PRACTICE EXAMINATION QUESTIONS FOR 1.1 ATOMIC STRUCTURE
(includes some questions from 1.4 Periodicity)

1. (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)
(Total 4 marks)

2. (a) Define the terms

(i) *mass number* of an atom,

.....

(ii) *relative molecular mass*.

.....

.....

(3)

(b) (i) Complete the electron arrangement for a copper atom.

$1s^2$ .....

(ii) Identify the block in the Periodic Table to which copper belongs.

.....

(iii) Deduce the number of neutrons in one atom of ^{65}Cu

.....

(3)

(c) A sample of copper contains the two isotopes ^{63}Cu and ^{65}Cu only. It has a relative atomic mass, A_r, less than 64. The mass spectrum of this sample shows major peaks with *m/z* values of 63 and 65, respectively.

(i) Explain why the A_r of this sample is less than 64.

.....

(ii) Explain how Cu atoms are converted into Cu^+ ions in a mass spectrometer.

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.....

(iii) In addition to the major peaks at *m/z* = 63 and 65, much smaller peaks at *m/z* = 31.5 and 32.5 are also present in the mass spectrum. Identify the ion responsible for the peak at *m/z* = 31.5 in the mass spectrum. Explain why your chosen ion has this *m/z* value and suggest **one** reason why this peak is very small.

Identity of the ion .....

Explanation for m/z value .....

.....

Reason why this peak is very small .....

.....

(6)
(Total 12 marks)

3. A sample of iron from a meteorite was found to contain the isotopes ^{54}Fe, ^{56}Fe and ^{57}Fe.

(a) The relative abundances of these isotopes can be determined using a mass spectrometer. In the mass spectrometer, the sample is first vaporised and then ionised.

(i) State what is meant by the term *isotopes*.

.....

.....

(ii) Explain how, in a mass spectrometer, ions are detected and how their abundance is measured.

How ions are detected .....

.....

How abundance is measured .....

.....

(5)

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

.....

.....

(ii) The relative abundances of the isotopes in this sample of iron were found to be as follows.

m/z	54	56	57
Relative abundance (%)	5.8	91.6	2.6

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

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.....

(4)

(c) (i) Give the electron arrangement of an Fe^{2+} ion.

.....

(ii) State why iron is placed in the d block of the Periodic Table.

.....

.....

(iii) State the difference, if any, in the chemical properties of isotopes of the same element. Explain your answer.

Difference .....

Explanation .....

.....

(4)
(Total 13 marks)

4. (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)
(Total 9 narks)

5. (a) Define the term *atomic number* of an element.

.....

(1)

(b) Give the symbol, including mass number and atomic number, for an atom of an element which contains 12 neutrons and 11 electrons.

.....

(2)

(c) In terms of s and p sub-levels, give the electronic configuration of an aluminium atom.

.....

(1)

(d) How many neutrons are there in one ^{27}Al atom?

.....

(1)

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

.....

.....

(2)

(f) Parts (i) to (iv) below refer to the operation of a mass spectrometer.

(i) Name the device used to ionise atoms in a mass spectrometer.

.....

(ii) Why is it necessary to ionise atoms before acceleration?

.....

.....

(iii) What deflects the ions?

.....

(iv) What is adjusted in order to direct ions of different mass to charge ratio onto the detector?

.....

(4)

(g) A meteorite was found to contain three isotopes of element **X**.
A mass spectrometer gave the following information about these isotopes.

m/*z*	24.0	25.0	26.0
Relative abundance	64.2	20.3	15.5

(i) Calculate the relative atomic mass of **X**.

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.....

.....

(ii) Using the Periodic Table, suggest the most likely identity of element **X**.

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(iii) Suggest one reason why the relative atomic mass of **X**, given in the Periodic Table, differs from your answer to part (g)(i).

.....

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(5)
(Total 16 marks)

6. (a) The diagram in **Figure 1** shows the behaviour of the three fundamental particles when passed through an electric field.

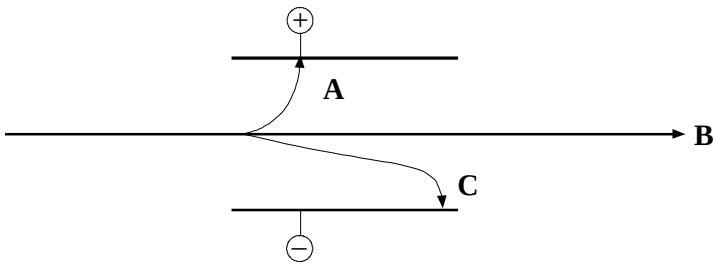

Figure 1

(i) Identify the particles represented by **A**, **B**, and **C**.

A ..... **B** .....

C .....

(1)

(ii) Explain the shapes and directions of the paths traced by the fundamental particles as they pass through the electric field.

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(3)

(b) **Figure 2** is a simplified diagram of a mass spectrometer.

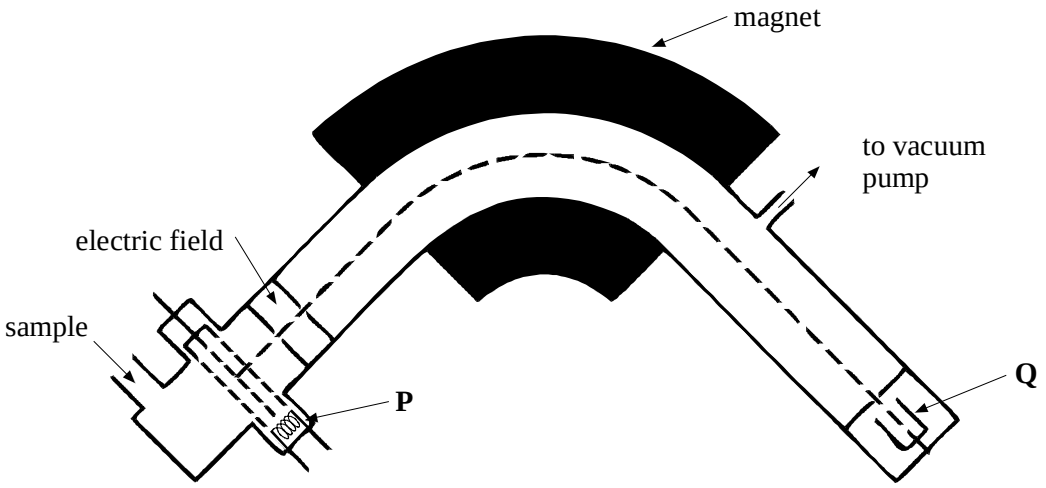

Figure 2

(i) State and explain the purpose of the part of the mass spectrometer labelled **P**.

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.....

(2)

(ii) State the purpose of the *electric field*, of the *magnet* and of the part labelled **Q.**

Electric field .....

Magnet .....

Part **Q** .....

(3)
(Total 11 marks)

7. (a) Define the term *atomic number* of an atom.

.....

(1)

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

.....

(1)

(c) The table below concerns a sample of krypton.

Mass number	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* of an element.

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.....

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

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.....

(5)

(d) Explain why the first ionisation energy of rubidium is less than the first ionisation energy of krypton.

.....

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(2)

(Total 9 marks)

8. (a) Explain the terms:

(i) *mass number;*

.....

.....

(1)

(ii) *relative atomic mass.*

.....

.....

(2)

(b) Sulphur consists of three isotopes. The table below shows the relative abundance of each isotope.

Mass number of isotope	32	33	34
Relative abundance/%	95.0	0.8	4.2

Figure 1

Using the data from **Figure 1,** calculate the relative atomic mass, A_r of sulphur, giving your final answer to 1 decimal place.

(2)
(Total 5 marks)

9. (a) Define the term *mass number* of an isotope.

.....

(1)

(b) Write the symbol, including mass number and atomic number, for the isotope which has eight electrons and nine neutrons in each atom.

.....

(2)

(c) The table below shows some data about fundamental particles.

Particle	Proton	neutron	Electron
Mass /g	1.6725×10^{-24}	1.6748×10^{-24}	0.0009×10^{-24}
Relative charge			

(i) Complete the table by giving a value for the relative charge of each particle.

(ii) Calculate the mass of an atom of hydrogen which is made from a proton and an electron.

.....

(iii) Calculate the mass of one mole of such hydrogen atoms giving your answer to four decimal places.
(The Avogadro constant, $L = 6.0225 \times 10^{23}$ mol^{-1})

.....

(iv) An accurate value for the mass of one mole of hydrogen atoms is 1.0080 g. Give one reason why this value is different from your answer to part (c)(iii).

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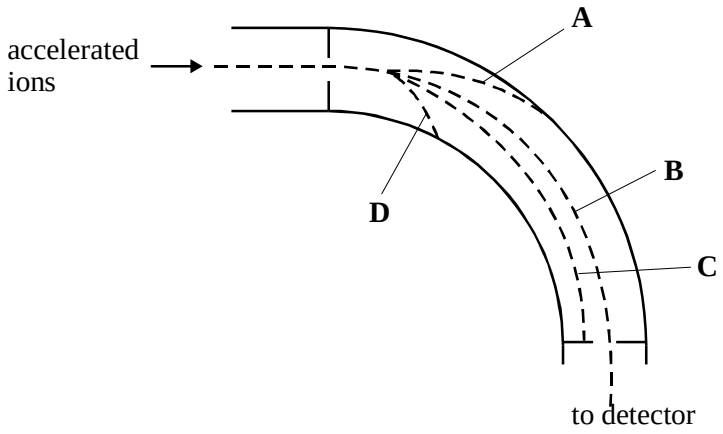
(4)

(d) The diagram below shows a section of a mass spectrometer between the acceleration stage and the detection stage. The accelerated ions are from a sample of krypton which has been ionised as follows:

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

The ions are deflected in four distinct paths, **A, B, C** and **D.** Ions are detected and a mass spectrum is then produced.



(i) What accelerates the Kr^{+} ions before they are deflected?

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(ii) What deflects the moving ions round a curved path?

.....

(iii) Why do the Kr^{+} ions from this sample of krypton separate into four paths?

.....

(iv) What adjustment could be made to the operating conditions of the mass spectrometer in order to direct the ions following path **C** onto the detector?

.....

(v) For each type of ion what two measurements can be made from the mass spectrum?

Measurement 1.....

Measurement 2.....

(6)
(Total 13 marks)

10. (a) Name the device, in a mass spectrometer, which causes particles to become ionised.

.....

(1)

(b) What happens to these particles immediately after they are ionised in a mass spectrometer?

.....

(1)

(c) What factor, other than the mass to charge ratio of an ionised particle, determines how much that particle is deflected in a magnetic field of a given strength?

.....

(1)

(d) The mass spectrum of krypton has peaks with *m/z* of 82, 83, 84, and 86 whose relative abundances are 1, 1,5, and 2, respectively. Calculate a value for the relative atomic mass of krypton.

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(3)
(Total 6 marks)

11. (a) State, in terms of the fundamental particles present, the meaning of the term *isotopes*.

.....

.....

(1)

(b) An atom contains one more proton than, but the same number of neutrons as, an atom of ^{36}S. Deduce the symbol, including the mass number and the atomic number, of this atom.

.....

(2)

(c) The table below gives the relative abundance of each isotope in a mass spectrum of a sample of germanium, Ge.

m/z	70	72	74
Relative abundance (%)	24.4	32.4	43.2

(i) Complete the electron arrangement of a Ge atom.

$1s^2$ .....

(ii) Use the data above to calculate the relative atomic mass of this sample of germanium. Give your answer to one decimal place.

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.....

.....

.....

(iii) State what is adjusted in a mass spectrometer in order to direct ions with different *m/z* values onto the detector. Explain your answer.

Adjustment .....

Explanation .....

.....

.....

(iv) One of the isotopes of Ge, given in the table in part (c), has an ion that forms a small peak in the mass spectrum which is indistinguishable from a peak produced by $^{36}S^+$ ions. Identify this Ge ion and explain your answer.

Ion .....

Explanation .....

.....

(8)
(Total 11 marks)

12. Aluminium, magnesium and vanadium are metals.

(a) Complete the electronic configurations for aluminium and vanadium.

Electronic configuration of aluminium $1s^2$ .....

Electronic configuration of vanadium $1s^2$ .....

(2)

(b) State the block in the Periodic Table to which magnesium belongs.

.....

(1)
(Total 3 marks)

13. (a) Give the symbol, including mass number and atomic number, for the isotope which has a mass number of 34 and which has 18 neutrons in each nucleus

.....

(2)

(b) Some data obtained from the mass spectrum of a sample of carbon are given below.

Ion	$^{12}C^+$	$^{13}C^+$
Absolute mass of one ion/g	1.993×10^{-23}	2.158×10^{-23}
Relative abundance/%	98.9	1.1

Use these data to calculate a value for the mass of one neutron, the relative atomic mass of 13 C and the relative atomic mass of carbon in the sample.
You may neglect the mass of an electron.

Mass of one neutron. .....

Relative atomic mass of ^{13}C. .....

.....

.....

Relative atomic mass of carbon in the sample.....

.....

.....

.....

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(6)
(Total 8 marks)

14. (a) Describe the process by which particles are ionised in a mass spectrometer.

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(2)

(b) Give two reasons why particles must be ionised before being analysed in a mass spectrometer.

Reason 1 .....

Reason 2 .....

(2)

(c) A sample of boron contains 20% by mass of ^{10}B and 80% by mass of ^{11}B. Calculate the relative atomic mass of boron in this sample.

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.....

(2)
(Total 6 marks)

15. (a) Complete the following to show the electronic configuration of silicon.

$1s^2\ 2s^2$ .....

(1)

(b) Write chemical equations, including state symbols, for the following enthalpy changes:

the first molar ionisation energy of silicon;

.....

the second molar ionisation energy of silicon.

.....

(3)
(Total 4 marks)

16. **Figure 1** contains data relating to the relative isotopic abundance of the element titanium, Ti.

Isotope	^{46}Ti	^{47}Ti	^{48}Ti	^{49}Ti	^{50}Ti
% abundance	8.02	7.31	73.81	5.54	5.32

Figure 1

(a) Explain what is meant by the term *relative isotopic abundance.*

.....

.....

.....

(2)

(b) Using the data from **Figure 1**, calculate the relative atomic mass, A_r, of titanium.

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.....

.....

(2)

(Total 4 marks)

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

$1s^2$ .....

(1)

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

.....

(1)

(c) 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)

(d) 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.

.....

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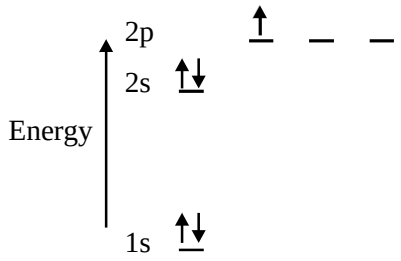
(5)
(Total 9 marks)

18. The diagram below shows the electronic structure of boron.



(a) The electrons are represented by arrows. What property of the electrons do these 'up' and 'down' arrows represent?

.....

(1)

(b) Suggest why electrons which occupy the 2p sub-levels have a higher energy than electrons in the 2s sub-level.

.....

(1)

(c) Explain the meaning of the term *first ionisation energy.*

.....

.....

(2)

(d) Explain why boron has a lower first ionisation energy than beryllium.

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(3)

(e) Explain why the first ionisation energy of helium is very large.

.....

.....

(1)
(Total 8 marks)

19.

(a) (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.

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(4)

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

.....

(1)
(Total 5 marks)

20. 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)

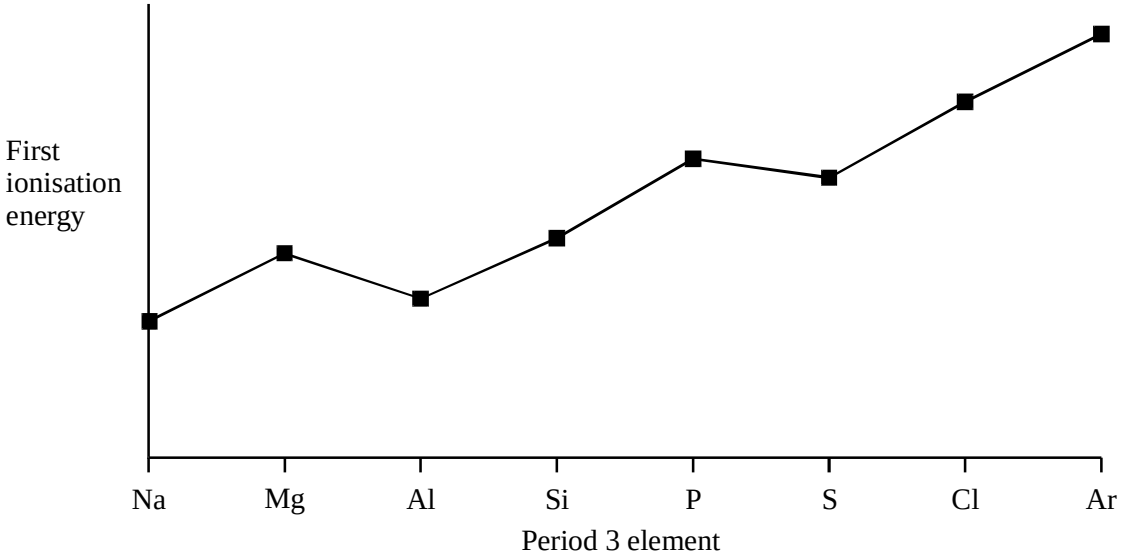
21. (a) What is meant by the term *first ionisation energy*?

.....

.....

(2)

(b) 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?

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.....

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

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.....

(5)
(Total 7 marks)

22. Explain why atomic radius decreases across Period 3 from sodium to chlorine.

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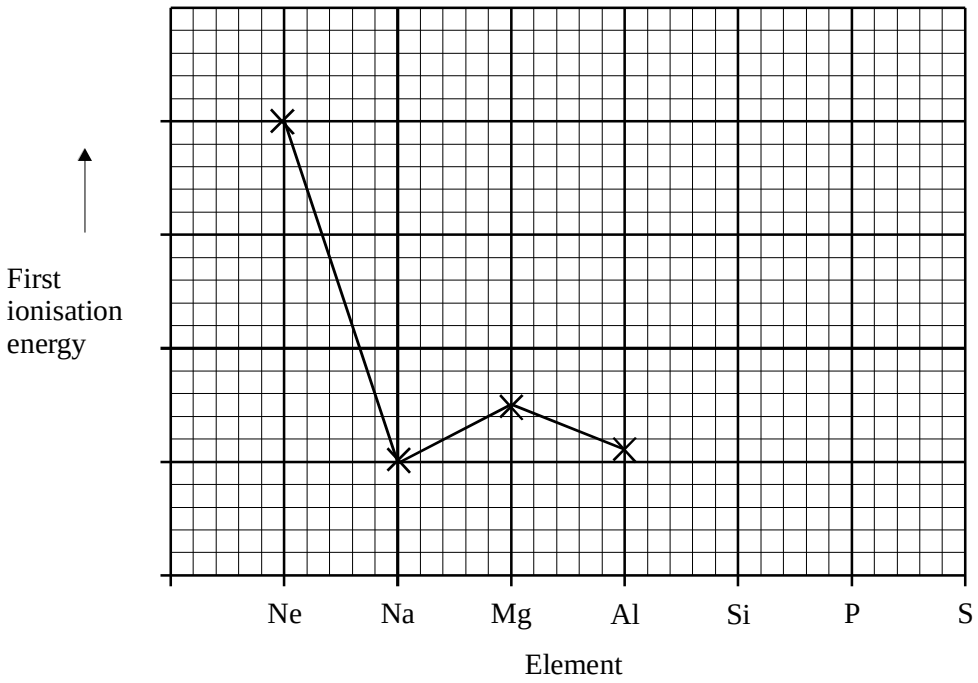
(2)
(Total 2 marks)

23. The diagram below shows the trend in the first ionisation energies of the elements from neon to aluminium.



(a) Draw crosses on the graph to show the first ionisation energies of silicon, phosphorus and sulphur.

(3)

(b) Write an equation to illustrate the process which occurs during the first ionisation of neon.

.....

(1)

(c) Explain why the first ionisation energy of neon and that of magnesium are both higher than that of sodium.

Explanation for neon .....

.....

.....

Explanation for magnesium .....

.....

.....

(4)

(d) Explain why the first ionisation energy of aluminium is lower than that of magnesium.

.....

.....

(2)
(Total 10 marks)

24. Values for the covalent radii of the elements in Period 3 are given in the table below.

Elements	Na	Mg	Al	Si	P	S	Cl	Ar
Covalent radius/nm	0.157	0.136	0.125	0.117	0.110	0.104	0.099	—

Explain the decrease in the values shown in the table.

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.....

(Total 3 marks)

25. (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)

26. (a) Ionisation is the first of the four main stages involved in obtaining the mass spectrum of a sample of gaseous titanium atoms. Explain how ionisation is achieved. Name the remaining three stages and, in each case, state how each stage is achieved. Explain why it would be difficult to distinguish between $^{48}Ti^{2+}$ and $^{24}Mg^{+}$ ions using a mass spectrometer.

(10)

(b) State any differences and similarities in the atomic structure of the isotopes of an element. State the difference, if any, in the chemistry of these isotopes. Explain your answer.

(4)

(c) The table below gives the percentage abundance of each isotope in the mass spectrum of a sample of titanium.

m/z	46	47	48	49	50
% abundance	8.02	7.31	73.81	5.54	5.32

Define the term *relative atomic mass* of an element. Use the above data to calculate the value of the relative atomic mass of titanium in this sample. Give your answer to two decimal places.

(4)
(Total 18 marks)

27. (a) Describe, in terms of charge and mass, the properties of protons, neutrons and electrons. Explain fully how these particles are arranged in an atom of ^{14}N.

(6)

(b) Account for the existence of isotopes.

(2)

(c) The mass spectrum of an element has peaks with relative intensity and *m/z* values shown in the table below.

m/z	80	82	83	84	86
Relative intensity	1	5	5	25	8

Identify this element and calculate its accurate relative atomic mass

(4)
(Total 12 marks)

28. A sample of element **Q** was extracted from a meteorite. The table below shows the relative abundance of each isotope in a mass spectrum of this sample of **Q**.

m/z	64	66	67	68
Relative abundance (%)	38.9	27.8	14.7	18.6

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

(2)

(b) Use the data above to calculate the relative atomic mass of this sample of **Q**. Give your answer to one decimal place. Suggest the identity of **Q**.

(3)

(c) In order to obtain a mass spectrum of **Q**, a gaseous sample is first ionised. Describe how ionisation is achieved in a mass spectrometer. Give **three** reasons why ionisation is necessary.

(5)
(Total 10 marks)

29. Describe and explain the variation in first ionisation energy of the elements across Period 3 from sodium to argon.

(Total 9 marks)