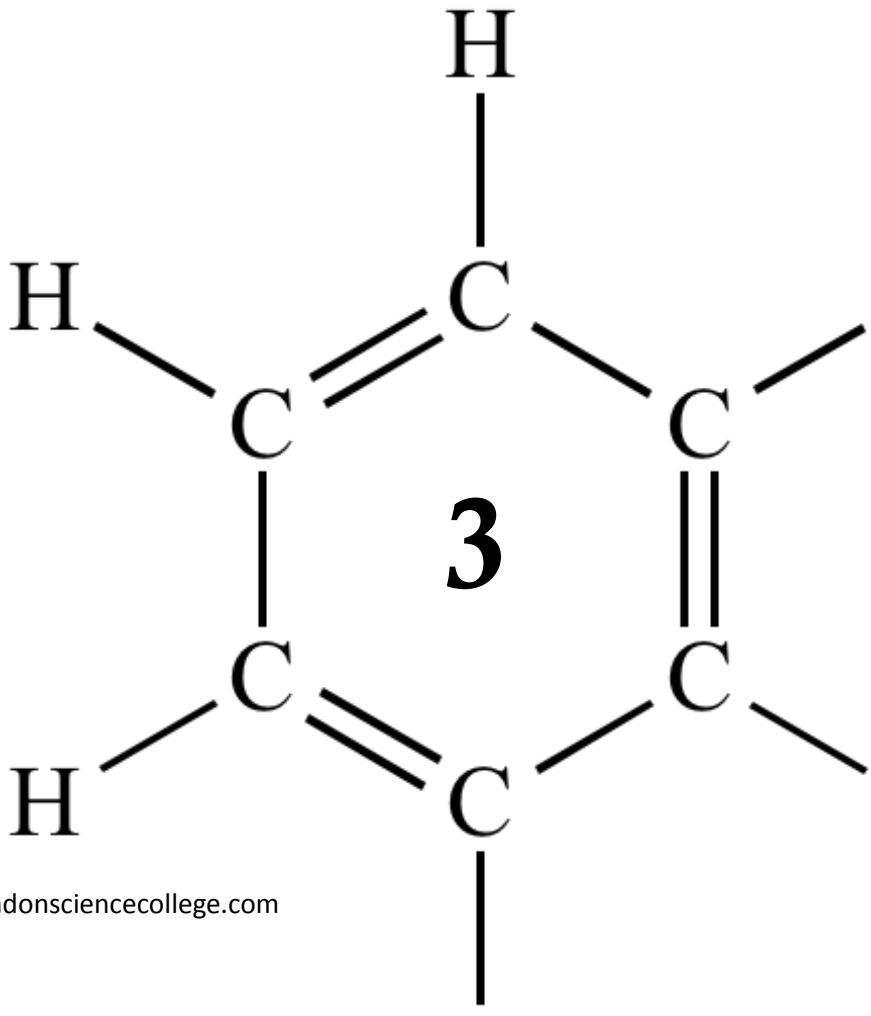
LONDON SCIENCE COLLEGE

AQA AS CHEMISTRY

ATOMIC STRUCTURE



3

1 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.

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(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.

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(1)

(ii) Deduce the full electron configuration of a rubidium atom.

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(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 .....

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(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)

2 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)

3 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.

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(1)

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

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(1)

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

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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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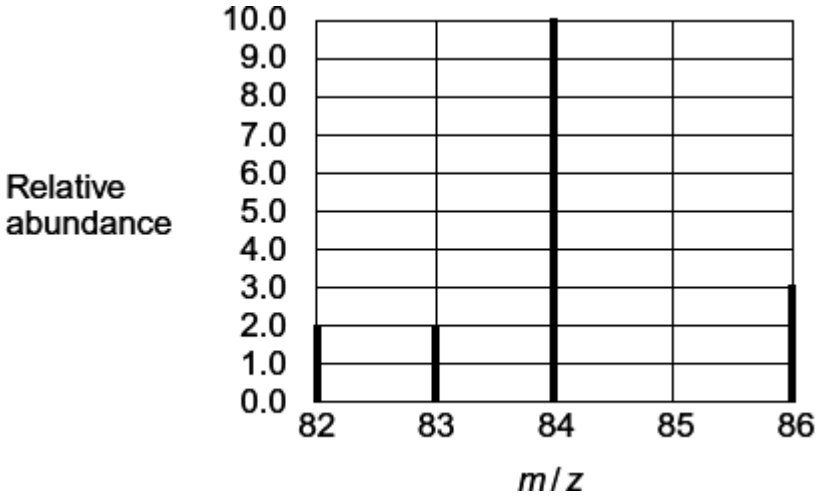
(1)
(Total 7 marks)

4 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)

5 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).....

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(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

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(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) .....

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(2)
(Total 12 marks)

6 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.

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(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).....

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(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.

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(1)

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

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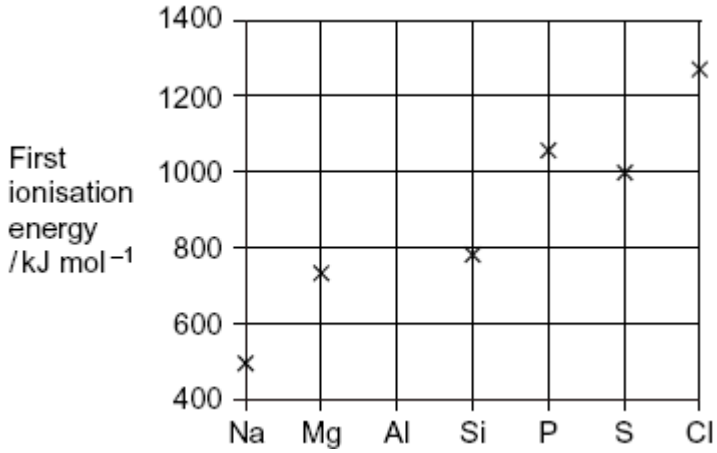
(1)
(Total 10 marks)

7 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 $1s^2\ 2s^2\ 2p^6\ 3s^1$

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(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)

8 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)

9 (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)

10 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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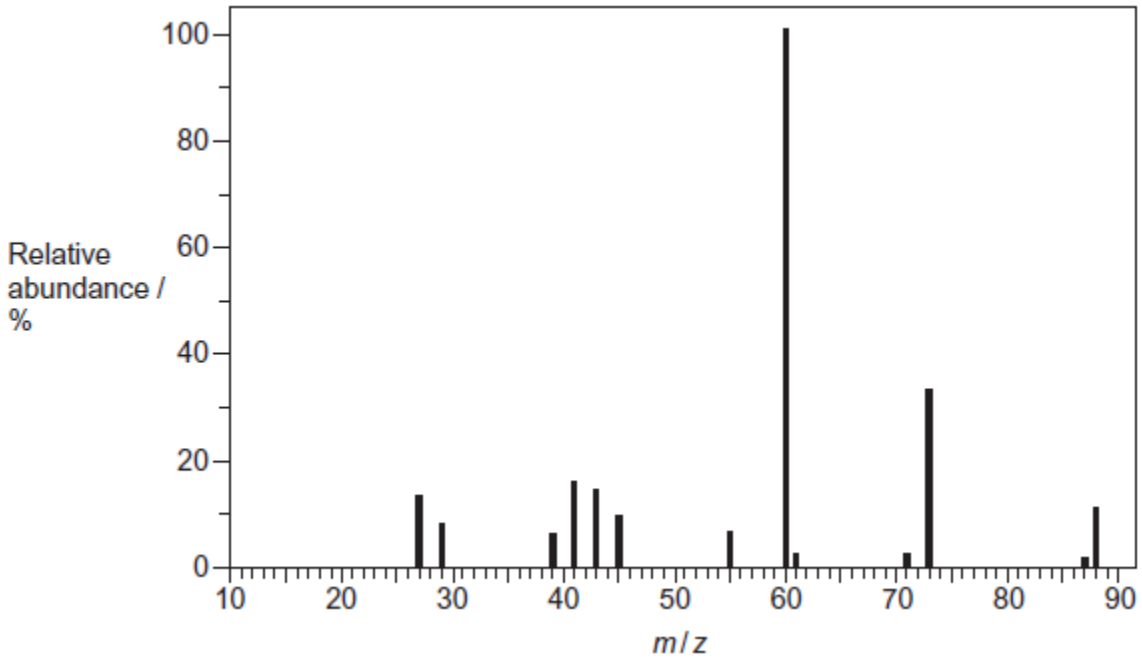
(3)

(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.

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(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.

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(2)
(Total 6 marks)

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

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

$1s^2$ .....

(1)

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

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(2)

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

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(1)

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

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(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 .....

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(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 .....

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Explanation .....

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(3)

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

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(1)

(Total 13 marks)