1 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 .....

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(3)

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

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(1)

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

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

Shape of ClF_3 Shape of CCl_2

(2)

(ii) Name the shape of CCl_2

.....

(1)

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

.....

(1)

(Total 11 marks)

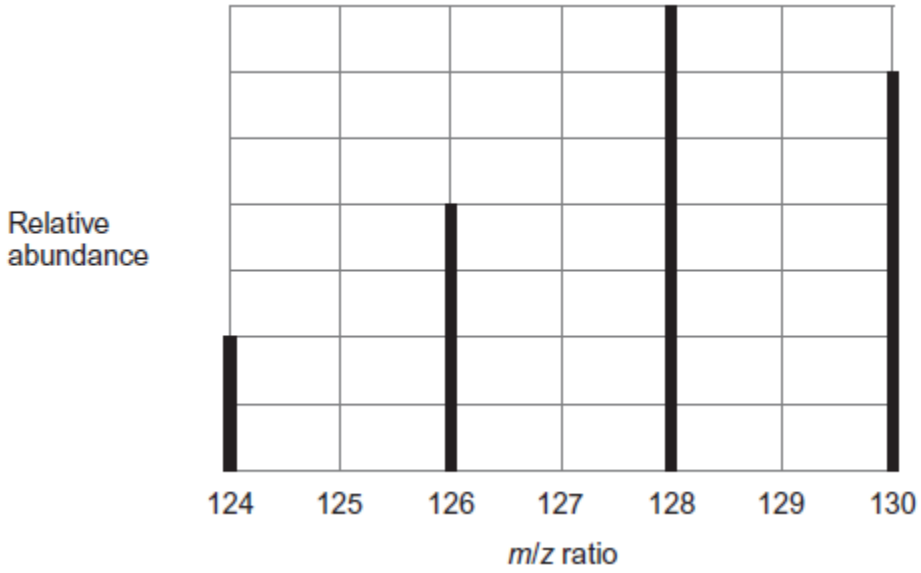
2 Tellurium is the element with atomic number of 52

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

[Kr] .....

(1)

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



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

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(3)

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

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(1)

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

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(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.

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(2)

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

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

Explanation .....

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(2)
(Total 12 marks)

3 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.

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(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.

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(1)

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

Trend .....

Explanation .....

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(3)
(Total 7 marks)

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

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

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

Mass number = ...

(4)

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

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(2)

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

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

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(2)
(Total 8 marks)

5 Which of these atoms has the largest atomic radius?

A Ar ⬭

B Cl ⬭

C Mg ⬭

D Na ⬭

(Total 1 mark)

6 Which of these atoms has the smallest number of neutrons?

A ^{3}H ⬭

B ^{4}He ⬭

C ^{5}He ⬭

D ^{4}Li ⬭

(Total 1 mark)

7 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)

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(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)

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

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

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(2)

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

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(4)
(Total 6 marks)

9 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)

10 (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 ^1H

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.

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(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.

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(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)

11 (a) Nickel is a metal with a high melting point.

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

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(1)

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

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(2)

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

(2)

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

.....

.....

.....

(1)

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

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

.....

(1)

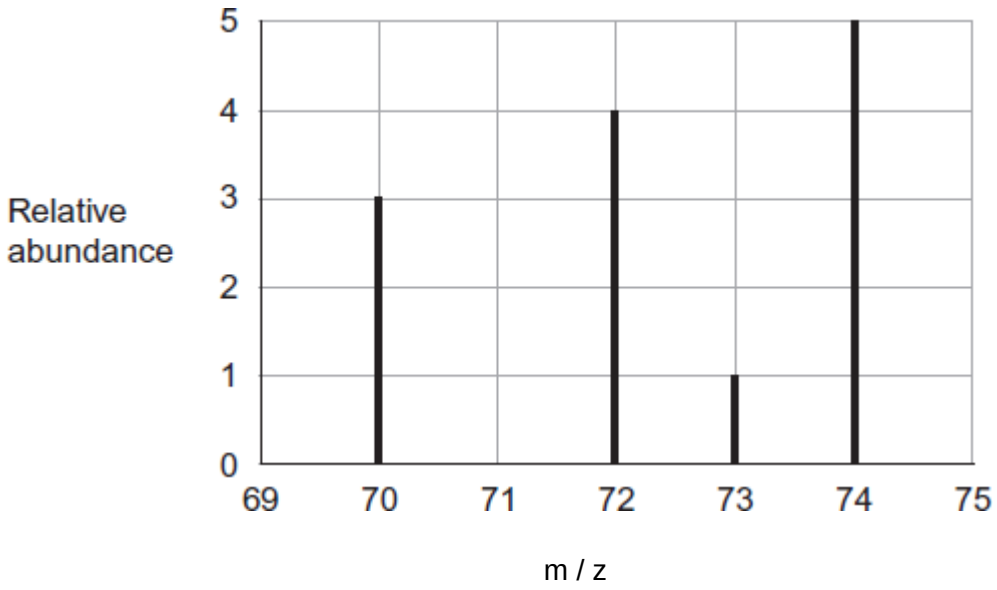
(ii) Balance the following equation to show how anhydrous nickel(II) chloride can be obtained from the hydrated salt using $SOCl_2$
Identify **one** substance that could react with both gaseous products.

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

Substance .....

(2)
(Total 9 marks)

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



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

.....

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.....

(2)

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

Give your answer to one decimal place.

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(3)

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

.....

(1)

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

Isotope .....

Reason .....

(2)

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

Explain how this current is generated.

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(2)

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

.....

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

(1)

(Total 11 marks)

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

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

.....

(1)

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

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

Type of bond .....

Explanation .....

.....

.....

(2)

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

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

.....

(1)

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

.....

(1)

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

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

Name of shape .....

(2)

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

(1)

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

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(1)

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

Tick (✓) one box.

First ☐

Second ☐

Third ☐

(1)

(Total 10 marks)

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

.....

.....

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(1)

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

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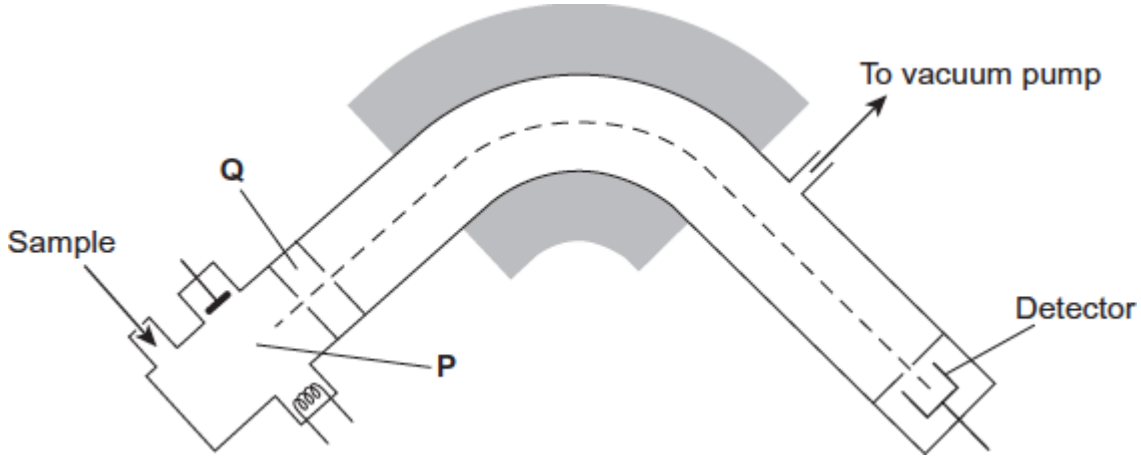
(1)

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



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

P .....

Q .....

(2)

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

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

Measurement 1 .....

Measurement 2 .....

(2)

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

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

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(3)

(ii) Identify **R**.

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(1)

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

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

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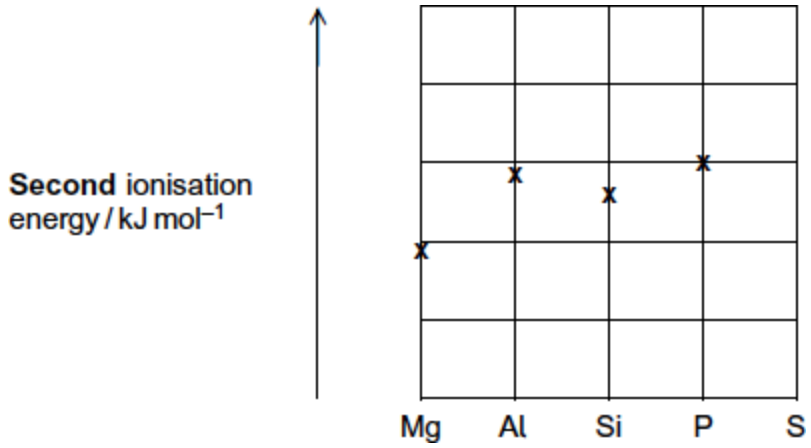
(Extra space) .....

.....

(1)

(Total 11 marks)

15 (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.

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(Extra space) .....

.....

(1)
(Total 8 marks)

16 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.

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(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.

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(3)

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

Name of relevant part .....

Explanation .....

.....

.....

(2)

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

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

Explanation .....

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(3)
(Total 16 marks)

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

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

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

(1)

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

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

P_4 .....

H_3PO_4 .....

(2)

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

Atom	Precise relative atomic mass
^{1}H	1.00794
^{16}O	15.99491
^{31}P	30.97376
^{32}S	32.06550

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(1)

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

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

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(Extra space) .....

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(1)

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

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(Extra space) .....

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(1)

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

Equation .....

IUPAC name .....

(2)
(Total 8 marks)

18 The element nitrogen forms compounds with metals and non-metals.

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

.....

(1)

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

.....

(1)

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

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(1)

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

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(3)

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

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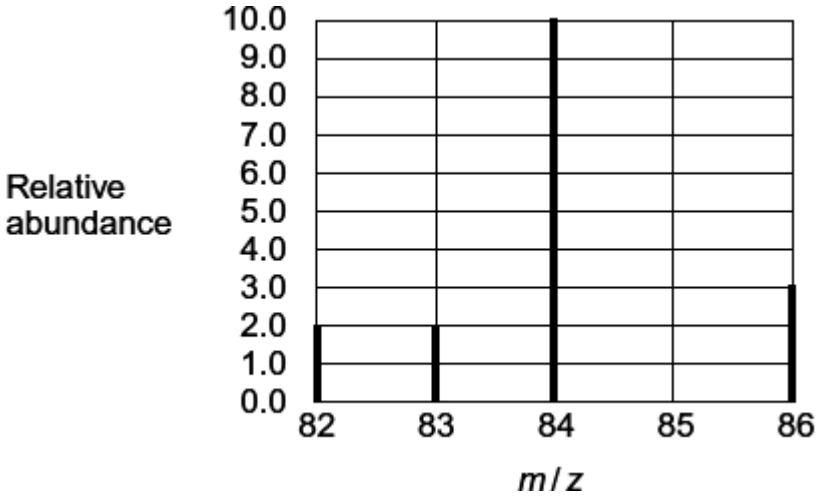
(1)
(Total 7 marks)

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



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

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

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(Extra space) .....

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(4)

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

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

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

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(Extra space) .....

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(5)
(Total 9 marks)

20 Mass spectrometry can be used to identify isotopes of elements.

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

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(1)

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

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(1)

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

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(Extra space).....

.....

(2)

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

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

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

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.....

(3)

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

.....

(2)

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

.....

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(1)

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

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(Extra space) .....

.....

(2)
(Total 12 marks)

21 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 .....

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.....

(Extra space).....

.....

(3)

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

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

How selenium deviates from this trend .....

Explanation .....

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(Extra space).....

(3)

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

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.....

(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)

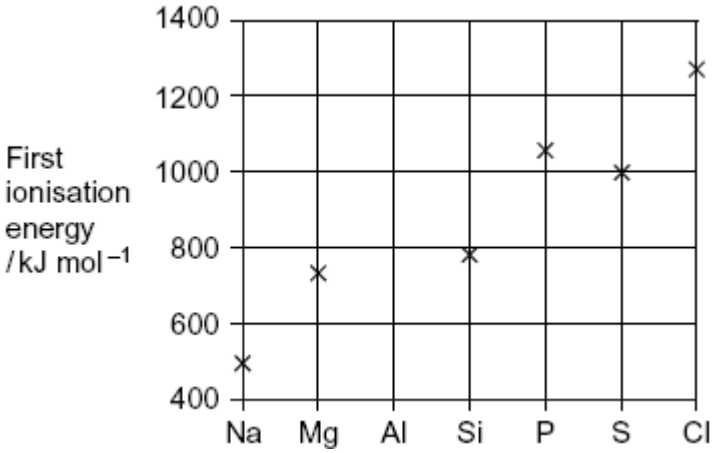
(f) Identify the element that has a 5+ ion with an electron configuration of $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}$

.....

(1)

(Total 10 marks)

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



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

(1)

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

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(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.

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(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 .....

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(3)
(Total 11 marks)

23 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)

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

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

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

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(4)

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

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

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(2)

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

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

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(2)

(Total 8 marks)

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

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

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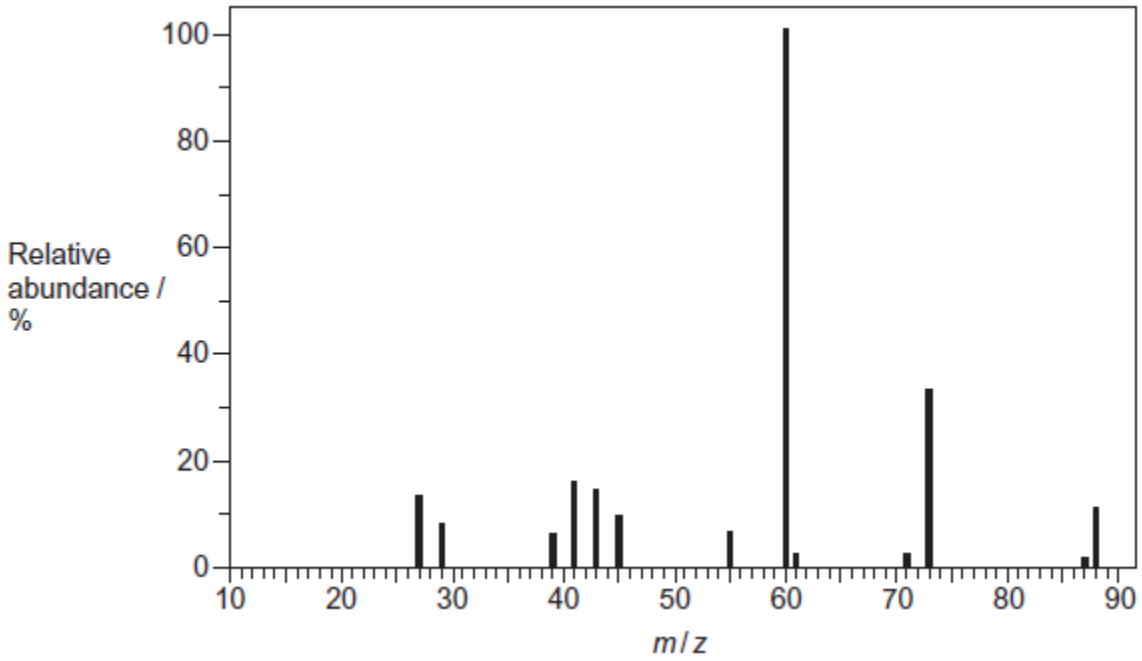
(3)

(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.)
Show your working.

.....

.....

.....

(2)
(Total 6 marks)

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

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

$1s^2$ .....

(1)

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

.....

.....

.....

(2)

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

.....

(1)

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

.....

.....

.....

(1)

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

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

(1)

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

Trend .....

Explanation .....

.....

.....

(3)

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

How sulfur deviates from the trend .....

.....

Explanation .....

.....

.....

(3)

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

.....

(1)
(Total 13 marks)

27 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

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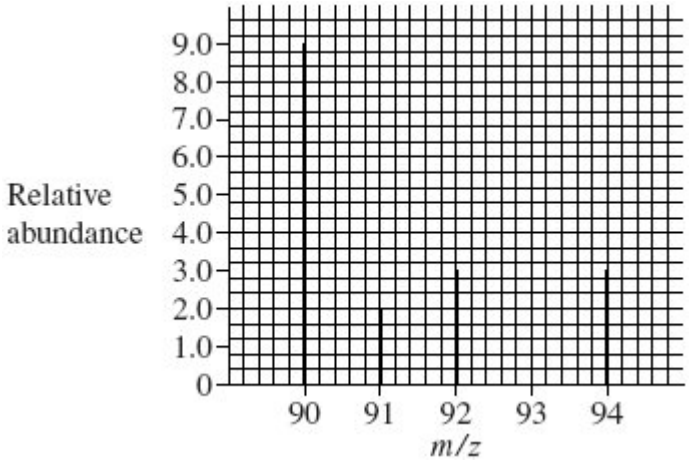
(3)

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

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

Identify element **Z**.



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(4)

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

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

.....

.....

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(4)

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

.....

.....

.....

.....

(2)

(Total 15 marks)

28 (a) Complete the electronic configuration for the sodium ion, Na^+

$1s^2$ .....

(1)

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

.....

(2)

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

.....

.....

.....

.....

(3)

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

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

Deduce the identity of element **X**.

.....

(1)

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

Trend .....

Explanation .....

.....

.....

(3)

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

.....

.....

.....

.....

(3)

(e) Sodium reacts with ammonia to form the compound $NaNH_2$ which contains the NH_2^- ion.

Draw the shape of the NH_2^- ion, including any lone pairs of electrons.

Name the shape made by the three atoms in the NH_2^- ion.

Shape of NH_2^-

Name of shape .....

(2)

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

.....

(1)

(Total 16 marks)

29 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 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)

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

(a) Define the term *atomic number*.

.....

(1)

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

.....

(1)

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

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

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

.....

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

.....

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

.....

.....

.....

(5)

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

.....

(1)

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

.....

(1)

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

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

.....

.....

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

.....

.....

(4)

(Total 13 marks)

31 A student studying GCSE science is puzzled by data which indicate that a sodium atom is larger than a chlorine atom and that a sodium ion is smaller than a chloride ion. How should an A–level Chemistry student explain this apparently conflicting information.

(Total 6 marks)

32 (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)

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

.....

.....

(2)

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

$1s^2$ .....

(1)

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

.....

(1)

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

.....

(1)

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

Reason 1 .....

Reason 2 .....

(2)

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

(i) State and explain this general trend.

Trend ……..

Explanation .....

.....

.....

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

.....

.....

.....

(5)
(Total 12 marks)

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

.....

(1)

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

.....

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

.....

.....

.....

.....

(4)

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

.....

(1)

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

Trend .....

Explanation .....

.....

.....

(3)
(Total 9 marks)

35 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)

36 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)

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

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

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

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

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

(Total 1 mark)

38 (a) Complete the following table.

	Relative mass	Relative charge
Proton		
Electron		

(2)

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

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

.....

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

.....

(3)

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

.....

.....

(2)

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

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

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

.....

.....

.....

(2)

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

.....

.....

(1)
(Total 10 marks)

39 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)

40 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)

41 (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)

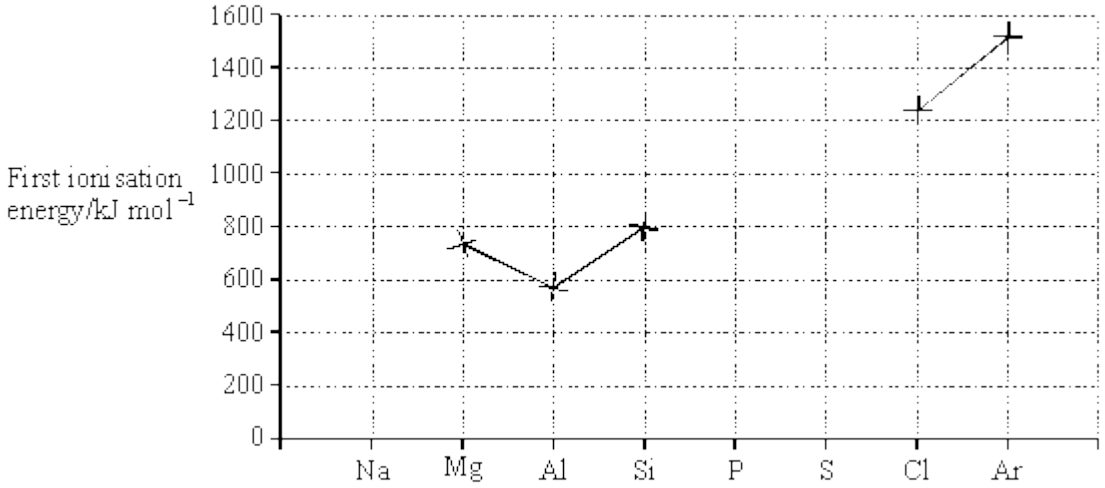
(d) An atom has half as many protons as an atom of ^{28}Si and also has six fewer neutrons than an atom of ^{28}Si. Give the symbol, including the mass number and the atomic number, of this atom.

.....

(2)

(Total 9 marks)

42 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)

43 (a) Complete the following table.

Particle	Relative charge	Relative mass
Proton		
Neutron		
Electron		

(3)

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

.....

(2)

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

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

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

(2)

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

Block .....

Explanation .....

(2)

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

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

Bonding in Na_2S .....

Bonding in CS_2.....

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

.....

.....

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

(iv) When heated with steam, CS_2 reacts to form hydrogen sulphide, H_2S, and carbon dioxide.
Write an equation for this reaction.

.....

(7)
(Total 16 narks)

44 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)

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

(7)

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

(7)
(Total 14 marks)

46 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)

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

.....

.....

(2)

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

Trend .....

Explanation .....

(3)

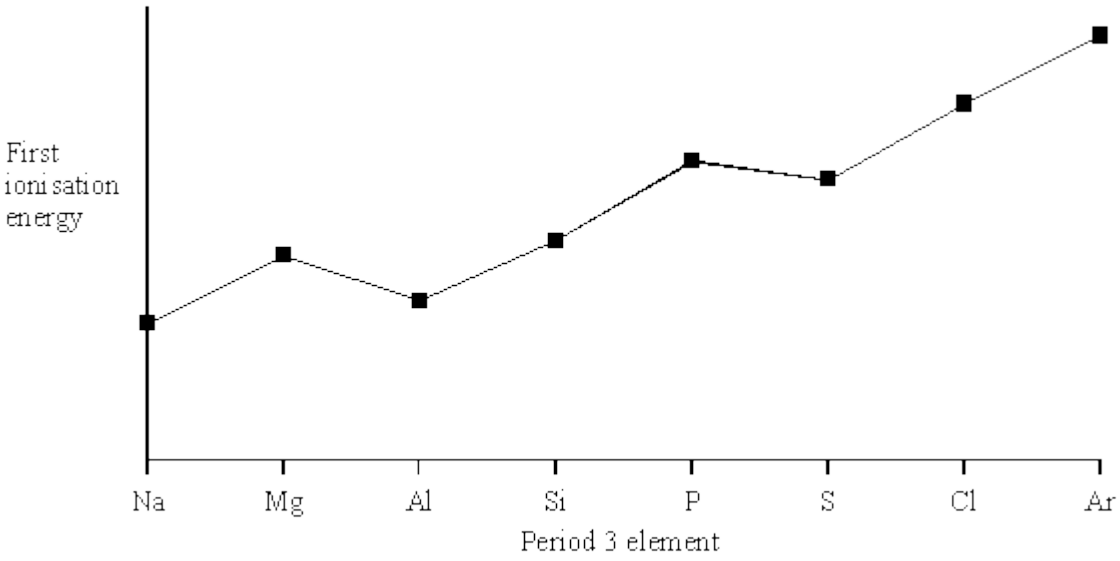
(c) What is meant by the term *first ionisation energy*?

.....

.....

(2)

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



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

.....

.....

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

.....

.....

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

.....

.....

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

.....

.....

.....

(5)
(Total 12 marks)

48 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)

49 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)

50

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)

51 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)

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

A A boron atom is smaller than a beryllium atom.

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

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

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

(Total 1 mark)

53 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)

54 Which atom has an incomplete sub-shell?

A Be

B Ca

C Ge

D Zn

(Total 1 mark)

55 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)

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

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

(Total 1 mark)

57 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)

1

(a) Silicon / Si

If not silicon then CE = 0 / 3

1

covalent (bonds)

M3 dependent on correct M2

1

Strong or many of the (covalent) bonds need to be broken / needs a lot of energy to break the (covalent) bonds

Ignore hard to break

1

(b) Argon / Ar

If not argon then CE = 0 / 3. But if Kr chosen, lose M1 and allow M2+M3

1

Large(st) number of protons / large(st) nuclear charge

Ignore smallest atomic radius

1

Same amount of shielding / same number of shells / same number of energy levels

Allow similar shielding

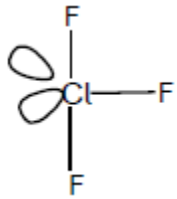
1

(c) Chlorine / Cl

*Not Cl_2, Not C**L**, Not Cl^2*

1

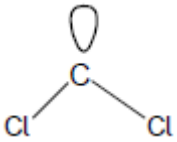
(d) (i)



Or any structure with 3 bonds and 2 lone pairs

Ignore any angles shown

1



Or a structure with 2 bonds and 1 lone pair

1

(ii) Bent / v shape

Ignore non-linear, angular and triangular

Apply list principle

1

(iii) $\frac{1}{2}Cl_2 + \frac{3}{2}F_2 \longrightarrow ClF_3$

No multiples

Ignore state symbols

1

[11]

2 (a) $5s^2\ 4d^{10}\ 5p^4$ / $4d^{10}\ 5s^2\ 5p^4$

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^4$

or $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 5s^2\ 5p^4$

Allow any order but must finish with $5p^4$

1

(b) (i) $\frac{(124\times2)+(126\times4)+(128\times7)+(130\times6)}{19}$ or $\frac{2428}{19}$

M1 for top line

1

127.8

M2 for correct denominator

1

127.8 with no working shown scores 3 marks

1

Or

$\frac{(124\times10.5)+(126\times21.1)+(128\times36.8)+(130\times31.6)}{100}$

1

Mark for 100 dependent on top line correct

1

127.8

1

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

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]

3

(a) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$

Allow correct numbers that are not superscripted

1

(b) $Ca(s) + 2H_2O(l) \longrightarrow Ca^{2+}(aq) + 2OH^-(aq) + H_2(g)$

State symbols essential

1

(c) Oxidising agent

1

(d) $Ca(g) \longrightarrow Ca^+(g) + e^-$

State symbols essential

Allow 'e' without the negative sign

1

(e) Decrease

If answer to 'trend' is not 'decrease', then chemical error = 0 / 3

1

Ions get bigger / more (energy) shells

Allow atoms instead of ions

1

Weaker attraction of ion to lost electron

1

[7]

4

(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

$7.2y = 32.16 \times 100 – 32 \times 91 – 33 \times 1.8 = 244.6$

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]

5 D

[1]

6 D

[1]

7 (a) **Y**

1

(b) **X**

1

(c) Jump in trend of ionisation energies after removal of fifth electron

Fits with an element with 5 outer electrons ($4s^2 3d^3$) like V

1

(d) Explanation: Two different colours of solution are observed

1

Because each colour is due to vanadium in a different oxidation state

1

(e) **Stage 1:** mole calculations in either order

Moles of vanadium = $50.0 \times 0.800 / 1000 = 4.00 \times 10^{-2}$

Extended response

Maximum of 5 marks for answers which do not show a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.

1

Moles of SO_2 = pV / RT = (98 000 × 506 × 10^{-6}) / (8.31 × 293)

= 2.04 × 10^{-2}

1

Stage 2: moles of electrons added to NH_4VO_3

When SO_2 (sulfur(IV) oxide) acts as a reducing agent, it is oxidised to sulfate(VI) ions so this is a two electron change

1

Moles of electrons released when SO_2 is oxidised = 2.04 × 10^{-2} × 2

= 4.08 × 10^{-2}

1

Stage 3: conclusion

But in NH_4VO_3 vanadium is in oxidation state 5

1

4.00 × 10^{-2} mol vanadium has gained 4.08 × 10^{-2} mol of electrons
therefore 1 mol vanadium has gained 4.08 × 10^{-2} / 4.00 × 10 – 2 = 1 mol of electrons to the nearest integer, so new oxidation state is 5 – 1 = 4

1

[11]

8 (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]

9 A

[1]

10 (a) (i) 1.6734×10^{-24} (g)

Only.

1.6734×10^{-27} kg

Not 1.67×10^{-24} (g).

1

(ii) **B**

1

(b) (i) $\frac{10x + 11y}{x + y} = 10.8$

OR ratio 10:11 = 1:4 **OR** 20:80 etc

Allow idea that there are 5 × 0.2 divisions between 10 and 11.

1

abundance of ^{10}B is 20(%)

OR

$\frac{10x}{100} + \frac{11(100-x)}{100} = 10.8$

$10x + 1100 - 11x = 1080$

$\therefore x = 1100 - 1080 = 20\%$

Correct answer scores M1 and M2.

1

(ii) Same number of electrons (in outer shell or orbital)

Ignore electrons determine chemical properties.

Same electronic configuration / arrangement

Ignore protons unless wrong.

1

(c) Range between 3500 and 10 000 kJ mol^{-1}

1

(d) $B^+(g) \longrightarrow B^{2+}(g) + e^{(-)}$

$B^+(g) - e^{(-)} \longrightarrow B^{2+}(g)$

$B^+(g) + e^{(-)} \longrightarrow B^{2+}(g) + 2e^{(-)}$

Ignore state symbol on electron even if wrong.

1

(e) Electron being removed from a positive ion (therefore needs more energy) / electron being removed is closer to the nucleus

Must imply removal of an electron.

Allow electron removed from a + particle / species or from a 2+ ion.

Not electron removed from a higher / lower energy level / shell.

Not electron removed from a higher energy sub-level / orbital.

Ignore electron removed from a lower energy sub-level / orbital.

Ignore 'more protons than electrons'.

Not 'greater nuclear charge'.

Ignore 'greater effective nuclear charge'.

Ignore shielding.

1

[8]

11 (a) (i) d (block) **OR** D (block)

Ignore transition metals / series.

Do not allow any numbers in the answer.

1

(ii) Contains positive (metal) ions or protons or nuclei and <u>delocalised / mobile / free / sea of</u> electrons

Ignore atoms.

1

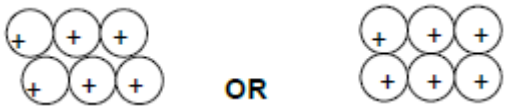
<u>Strong attraction</u> between them or <u>strong metallic</u> bonds

Allow 'needs a lot of energy to break / overcome' instead of 'strong'.

If strong attraction between incorrect particles, then CE = 0 / 2.

If molecules / intermolecular forces / covalent bonding / ionic bonding mentioned then CE=0.

1

(iii) 

M1 is for regular arrangement of atoms / ions (min 6 metal particles).

M2 for + sign in each metal atom / ion.

Allow 2^+ sign.

2

(iv) <u>Layers / planes / sheets of atoms or ions</u> can slide over one another

QoL.

1

(b) (i) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^8\ (4s^0)$

Only.

1

(ii) $NiCl_2.6H_2O$ + **6** $SOCl_2$ ⟶ $NiCl_2$ + **6** SO_2 + **12** HCl

Allow multiples.

1

NaOH / NH_3 / $CaCO_3$ / CaO

Allow any name or formula of alkali or base.

Allow water.

1

[9]

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

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

If moles and atoms mixed, max = 1

1

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

1

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 C−12) on a scale in which an atom of C−12 has a mass of 12

This expression = 2 marks.

(b) $$\frac{(70 \times 3) + (72 \times 4) + 73 + (74 \times 5)}{13} = \frac{941}{13}$$

1
1

= 72.4

72.4 only

1

(c) $^{(72)}\underline{Ge^{+}}$ or $\underline{germanium^{+}}$

Must show '+' sign.

Penalise wrong mass number

1

(d) 70

If M1 incorrect or blank CE = 0/2

Ignore symbols and charge even if wrong.

1

Lowest mass / lowest m/z

Accept lightest.

Accept fewest neutrons.

1

(e) Electron(s) transferred / flow (at the detector)

M1 must refer to electron flow at the detector.

If M1 incorrect CE = 0/2

1

(From detector / plate) to the (+) ion

Do not allow from a charged plate.

1

(f) They do not have the same electron configuration / they have different number of electrons (in the outer shell)

Ignore electrons determine the properties of an atom.

Ignore they are different elements or different number of protons.

1

[11]

13

(a) $Al + 1.5Cl_2 \rightarrow AlCl_3$

Accept multiples.

Also $2Al + 3Cl_2 \rightarrow Al_2Cl_6$

Ignore state symbols.

1

(b) Coordinate / dative (covalent)

If wrong CE=0/2 if covalent mark on.

1

Electron pair on Cl^- donated to $Al(Cl_3)$

QoL

Lone pair from Cl^- not just Cl

Penalise wrong species.

1

(c) Al_2Cl_6 or $AlBr_3$

Allow Br_3Al or Cl_6Al_2

Upper and lower case letters must be as shown.

Not $2AlCl_3$

1

(d) $SiCl_4$ / silicon tetrachloride

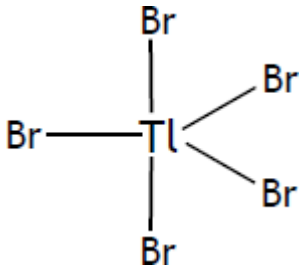
Accept silicon(4) chloride or silicon(IV) chloride.

Upper and lower case letters must be as shown.

Not silicon chloride.

1

(e)



Accept shape containing 5 bonds and no lone pairs from Tl to each of 5 Br atoms.

Ignore charge.

1

Trigonal bipyramid(al)

1

(f) (i) Cl — Tl — C

Accept this linear structure only with no lone pair on Tl

1

(ii) (Two) bonds (pairs of electrons) repel equally / (electrons in) the bonds repel to be as far apart as possible

Dependent on linear structure in (f)(i).

Do not allow electrons / electron pairs repel alone.

1

(g) Second

1

[10]

14 (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]

15 (a) (i) Higher than P

1

(ii) $1s^2\ 2s^2\ 2p^6\ 3s^1$

Allow any order

1

(iii) $Al^{+}(g) + e^{(-)} \longrightarrow Al^{2}+(g) + 2e^{(-)}$

OR

$Al^{+}(g) \longrightarrow Al^{2+}(g) + e^{(-)}$

OR

$Al^{+}(g) - e^{(-)} \longrightarrow Al^{2+}(g)$

1

(iv) Electron in Si (removed from) (3)p orbital / electron (removed) from higher energy orbital or sub-shell / electron in silicon is more shielded

Accept converse arguments relating to Al
Penalise incorrect p-orbital

1

(b) Sodium / Na

Allow Na^{+}

1

Electron (removed) from the 2nd shell / 2p (orbital)

M2 is dependent on M1
Allow electron from shell nearer the nucleus (so more attraction)

1

(c) Silicon / Si

Not SI

1

(d) Heat or energy needed to overcome the attraction between the (negative) electron and the (positive) nucleus or protons

Not breaking bonds

QoL

Or words to that effect eg electron promoted to higher energy level (infinity) so energy must be supplied

1

[8]

16 (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 bigger (atom) / e further from nucleus / electron lost from a higher energy level/ More shielding in Rb / less attraction of nucleus in Rb for outer electron / more 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

(d) (i) s / block s / group s

Only

1

(ii) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^1$

Allow $3d^{10}$ before $4s^2$

Allow in any order.

1

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

M1 is for top line

1

1

$= \underline{85.6}$

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

$\underline{85.6}$

M3 = 85.6

1

(f) Detector

Mark independently

Allow detection (plate).

1

Current / digital pulses / electrical signal related to abundance

Not electrical <u>charge</u>.

1

(g) Smaller

Chemical error if not smaller, CE = 0/3

If blank mark on.

1

Bigger nuclear charge / more protons in Sr

Not bigger nucleus.

1

Similar/same shielding

QWC

(Outer) <u>electron</u> entering same shell/sub shell/orbital/same number of shells.

Do not allow incorrect orbital.

1

[16]

17 (a) **2**$Ca_5F(PO_4)_3$ + $9SiO_2$ + **15**C ⟶ $9CaSiO_3$ + CaF_2 + **15**CO + **6**P

1

(b) **M1** (P_4 =) **0**

M2 (H_3PO_4 =) **(+) 5**

*Accept Roman numeral V for **M2***

2

(c) H_2SO_4

***Both numbers** required*

M_r = 2(1.00794) + 32.06550 + 4(15.99491)
= **98.06102 or 98.0610 or 98.061 or 98.06 or 98.1**

Calculations not required

<u>and</u>

H_3PO_4

M_r = 3(1.00794) + 30.97376 + 4(15.99491)
= **97.97722 or 97.9772 or 97.977 or 97.98 or 98.0**

1

(d) (i) A substance that <u>speeds up</u> a reaction OR <u>alters / increases the rate</u> of a reaction **AND** is <u>chemically unchanged at the end / not used up</u>.

Both ideas *needed*

Ignore reference to activation energy or alternative route.

1

(ii) The <u>addition of water</u> (**QoL**) to a molecule / compound

QoL- for the underlined words

1

(iii) **M1** $CH_3CH{=}CH_2 + H_2O \longrightarrow CH_3CH(OH)CH_3$

(C_3H_6)

*For **M1** insist on correct structure for the alcohol but credit correct equations using either C_3H_6 or double bond not given.*

M2 propan-2-ol

2

[8]

18 (a) N^{3-} / N^{-3}

1

(b) F^-/ fluoride

Ignore fluorine/F

Penalise Fl

1

(c) Li_3N / NLi_3

1

(d) $\frac{81.1}{40.1}$ $\frac{18.9}{14}$

M1 for correct fractions

1

(=2.02 = 1.35)

1.5 1 or 3 : 2

M2 for correct ratio

1

Ca_3N_2

If Ca_3N_2 shown and with no working award 3 marks

If Ca_3N_2 obtained by using atomic numbers then lose M1

1

(e) $3\ Si + 2\ N_2 \rightarrow Si_3N_4$

Accept multiples

1

[7]

19

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

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]

20 (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) $\frac{(64 \times 12) + (66 \times 8) + (67 \times 1) + (68 \times 6)}{27} \quad \frac{(= 1771)}{27}$

= <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]

21 (a) $Li(g) \rightarrow Li^{+}(g) + e^{-}(g)$

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

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

One mark for balanced equation with state symbols

Charge and state on electron need not be shown

1

(b) Increases

If trend wrong then CE = 0/3 for (b). If blank mark on.

1

Increasing nuclear charge / increasing no of protons

Ignore effective with regard to nuclear charge

1

Same or similar shielding / same no of shells / electron (taken) from same (sub)shell / electron closer to the nucleus / smaller atomic radius

1

(c) Lower

If not lower then CE = 0/3

1

Paired electrons in a (4) p orbital

If incorrect p orbital then M2 = 0

1

(Paired electrons) repel

If shared pair of electrons M2 + M3 = 0

1

(d) Kr is a bigger atom / has more shells / more shielding in Kr / electron removed further from nucleus/ electron removed from a higher (principal or main) energy level

CE if molecule mentioned

Must be comparative answer

QWC

1

(e) 2 / two / II

1

(f) Arsenic / As

1

[10]

22 (a) Cross between the Na cross and the Mg cross

1

(b) $Al(g) \rightarrow Al^{+}(g) + e–$

$Al(g) – e– \rightarrow Al^{+}(g)$

$Al(g) + e– \rightarrow Al^{+}(g) + 2e–$

One mark for state symbols consequential on getting equation correct.
Electron does not have to have the – sign on it
Ignore (g) if put as state symbol with e^{-} but penalise state symbol mark if other state symbols on e^{-}

2

(c) 2nd/second/2/II

Only

1

(d) Paired electrons <u>in (3)p orbital</u>

Penalise wrong number
If paired electrons repel allow M2

1

repel

1

(e) Neon/Ne

No consequential marking from wrong element

1

$1s^2 2s^2 2p^6$/[He}$2s^2 2p^6$

Allow capital s and p
Allow subscript numbers

1

(f) Decreases

CE if wrong

1

Atomic radius increases/electron removed further from nucleus
or nuclear charge/electron in higher energy level/Atoms
get larger/more shells

Accept more repulsion between more electrons for M2
Mark is for distance from nucleus
Must be comparative answers from M2 and M3
CE M2 and M3 if mention molecules
Not more sub-shells

1

As group is descended more shielding

1

[11]

23 Mass number = number of protons + neutrons (in the nucleus/atom)

Not in a substance or compound or element

1

7 protons and 7 electrons

1

8 neutrons

1

[3]

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

1

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

Accept answer in words
Can have top line × 12 instead of bottom line ÷ 12

1

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 C-12
on a scale in which an atom of C-12 has a mass of 12

$$\frac{(95.12 \times 14) + (4.88 \times 15)}{100}$$

Allow 95.12 + 4.88 instead of 100

1

= 14.05

If not to 2 d.p. then lose last mark
Not 14.04

1

(b) ^{15}N is heavier/^{15}N has a bigger m/z/different m/z values

Not different no's of neutrons
Not ionisation potential

1

Electromagnet/electric field/magnet/accelerating potential or voltage/electric current

1

(c) No difference

1

Same no of electrons (in outer orbital/shell/sub shell)/same electron configuration

M2 dependent on M1
Not just electrons determine chemical properties
Ignore protons

1

[8]

25 (a) Percentage of oxygen is 36.4%

% of oxygen stated or shown in calculation.

1

Correct calculation of ratios (C 4.54, H 9.10, O 2.28)

Mark is for correct method, dividing % by A_r

1

Empirical formula C_2H_4O

Allow consequential answer from wrong percentage of oxygen (max 2 marks).

1

(b) 88

Accept 88.0

Do not penalise correct answer in g.

1

(c) Ratio MF / EF of 2 (88 / 44.0 = 2)

If use 132 / 44 = 3, molecular formula $C_6H_{12}O_3$ scores 2 marks.

1

Molecular formula is $C_4H_8O_2$

Accept consequential answers from (a) and (b)

1

[6]

26 (a) $2s^2 2p^6 3s^1$

$1s^2$ can be rewritten

Allow $2s^2 2p_x^2 2p_y^2 2p_z^2 3s^1$

Allow subscripts and capitals

1

(b) (i) Energy/enthalpy (needed) to remove one mole of electrons from one mole of atoms/compounds/molecules/elements

1

OR

Energy to form one mole of positive ions from one mole of atoms

OR

Energy/enthalpy to remove one electron from one atom

In the gaseous state (to form 1 mol of gaseous ions)

Energy given out loses M1

M2 is dependent on a reasonable attempt at M1

Energy needed for this change

$X(g) \rightarrow X^+(g) + e^{(-)}$ = 2 marks

This equation alone scores one mark

1

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

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

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

Do not penalise MG

Not equation with X

1

(iii) Electron being removed from a positive ion (therefore need more energy)/electron being removed is closer to the nucleus/Mg^+ smaller (than Mg)/Mg^+ more positive than Mg

Allow from a + particle/species

Not electron from a higher energy level/or higher sub-level

More protons = 0

1

(iv) Range from 5000 to 9000 kJ mol^{-1}

1

(c) Increase

If decrease CE = 0/3
If blank mark on

1

Bigger nuclear <u>charge</u> (from Na to Cl)/more <u>protons</u>

QWC

1

electron (taken) from same (sub)shell/similar or same shielding/
electron closer to the nucleus/smaller atomic radius

If no shielding = 0
Smaller ionic radius = 0

1

(d) Lower

If not lower CE = 0/3
If blank mark on
Allow does not increase

1

Two/pair of electrons in (3)p orbital or implied

Not 2p

1

repel (each other)

M3 dependent upon a reasonable attempt at M2

1

(e) Boron/B or oxygen/O/O_2

1

[13]

27

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

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

1

If moles and atoms mixes Max = 1

1

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 C-12 on a scale in which an atom of C-12 has a mass of 12

This expression = 2 marks

(b) d block

Allow 3d/D
Other numbers lose M1
Ignore transition metals

1

[Ar] $3d^2 4s^2$

1

Can be written in full
Allow subscripts
$3d^2$ and $4s^2$ can be in either order

27

1

(c) $\frac{(90 \times 9) + (91 \times 2) + (92 \times 3) + (94 \times 3)}{17}$

(= 1550)

1

(or ∑ their abundances)

If one graph reading error lose M1 and allow consequential M2 and M3.
If 2 GR errors penalise M1 and M2 but allow consequential M3
If not 17 or ∑ their abundances lose M2 and M3

1

= 91.2

91.2 = 3 marks provided working shown.

1

Zr/Zirconium

M4 -allow nearest consequential element from M3
accept Zr in any circumstance

1

(d) High energy electrons/bombarded or hit with electrons

accept electron gun

1

knocks out electron(s) (to form ions)

1

Z^+ = <u>90</u> deflected most

If not 90 lose M3 and M4
If charge is wrong on 90 isotope lose M3 only
Accept any symbol in place of Z

1

since lowest mass/lowest m/z

Allow lightest

1

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

QWC

1

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

Implication that current depends on the number of ions

1

[15]

28 (a) $2s^2\ 2p^6$;

If ignored the $1s^2$ given and written $1s^2 2s^2 2p^6$ mark as correct
Allow capitals and subscripts

1

(b) (i) $Na^+(g) \rightarrow Na^{2+}(g) + e^{(-)}$;

One mark for equation and one mark for state symbols

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

M2 dependent on M1
Allow $Na^+(g) - e^{(-)} \rightarrow Na(g)$
Allow $X^+(g) \rightarrow X^{2+}(g) + e$ = 1 mark

2

(ii) $Na^{(2+)}$ requires loss of e^- from a 2(p) orbital or 2nd energy level or 2nd shell and $Mg^{(2+)}$ requires loss of e^- from a 3(s) orbital or 3rd energy level or 3rd shell / $Na^{(2+)}$ loses e from a lower (energy) orbital/ or vice versa;

Not from 3p

1

Less shielding (in Na);

Or vice versa for Mg

1

$e^{(-)}$ closer to nucleus/ more attraction (of electron to nucleus) (in Na);

M3 needs to be comparative

1

(iii) Aluminium /Al;

1

(c) Decreases;

If not decreases CE = 0
If blank, mark on

1

Increasing nuclear charge/ increasing number of protons;

1

Electrons in same shell or level/ same shielding/ similar shielding;

1

(d) Answer refers to Na;

Allow converse answers relating to Mg.

Na fewer protons/smaller nuclear charge/ fewer delocalised electrons;

Allow Mg is 2+ and Na is +.
If vdw CE = 0.

1

Na is a bigger ion/ atom;

1

Smaller attraction between nucleus and delocalised electrons;

If mentioned that charge density of Mg^{2+} is greater then allow first 2 marks.
(ie charge / size / attraction).
M3 allow weaker metallic bonding.

1

(e) (Bent) shape showing 2 lone pairs + 2N−H bond pairs;

Atoms must be labelled.
Lone pairs can be with or without lobes.

1

Bent / v shape/ triangular;

Not tetrahedral.
Allow non-linear.
Bent-linear = contradiction.

1

(f) Ne has full sub-levels/ can't get any more electrons in the sub-levels/
Ne has full shells;

Not $2s^2\ 2p^6$ alone.
Not stable electron configuration.

1

[16]

29 (a)

Particle	Relative Charge	Relative mass
Proton	+1	1
Neutron	0	1

1

1

Need +1 for proton

(b) d block/ D block;

Or D or d

1

(c) (i) 74;

Not 74.0

1

(ii) 112;

Not 112.0

1

(d) (i) To accelerate/ make go faster;

1

To deflect/ to bend the beam;

Any order
Not just attract to negative plate

1

(ii) Electromagnet / magnet / electric field /accelerating potential or voltage;

Not electric current
Not electronic field

1

(e) None/ nothing;

If blank mark on.
If incorrect CE = 0

1

Same number of electrons (in outer orbital/shell)/ both have 74 electrons/same electron configuration;

Not just electrons determine chemical properties
Ignore protons and neutrons unless wrong statement.

1

(f) $\frac{(182 \times 26.4) + (183 \times 14.3) + (184 \times 30.7) + (186 \times 28.6)}{100}$;

If transcription error then
M1 = AE = –1 and mark
M2 consequentially

1

= 183.90; allow range from 183.90 – 184.00;

1

[12]

30 (a) Number of protons in the nucleus

1

(b) They may have different numbers of neutrons

1

(c) (i) Mass spectrometer

1

(ii) $\frac{\text{Mean mass of an atom}}{\text{Mass of 1 atom of } {}^{12}C} \times 12$

2

(iii) $A_r = \frac{\text{sum of relative m/z x rel. abundance}}{\text{Total abundance}}$

1

= (82 × 12 + 83 × 12 + 84 × 50 + 86 × 26)/100 = 84.16

1

(d) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6$

1

(e) Krypton was thought to be an inert gas
(or has 8 electrons in outer shell)

1

(f) (i) Krypton has more protons than bromine

1

But its outer electrons are in the same shell
(or have similar shielding)

1

(ii) Al electron is in a 3p orbital, magnesium in 3s

1

Energy of 3p is greater than 3s

1

[13]

31 A chlorine atom has more protons in its nucleus than has a sodium atom

1

Both have three shells of electrons

1

Electrons more strongly attracted by chlorine nucleus
so size smaller than Na

1

An electron shell is lost when a sodium ion is formed from a sodium atom

1

Inner electrons more strongly attracted so ion smaller than atom

1

An electron is added to the outer shell when a chloride ion is formed

1

Greater repulsion between shells so size of chloride ion
greater than Cl atom

1
MAX 6
QWC

[6]

32 *(penalty for sig fig error =1 mark per question)*

(a) neutron: relative mass = 1 relative charge = 0
(not 'neutral')

1

electron: relative mass = 1/1800 → 0/negligible *or*

5.56 × 10–4 → 0 relative charge = –1

1

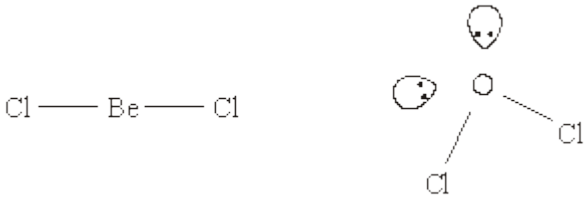
(b) $^{17}O/O^{17}$ mass number (*Do not accept 17.0*)

1

oxygen symbol 'O'
(if 'oxygen' + — 'mass number = 17'(1))
(if 'oxygen'+ — 'mass number = 17'(0))
(if at N^0 given but ≠ 8, treat as 'con' for M2)
(if lp on Be, diagram = 0)
(ignore bond angles)
(not dot and cross diagrams)

1

(c)



2

QoL Linear **(1)** bent / V-shaped / angular **(1)**

(mark name and shape independently)
(accept (distorted) tetrahedral)
(if balls instead of symbols, lose M1 – can award M2)
(penalise missing 'Cl' once only)
(not 'non-linear')

2

(d) M_r ($Mg(NO_3)_2$ = 58(.3) *(if At N ^{0} used, lose M1 and M2)*

1

moles $Mg(OH)_2$ = 0.0172 (conseq on wrong M2) (answer to 3+ s.f.)

1

moles HCl = 2 × 0.0172 = 0.0344 *or* 0.0343 (mol) *(process mark)*

1

vol HCl = $\frac{0.0343 \times 1000}{1}$ = 34.3 – 34.5 (cm^3) *(unless wrong unit)*

*(if candidate **used** 0.017 or 0.0171 lose M2)*
(just answer with no working, if in range = (4).
if, say, 34 then =(2))
(if not 2:1 ratio, lose M3 and M4)
(if work on HCl, CE = 0/4)

1

[12]

33 (a) enthalpy/energy change/required when an electron is removed/ knocked out / displaced/ to form a uni-positive ion

(ignore 'minimum' energy)

1

from a gaseous atom

(could get M2 from a correct equation here)
(accept 'Enthalpy/energy change for the process...'
followed by an appropriate equation, for both marks)
(accept molar definitions)

1

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

(accept capitals and subscripts)

1

(c) 's' block

(not a specific 's' orbital – e.g. 2s)

1

(d) $Mg^+(g) \rightarrow Mg^{2+}(g) + e^-$ or

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

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

1

(e) Mg^{2+} ion smaller than Ne atom / Mg^{2+} e^- closer to nucleus

(Not 'atomic' radius fo Mg^{2+})

1

Mg^{2+} has more protons than Ne / higher nuclear charge or
e^- is removed from a charged Mg^{2+}ion / neutral neon atom

(accept converse arguments)

*(If used 'It' or Mg/magnesium/Mg^{3+} etc. & 2 correct reasons, allow **(1)**)*

1

(f) (i) trend: increases

(if 'decreases', CE = 0/3)

1

Expl^n: more protons / increased proton number /
increased nuclear charge

(NOT increased atomic number)

1

same shell / same shielding / smaller size

1

(ii) QoL reference to the e^- pair in the 3p sub-level

(penalise if wrong shell, e.g. '2p', quoted)

1

repulsion between the e^-in this e^-pair

(if not stated, 'e $^-$ pair' must be clearly implied)

(mark M4 and M5 separately)

1

[12]

34 (a) $2Al + 3CuCl_2 \rightarrow 2AlCl_3 + 3Cu$;

(accept multiples/fractions)

OR

$2Al + 3Cu^{2+} \rightarrow 2Al^{3+} + 3Cu$;

1

(b) (i) increases;

1

(ii) lower than expected / lower than Mg /

1

less energy needed to ionise; e^- removed from (3)p sub-level;

1

('e^- removed' may be implied)

of higher energy / further away from nucleus / shielded by <u>3s</u> e^-s;

1

(c) $Al^+(g) \rightarrow Al^{2+}(g) + e^-$;

1

(d) trend: increases;

1

more protons / higher charge on cation / more delocalised e^- / smaller atomic/ionic radius;
stronger attraction between (cat)ions and delocalised/free/mobile e^-

1

OR

stronger metallic bonding;

1

[9]

35 D

[1]

36 B

[1]

37 A

[1]

38 (a) Proton mass = 1 charge = +1

Electron mass ≤ 1/1800 Or ≤ 5.6×10^{-4} charge = –1

(Do not accept +1 for proton mass or 'g' units)

2

(b) (i) 13

1

(ii) Si

1

Mass number = 28 **and** atomic number = 14

(Do not accept 28.1 or 28.0 or 'Silicon')

5

(c) Mean (average) mass of an atom / all the isotopes

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

Or Mass of 1 mole of atoms of an element **(1)**

1/12th mass of 1 mole of ^{12}C **(1)**

Or Average mass of an atom / all the isotopes **(1)**

relative to the mass of a ^{12}C atom taken as exactly 12 / 12.000 **(1)**

(Penalise 'weight' once only) (Ignore 'average' mass of ^{12}C)

(Do not allow 'mass of average atom')

2

(d) $A_r = (24 \times 0.735) + (25 \times 0.101) + (26 \times 0.164)$ 1 = 24.4 1

(mark M2 conseq on transcription error or incorrect addition of %)

(e) M_r = highest m/z value 1

(NOT 'highest/largest/right-hand' peak)

3

[10]

39 (a) Enthalpy change/required when an electron is removed/knocked out/displaced (Ignore 'minimum' energy)

1

From a gaseous atom

(could get this mark from equation)

1

(b) $Mg^+(g) \rightarrow Mg^{2+}(g) + e^-$ Equation

1

Or $Mg^+(g) + e^- \rightarrow Mg^{2+}(g) + 2e^-$ State symbols (*Tied to M1*)

1

(c) Increased/stronger nuclear charge **or** more protons

1

Smaller atom **or** electrons enter the same shell **or** same/similar shielding

1

(d) Electron removed from a shell of lower energy **or** smaller atom **or** e^- nearer

1

nucleus **or** e^- removed from 2p rather than from 3s
Less shielding

(Do not accept 'e ⁻ from inner shell')

1

[8]

40 (a) **4**LiH + $AlCl_3 \rightarrow LiAlH_4$ + **3**LiCl

1

(b) H^- = $1s^2$ **or** $1s_2$

1

(c) Tetrahedral or diagram

(Not distorted tetrahedral)

1

(Equal) repulsion

1

between four bonding pairs / bonds

(Not repulsion between H atoms loses M2 and M3)

(Not 'separate as far as possible')

('4' may be inferred from a correct diagram)

1

(d) Dative (covalent) or coordinate

1

Lone pair **or** non-bonding pair of electron **or** both e^-

1

QoL Donated from H^- to Al **or** shared between H and Al

(tied to M2)

(Not 'from H atom') (Not 'to Al ion') (Not 'e $^-$s transferred')

1

[8]

41

(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)** OR, isotopes have the same electron configuration / same number of e^-

(iii) $23/6.023 \times 10^{23}$ **(1)**

CE = 0 if inverted or multiplied

tied to M1 $3.8(2) \times 10^{-23}$ [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)**

OR d sub-shell being filled / is incomplete
OR highest energy sub-shell is (3)d
NOT transition element / e^- configuration ends at 3d
Q of L

1

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

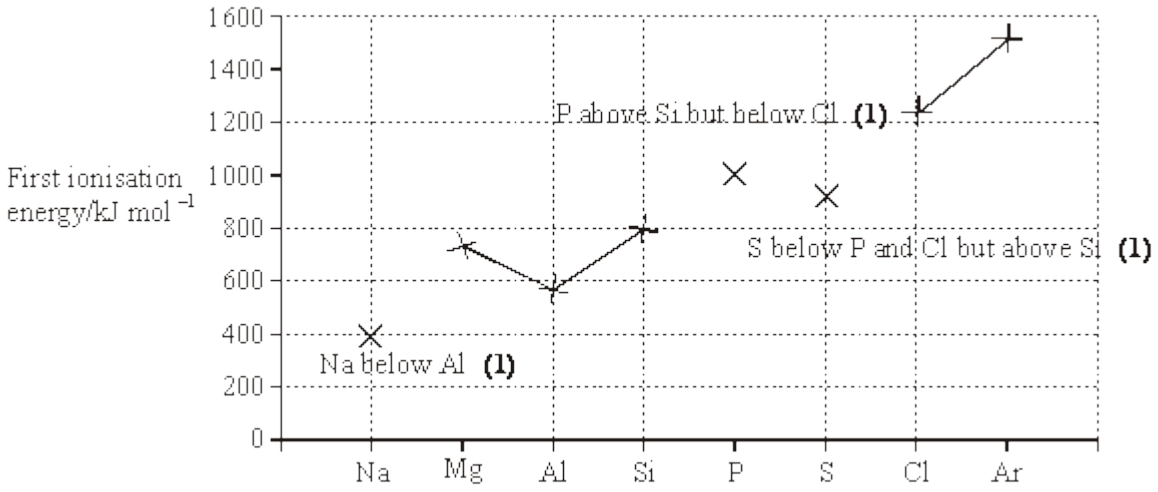
allow N^{15}_{7}

Mass number = 15 AND atomic number = 7 **(1)**

2

[9]

42 (a)



1

(b) Increased nuclear charge / proton number **(1)**

NOT increased atomic number

Electrons enter same shell / energy level OR atoms get smaller OR same shielding **(1)**

Stronger attraction between nucleus and (outer) electrons **(1)**

Q of L

3

(c) *Explanation for aluminium*: (third) electron in (3)p sub-shell **(1)**
Sub-shell further away from nucleus OR of higher energy **(1)**
OR extra shielding from (3)s

Explanation for sulphur: Pair of electrons in (3)p orbital **(1)**
Repulsion between electrons **(1)**

tied to reference to e^- pair in M3

Penalise '2p' once only

4

[10]

43 (a)

Particle	Relative charge	Relative mass	
Proton	+1 **or** 1+	1	**(1)**
Neutron	0 **or** no charge/neutral/zero	1 (not – 1)	**(1)**
Electron	–1 or 1–	1/1800 to 1/2000	**(1)**

or negligible
or zero
or 5.0×10^{-4} to 5.6×10^{-4}

if 'g' in mass column - wrong
penalise once

3

(b) $^{38}_{18}Ar$ **(1)(1)**

Allow numbers before or after Ar

2

(c) *S*: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$ **(1)**

Allow upper case letters

S^{2-}: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ **(1)**

If use subscript penalise once

2

(d) *Block*: p **(1)**
Explanation: Highest energy or outer orbital is (3) p

OR outer electron, valency electron in (3) p
NOT 2p etc.

2

(e) (i) *Bonding in Na_2S*: ionic **(1)**

Bonding in CS_2: covalent **(1)**

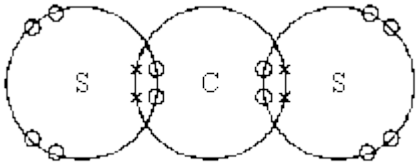
ignore other words such as dative / polar / co-ordinate

(ii) Clear indication of electron transfer from Na to S **(1)**

1 e^- from each (of 2) Na atoms or 2 e^- from 2 Na atoms **(1)**

QoL correct English

(iii)



Correct covalent bonds **(1)**

All correct including lone pairs **(1)**

Allow all •s or all ×s

M2 tied to M1

NOT separate e⁻s in S•- 2 l p

(iv) $CS_2 + 2H_2O \rightarrow CO_2 + 2H_2S$ **(1)**

Ignore state symbols even if wrong

7

[16]

44 (a) $Na(g) \rightarrow Na^+(g) + e^-$

OR $Na(g) + e^- \rightarrow Na^+(g) + 2e^-$

(-) on electron not essential
equation (1)
state symbols (1)
Ignore state symbols on electrons

2

(b) *Trend* : Increases **(1)**

Explanation : Increased nuclear charge or proton number **(1)**

Stronger attraction (between nucleus and (outer) e^-) **(1)**

Trend wrong

Allow M2 only if M3 correct (con)

3

(c) *How values deviate from trend*: (both values) too low **(1)**

Explanation for Al: e^- removed from (3) p **(1)**

e^- or orbital is higher in energy or better shielded than (3)**s**

or p electron is shielded by 3s electrons **(1)**

Allow e^- is further away

Mark independently

Explanation for S: e^- removed from (3)p electron pair **(1)**

repulsion between paired e^- (reduces energy required) **(1)**

Mark separately
If deviation wrong allow M2 and M4
If M3 and / or M5 right (con)
If used 'd' rather than 'p' orbital - lose M2 + M4 but may get M3, M5 (explanation marks)

5

[10]

45 (a) Proton: mass 1, charge + 1 **(1)**
Neutron: mass 1, charge 0 **(1)**
Electron mass 1/1840, charge -1 **(1)**

Allow mass = 0, or negligible, or 1/1800 to 1/2000

Isotopes have the same number of protons **(1)**

OR atomic number

different number of neutrons **(1)**

Isotopes have the same electronic configuration **(1)**

OR same number of electrons

Chemical properties depend on electrons **(1)**

7

(b) $\frac{\text{average (1) mass of an atom/isotopes}}{\text{mass of 1 atom of } {}^{12}C} \times 12$ **(1)**

OR $\frac{\text{mass of 1 mol of atoms}}{\text{mass of 1 atom of } {}^{12}C} \times 12$ *or in words*

Spectrum gives (relative) abundance **(1)**

OR % or amount

And *m/z* **(1)**
Multiply *m/z* by relative abundance for each isotope **(1)**

Allow instead of m/z mass no, A_r or actual value from example

Sum these values **(1)**
Divide by the sum of the relative abundances **(1)**

only award this mark if previous 2 given

Max 2 if e.g. has only 2 isotopes

7

[14]

46 D

[1]

47 (a) Ability (or power) of an atom to attract electron density
(or electrons or -ve charge) **(1)**
in a covalent bond **(1)**

or shared pair

If remove an electron lose first mark

2

(b) *Trend:* increases **(1)**
Explanation: nuclear charge (number of protons) increases **(1)**
electrons in same shell **(1)**

OR similar shielding

OR atoms similar size or smaller

OR 1 mol of e^-

3

(c) Heat / enthalpy / energy for removal of one electron **(1)**
from a gaseous atom **(1)**
can score in an equation

must have first mark to score the second

2

(d) (i) 2 **(1)**

(ii) Two elements (or Na / Mg) before the drop (in energy) to Al **(1)**

(iii) ionisation energy of Al < that for Mg **(1)**

(iv) fall in energy from P to S **(1)**
or discontinuity in trend

From Al to P there are 3 additional electrons **(1)**
or three elements
For second mark idea of block of 3 elements

5

[12]

48 C **[1]**

49 D **[1]**

50 D **[1]**

51 D **[1]**

52 D **[1]**

53 A **[1]**

54 C **[1]**

55 A **[1]**

56 B **[1]**

57 C **[1]**