 = 8\%$

1

[6]

Q15.

(a) $[CH_3OCOCOOH]^+$

Allow names

1

$[CH_3OCOCOOCH_3]^+$

Do not allow molecular formula

1

(b) Positive ions are accelerated by an electric field

1

To a constant kinetic energy

1

The positive ions with m / z of 104 have the same kinetic energy as those with m / z of 118 and move faster

1

Therefore, ions with m / z of 104 arrive at the detector first

1

[6]

Q16.

(a) **M1**

$v = \frac{d}{t} = \frac{0.750}{2.48 \times 10^{-5}} = 30241.9\ m\ s^{-1}$

M1 *Calculation of v*

M2

$m = \frac{2ke}{v^2} = \frac{2 \times 1.36 \times 10^{-16}}{(\text{ans to M1})^2}$

***M2** Calculation of m (in kg)*

$m = \frac{2ke}{v^2} = \frac{2 \times 1.36 \times 10^{-16}}{(30241.9)^2} = 2.974 \times 10^{-25}$ *kg*

M3

m = (ans to M2) × 1000

***M3** calculation of m (in g)*

$m = 2.974 \times 10^{-25} \times 1000 = 2.974 \times 10^{-22}$ *g*

M4

mass = (ans to M3) × 6.022 × 10^{23}

***M4** calculation of mass of one mole of ions*

mass = $2.974 \times 10^{-22} \times 6.022 \times 10^{23} = 179(.1)$

M5

Mass of one mole = (ans to M4) - 1 = 178(.1)

***M5** subtracts 1 for mass of* H^+

Mass of one mole = 179.1 - 1 = 178(.1)

5

(b) (High energy) electrons (from an electron gun) are used to knock out an electron (from each molecule or atom.)

1

(c) Ion that reaches detector last: CO^{2+}

Justification: Has the highest mass (to charge ratio) (so will travel the slowest)

2

(d) **M1** (ions hit a detector and) each ion gains an electron (generating a current)

M2 (the abundance is) proportional to (the size of) the current

Allow the use of electron multiplier to amplify the current

2

[10]

Q17.

(b) M1: $^{112}Sn^+$

1

M2 missing abundance = 30.84%

M3

If M2 missing then allow M3 if denominator = 69.16

1

$$\text{RAM} = \frac{(112 \times 22.41) + (114 \times 11.78) + (117 \times 34.97) + (120 \times 30.84)}{100}$$ 1

M4 RAM = 116.5 answer must be to 1dp

Allow M4 ecf 1

[6]

Q18.

(a) $Sr(g) + e^- \rightarrow Sr^+(g) + 2e^-$

Allow $Sr(g) \rightarrow Sr^+(g) + e^-$ 1

(b) M1 V = (d÷t =) 0.950 ÷ 9.47 × 10^{-4} OR 1003 m s^{-1}

Recall and conversion of d into metres

M2 $m = \frac{2KE}{v^2}$ or $\frac{2 \times 7.02 \times 10^{-20}}{1003^2}$ (= 1.396 x 10^{-25} kg)

Allow $\frac{2 \times 7.02 \times 10^{-20}}{M1^2}$ *or* $\frac{2KE\,t^2}{d^2}$

M3 mass of ion = 1.396 × 10^{-22} (g)

M3 = M2 x1000

M4 mass of one mol of ions in g =

1.396 × 10^{-22} × 6.022 x 10^{23} (= 84.04)

M4 = M3 x Avogadro's number

Conversion to g may be seen in M4

M5 mass number = 84

Answer as whole number 5

(c) **M1** (Ions hit a detector/electron multiplier and) each ion gains an electron (generating a current)

M2 current is proportional to abundance 2

(d) **M1** Abundance ^{87}Sr = 2 × 18 ÷ 3 = 12(%)

M2 $A_r = \frac{(82 \times 88) + (12 \times 87) + (6 \times 86)}{100}$

M3 = 87.8

Answer to 1 decimal place 3

(e) the protein (ion) does not break up/fragment 1

[12]

Q19.

(a) <u>average/mean mass of 1 atom (of an element)</u>
1/12 mass of one atom of ^{12}C
or
<u>average/mean mass of atoms of an element</u>
1/12 mass of one atom of ^{12}C
or
<u>average/mean mass of atoms of an element × 12</u>
mass of one atom of ^{12}C
or
<u>(average) mass of one mole of atoms</u>
1/12 mass of one mole of ^{12}C
or
<u>(weighted) average mass of all the isotopes</u>
1/12 mass of one atom of ^{12}C
or
average mass of an atom/isotope (compared to C−12) on a scale in which an atom of C−12 has a mass of 12

M1 = top line

1

M2 = bottom line

1

if moles and atoms/isotopes mixed max = 1

(b) **M1** $186.3 = \frac{(185 \times 10) + (X \times 17)}{27}$

correct expression

1

M2 (relative isotopic mass) = <u>187</u>(.1)

1

(c) same electron configuration

allow same number of electrons
allow same electron structure
ignore same number of protons
ignore different number of neutrons
*do **not** accept same number of neutrons*

1

(d) **M1** mass ^{185}Re $\left(= \frac{185}{6.02 \times 10^{23} \times 1000}\right) = 3.072 \times 10^{-25}$

calculate mass in kg

1

M2 $v = \frac{d}{t}$

recall of v = d/t

1

M3 $v^2 = \frac{2KE}{m}$ **or** $7.5(0) \times 10^{11}$

rearrangement to get v^2

1

M4 $v = \sqrt{\frac{2KE}{m}}$ **or** 8.66×10^5

allow $\sqrt{\frac{2 \times 1.153 \times 10^{-13}}{M1}}$

1

M5 $t\left(= \frac{1.45}{8.66 \times 10^5}\right) = 1.67 \times 10^{-6}$ (s)

M5 $t = \frac{1.45}{M4}$

allow 1.67×10^{-6} *to* 1.68×10^{-6} *(s)*

1

alternative method:

M1 mass ^{185}Re $\left(= \frac{185}{6.02 \times 10^{23} \times 1000}\right) = 3.072 \times 10^{-25}$

calculate mass in kg

1

M2 $v = \frac{d}{t}$ **or** $KE = \frac{md^2}{2t^2}$

recall of $v = d/t$

1

M3 $t^2 = \frac{md^2}{2KE}$

rearrangement to get t^2

1

M4 $t = d\sqrt{\frac{m}{2KE}}$ **or** $\sqrt{\frac{md^2}{2KE}}$ **or** $\sqrt{\frac{3.072 \times 10^{-25}}{2 \times 1.153 \times 10^{-13}}}$

allow $\sqrt{\frac{M1}{2 \times 1.153 \times 10^{-13}}}$

1

M5 $t = 1.67 \times 10^{-6}$ (s)

allow 1.67×10^{-6} *to* 1.68×10^{-6} *(s)*

1

(e) at the detector/(negative) plate the ions/Re^+ gain an electron

1

(relative) abundance depends on the size of the current

1

alternative answer

M1 ion knocks out an electron into electron multiplier

M2 signal from electron multiplier proportional to number of ions

[12]

Q20.

(a) Abundance of third isotope = 100 – 91.0 –1.8 = 7.2%

1

$$\frac{(32 \times 91) + (33 \times 1.8) + (y \times 7.2)}{100} = 32.16$$

1

7.2y = 32.16 × 100 – 32 × 91 – 33 × 1.8 = 244.6

1

y = 244.6 / 7.2 = 33.97

y = 34

Answer must be rounded to the nearest integer

1

(b) (for electrospray ionisation)

A high voltage is applied to a sample in a polar solvent

1

the sample molecule, M, gains a proton forming MH^+

1

OR

(for electron impact ionisation)

the sample is bombarded by high energy electrons

1

the sample molecule loses an electron forming M^+

1

(c) Ions, not molecules, will interact with and be accelerated by an electric field

1

Only ions will create a current when hitting the detector

1

[8]

Q21.

(a) 37

These answers only.
Allow answers in words.

1

48

Ignore any sum(s) shown to work out the answers.

1

(b) (i) Electron gun / high speed/high energy electrons

Not just electrons.
Not highly charged electrons.

1

Knock out electron(s)

Remove an electron.

1

(ii) $Rb(g) \rightarrow Rb^{+}(g) + e^{(-)}$

OR

$Rb(g) + e^{(-)} \rightarrow Rb^{+}(g) + 2e^{(-)}$

OR

$Rb(g) - e^{(-)} \rightarrow Rb^{+}(g)$

Ignore state symbols for electron.

1

(c) Rb is a bigg<u>er</u> (atom) / e furth<u>er</u> from nucleus / electron lost from a high<u>er</u> energy level/ <u>More</u> shielding in Rb / <u>less</u> attraction of nucleus in Rb for outer electron / <u>more</u> shells

Answer should refer to Rb not Rb molecule

If converse stated it must be obvious it refers to Na

Answer should be comparative.

1

(e) $\frac{(85 \times 2.5) + 87 \times 1}{3.5}$

M1 is for top line

1

1

= <u>85.6</u>

Only

1

OR

$\frac{(58 \times 5) + 87 \times 2}{7}$

M1 ${}^{85}Rb$ 71.4% and ${}^{87}Rb$ 28.6%

M2 divide by 100

1

1

<u>85.6</u>

M3 = <u>85.6</u>

1

(f) Detector

Mark independently

Allow detection (plate).

1

Current / digital pulses / electrical signal related to abundance

Not electrical <u>charge</u>.

1

Q22.

(a) (i) Different number / amount of neutrons

Not different neutrons

Ignore same protons and/or electrons

CE incorrect statement relating to protons / electrons

1

(ii) Same electron configuration / same number of electrons (in the outer shell)

Ignore same no of protons

Ignore electrons determine chemical properties

CE if wrong statement relating to protons / neutrons

1

(b) <u>Average mass of 1 atom (of an element)</u>
1/12 mass atom of ^{12}C

OR

<u>Average/mean mass of atoms of an element</u>
1/12 mass of one atom of ^{12}C

OR

<u>(Average) mass of one mole of atoms</u>
1/12 mass of one mole of ^{12}C

OR

<u>(Weighted) average mass of all the isotopes</u>
1/12 mass of one atom of ^{12}C

OR

Average mass of an atom/isotope compared to C-12 on a scale in which an atom of C-12 has a mass of 12

If moles and atoms mixes Max = 1

Mark top and bottom line independently

1/12 on bottom line can be represented as x 12 on top line

This expression = 2 marks

2

(c) (i)

$$\frac{(64\times12)+(66\times8)+(67\times1)+(68\times6)}{27}\ \frac{(=1771)}{27}$$

= <u>65.6</u>

If not 27 max 1 mark (for top line)

Mark is for dividing by 27 or string

*If **evidence** of arithmetic or transcription error seen in M1 or M2 allow consequential M3 and consequential (c)(ii)*

65.6 = 3 marks

3

(ii) $^{64}Zn^{+}$

M1 for identifying Zn / zinc

M2 is for the + sign and the 64

M2 is dependent on M1

2

(d) Size of the charge (on the ion) / different charges / different m/z

Allow forms 2+ ions

QWC

1

(e) (ions hit detector and) cause current/(ions) accept electrons/cause electron flow/electric pulse caused

bigger current = more of that isotope/current proportional to abundance

Implication that current depends on the number of ions

M2 dependent on M1

2

[12]

Q23.

(a) $\frac{(46 \times 9.1) + (47 \times 7.8) + (48 \times 74.6) + (49 \times 8.5)}{100} = \frac{4782.5}{100}$

1

= 47.8

Correct answer scores 2 marks.

Allow alternative methods.

Allow 1dp or more.

Ignore units

1

(b) $Ti(g) \longrightarrow Ti^+(g) + e^-$

or $Ti(g) + e^- \longrightarrow Ti^+(g) + 2e^-$

or $Ti(g) - e^- \longrightarrow Ti^+(g)$

State symbols essential

Allow electrons without $^-$ charge shown.

1

46

1

(c) $8.1(37) \times 10^{-26}$

1

(d) M1 is for re-arranging the equation

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

Allow t α square root of m

1

$$d = t_{47}\sqrt{\frac{2E}{47 \times 10^{-3} / L}} = t_{49}\sqrt{\frac{2E}{49 \times 10^{-3} / L}}$$

Or

d = 1.5(47)

This scores 2 marks

Allow this expression for M2

$$\frac{t_{47}}{\sqrt{47}} = \frac{t_{49}}{\sqrt{49}}$$

1

= 9.6(14) × 10^{-7}

Correct answer scores 3 marks.

1

[8]

Q24.

(a) $$\frac{(82 \times 2) + (83 \times 2) + (84 \times 10) + (86 \times 3)}{17} \qquad \frac{(1428)}{(17\ \ )}$$

M1 for the top line

M2 is for division by 17

1

= <u>84.0</u>

Not 84

No consequential marking from M1 or M2

Ignore units

1

The A_r in the Periodic table takes account of the <u>other isotopes</u> / <u>different amounts of isotopes</u> (or words to that effect regarding isotopes)

Award independently

Comparison implied

Isotope(s) alone, M4 = 0

1

(b) (Beam of electrons from) an electron gun / high speed / high energy electrons

1

Knocks out electron(s) (to form a positive ion)

1

$Kr(g) + e^- \rightarrow Kr^+(g) + 2e^{(-)}$

State symbols must clearly be (g)

1

OR

$Kr(g) \rightarrow Kr^+(g) + e^{(-)}$ / $Kr(g) - e^{(-)} \rightarrow Kr^+(g)$

The ^{84}Kr isotope

One mark for identifying the 84 isotope

1

Has 2 electrons knocked out / gets a 2+ charge

One mark for the idea of losing 2 electrons (from this isotope)

1

[9]

Q25.

(a) (Total number of) protons and neutrons (in nucleus of atom)

(number of) nucleons

1

(b) Zn

Do not allow Zn^{-1} or Zn^{+1} or ZN
Ignore numbers

1

(c) (i) P = ionise (sample)

Allow removing an electron / forms (+) ions

1

Q = accelerate (sample)

Allow speeds (ions) up
Penalise molecules / atoms

1

(ii) m / z

Allow mass / charge

1

(relative) abundance / (relative) intensity

QoL
Allow M1 + M2 in any order

1

(d) (i) $\frac{206 + 207 + (208 \times 2)}{4} = \frac{(829)}{4}$

M1 = topline

1

M2 = ÷ 4

1

= 207.3

Only
207.3 = 3 marks

1

(ii) Lead / Pb

Not PB

1

(iii) Same number of electrons (in outer shell) / same electronic configuration

Ignore electrons determine chemical properties
Ignore reference to p and n if correct
Penalise if incorrect

1

[11]

Q26.

(a) (Ions accelerated by) attraction to negatively charged plate / electric field

Mark independently

1

Ions detected by gaining electrons

Allow the transfer of electrons

1

Abundance determined by (size) of current flowing (or amount of electrons gained) in the detector

Allow current is proportional to abundance

1

(b) Mass = $\frac{52/1000}{6.022 \times 10^{23}}$

Mass = $8.6(4) \times 10^{-26}$

1

(c) $V^2 = (2 \times 1.269 \times 10^{-13}) / 8.64 \times 10^{-26}$

Allow correct rearrangement for V or V^2

1

$V = 1.71 \times 10^6\ ms^{-1}$

Allow ecf from (b) (note if 8.6×10^{-23} in (b) leads to approx. $5.4 \times 10^4\ ms^{-1}$)

1

(d) Sketch with peaks at 158, 160, 162

Mark independently

1

In ratio 25%:50%:25%

Allow approx. ratio 1:2:1

1

(e) % abundance ^{m}Xe = 20(%)

Working must be shown

1

131.31 = (0.28*129) + (0.25*131) + (0.27*132) + (0.20*m)

1

131.31 – 104.51 = 0.2m

1

Mass number = 134

Answer must be an integer

1

[12]

Q27.

(b) (i) $\frac{(124 \times 2)+(126 \times 4)+(128 \times 7)+(130 \times 6)}{19}$ or $\frac{2428}{19}$

M1 for top line

1

<u>127.8</u>

M2 for correct denominator

1

127.8 with no working shown scores 3 marks

1

Or

$\frac{(124 \times 10.5)+(126 \times 21.1)+(128 \times 36.8)+(130 \times 31.6)}{100}$

1

Mark for 100 dependent on top line correct

1

<u>127.8</u>

1

(ii) Other <u>isotopes</u> present / some <u>isotopes</u> absent / different abundances of <u>isotopes</u>

1

(c) $Te^{+} + e^{(-)} \rightarrow Te$

Ignore state symbols

Allow $Te^{2+} + 2e^{(-)} \rightarrow Te$

1

(d) 128

Only

1

Most abundant ion (QoL − superlative)

M2 dependent on correct M1

1

(e) 2+ ion formed / 2 electrons removed

Due to $^{128}Te^{2+}$ = 2 marks

1

From ^{128} (Te)

Mark independently

1

(f) Same

If not same CE = 0 / 2

1

(Each isotope has the) same number of protons / same nuclear charge and same number of electrons / electronic configuration

Ignore more neutrons in ^{130}Te

1

[12]

Q28.

(a) The average mass of an atom of an element

(Weighted) average mass of all isotopes of an element

1

Compared to 1/12th the mass of an atom of carbon-12

1

(b) R.A.M. = $\frac{(82 \times 6) + (83 \times 1) + (84 \times 28) + (86 \times 8)}{43}$

***M1** for working*

1

= 3615 / 43
= 84.1

***M2** for answer to 1 decimal place 36.2 scores 1/2*

1

(c) **M1** m = (84/1000)/6.02 x 10^{23} (= 1.395 x 10^{-25} kg)

Alternative method

***M1**: m = (84/1000)/6.02 x 10^{23} (= 1.395 x 10^{-25} kg)*

M2 v^2 = 2ke/m = 2 x (4.83 × 10^{-16}) / (1.395 x 10^{-25})

***M2**: $d^2 = 2\ ke\ t^2/m$*

M3 v = √(6924731183) = 83214.97

***M3**: d^2 = 2 x (4.83 × 10^{-16}) x (1.73 x 10^{-5})^2 / 1.395 x 10^{-25} d^2 = 2.07*

M4 d = v x t = 83214.97 x 1.72 × 10^{-5} = 1.43 (m)

***M4** = 1.44 (m)*

Allow answers in range 1.43 – 1.44 m

If m not converted to kg, then d = 0.045 m for max 3

4

[8]

Q29.

(a) (i) Atoms with the same number of protons / proton number **(1)**

NOT same atomic number

with different numbers of neutrons **(1)**

***NOT** different mass number / fewer neutrons*

(ii) Chemical properties depend on the number or amount of (outer) electrons **(1)** <u>OR</u>, isotopes have the same electron configuration / same number of e^-

(iii) 23/6.023 × 10^{23} **(1)**

CE = 0 if inverted or multiplied

tied to M1 3.8(2) × 10^{-23} [2-5 sig figs] **(1)**

5

(b) $1s^2\ 2s^2\ 2p^6\ 3s^1$ **(1)**

accept subscripted figures

1

(c) Highest energy e^- / outer e^-s / last e^- in (3)d sub-shell **(1)**

<u>OR</u> d sub-shell being filled / is incomplete
<u>OR</u> highest energy sub-shell is (3)d
<u>NOT</u> transition element / e^- configuration ends at 3d

Q of L

1

(d) $^{15}_{7}N$ N correct symbol **(1)**

allow N^{15}_{7}

Mass number = 15 <u>AND</u> atomic number = 7 **(1)**

2

[9]