

AQA A-LEVEL CHEMISTRY • 7405

# CHEMISTRY



**EXAM QUESTION PACK**

**3.1.1 ATOMIC STRUCTURE**

**SCORE**

**/749**

**PERCENTAGE**

**%**

**STEMUP**

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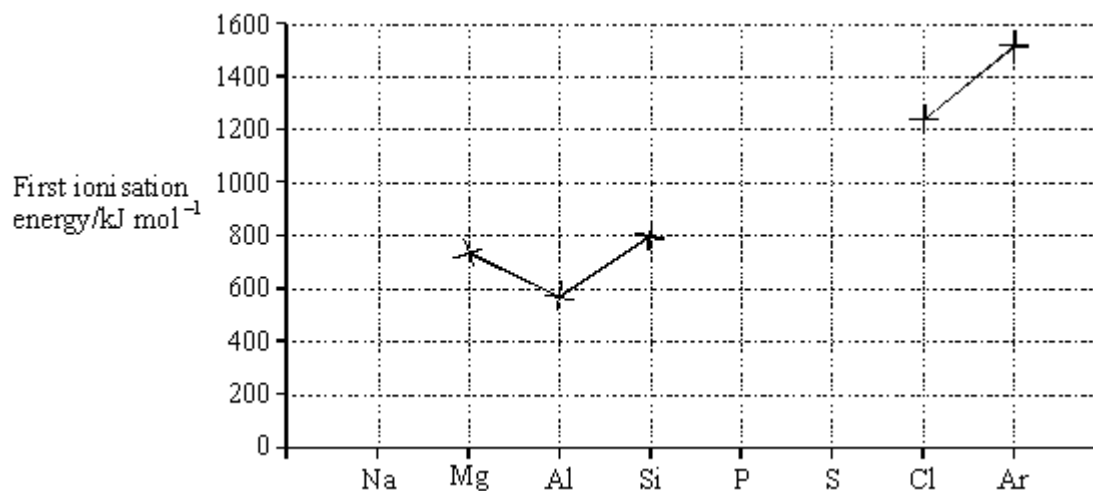
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**Q1.**

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.

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(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* \_\_\_\_\_

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*Explanation for sulphur* \_\_\_\_\_

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(4)

(Total 10 marks)

**Q2.**

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)

**Q3.**

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)

**Q4.**

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

\_\_\_\_\_

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(2)

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

Trend \_\_\_\_\_

Explanation \_\_\_\_\_

(3)

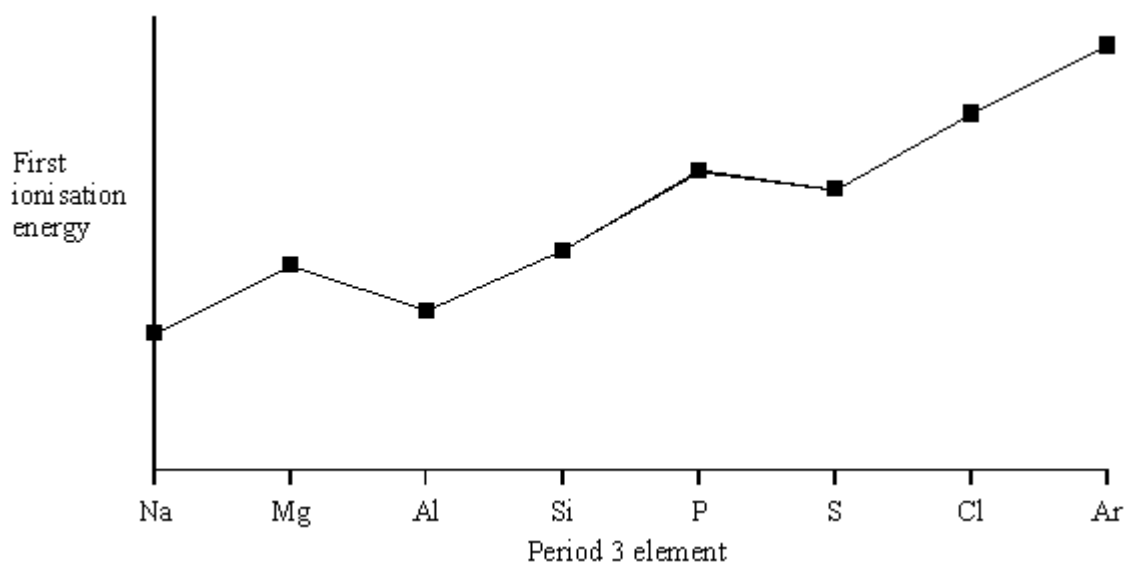
- (c) What is meant by the term *first ionisation energy*?

\_\_\_\_\_

\_\_\_\_\_

(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?

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(5)  
(Total 12 marks)

**Q5.**

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)

**Q6.**

Which one of the following does **not** have a pair of s electrons in its highest filled electron energy sub-level?

- A  $\text{H}^-$
- B Mg
- C  $\text{P}^{3+}$
- D Ar

(Total 1 mark)

**Q7.**

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 2p electron occupies a higher energy level than a 2s electron.

(Total 1 mark)

**Q8.**

Which one of the following ionisations requires less energy than the first ionisation energy of oxygen?

- A  $\text{S(g)} \rightarrow \text{S}^{\text{+}}(\text{g}) + \text{e}^{-}$
- B  $\text{O}^{\text{+}}(\text{g}) \rightarrow \text{O}^{2+}(\text{g}) + \text{e}^{-}$
- C  $\text{N(g)} \rightarrow \text{N}^{\text{+}}(\text{g}) + \text{e}^{-}$
- D  $\text{F(g)} \rightarrow \text{F}^{\text{+}}(\text{g}) + \text{e}^{-}$

(Total 1 mark)

**Q9.**

Which atom has an incomplete sub-shell?

- A Be
- B Ca
- C Ge
- D Zn

(Total 1 mark)

**Q10.**

In which one of the following pairs is the first ionisation energy of element Y greater than that of element X?

|   | electronic configuration<br>of element X | electronic<br>configuration<br>of element Y |
|---|------------------------------------------|---------------------------------------------|
| A | $1s^1$                                   | $1s^2$                                      |
| B | $1s^2 2s^2$                              | $1s^2 2s^2 2p^1$                            |
| C | $1s^2 2s^2 2p^3$                         | $1s^2 2s^2 2p^4$                            |
| D | $1s^2 2s^2 2p^6$                         | $1s^2 2s^2 2p^6 3s^1$                       |

(Total 1 mark)

**Q11.**

Which one of the following lists the first ionisation energies (in  $\text{kJ mol}^{-1}$ ) 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)

**Q12.**

Which one of the following is the electronic configuration of an element with a maximum oxidation state of +5?

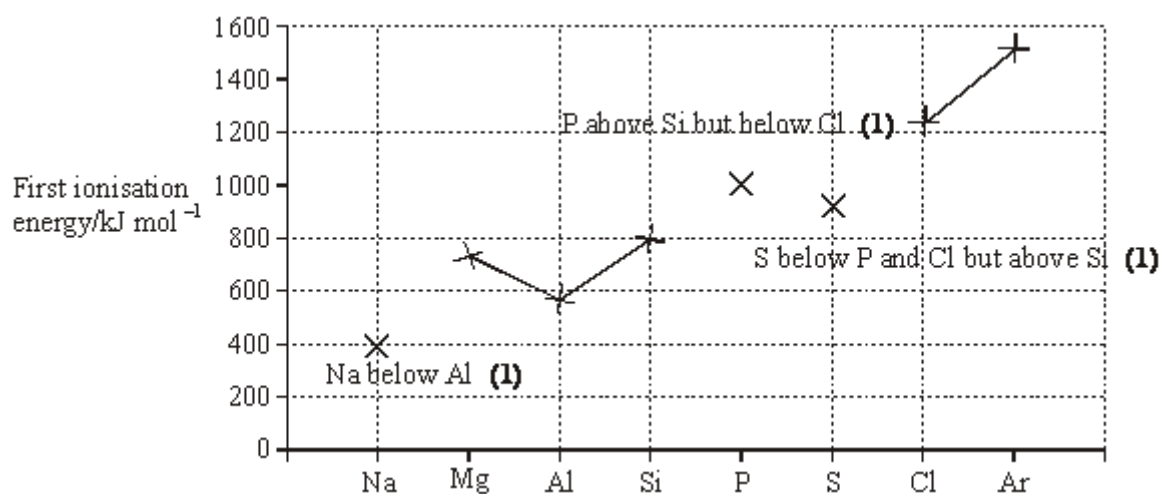
- A**     $1s^2 2s^2 2p^5$
- B**     $1s^2 2s^2 2p^6 3s^2 3p^1$
- C**     $1s^2 2s^2 2p^6 3s^2 3p^3$
- D**     $1s^2 2s^2 2p^6 3s^2 3p^6 3d^7 4s^2$

(Total 1 mark)

## Mark schemes

### Q1.

(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<sup>-</sup> pair in M3*

*Penalise '2p' once only*

4

[10]

### Q2.

(a)  $\text{Na(g)} \rightarrow \text{Na}^{\text{+}}\text{(g)} + \text{e}^{-}$

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

*(-) 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]

### Q3.

D

[1]

### Q4.

- (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]

**Q5.**

D

[1]

**Q6.**

D

[1]

**Q7.**

D

[1]

**Q8.**

A

[1]

**Q9.**

C

[1]

**Q10.**

A

[1]

**Q11.**

B

[1]

**Q12.**

C

[1]

## Examiner reports

### Q1.

Many candidates correctly positioned the crosses in the diagram, but errors were not uncommon. In some cases, the cross for sodium was omitted. Other common errors were to position the cross for sodium at the same level as that for aluminium, to place the cross for phosphorus below that for silicon and to place the cross for sulphur level either level with that for phosphorus, or level with that of silicon. Given that the questions in parts (b) and (c) are frequently asked, and so should be an essential part of a revision programme, the answers offered by many candidates were disappointing. The better candidates were well prepared and so scored well on this question; others lacked much of the basic knowledge required in this section of the specification. In part (b), many candidates attempted to explain the *deviations* from the general increase in ionisation energy across the period, rather than explaining the *general increase* itself, as required by the question, and so failed to earn the marks allocated to part (b). Where the explanation offered in part (b) helped to clarify an answer to part (c), which did require an explanation of the deviations from the general trend, credit for the marks allocated to part (c) was given. While some clear, concise and accurate explanations were seen in part (b), many attempts were vague. All that was required was for a link to be established between the increased nuclear charge of smaller atoms having no change in shielding and an increase in the attraction between the nucleus and the outer electrons. Many explanations lacked precision and failed to establish such a link. The phrase *effective nuclear charge* was incorrectly used as an explanation by some candidates. Many explanations in part (c) similarly were incomplete and lacked precision. Many candidates correctly identified the outermost electron in an aluminium atom as being in the 3p sub-level. The second mark, for explaining why this electron is more easily lost was less frequently earned. Some candidates successfully explained the second point, but omitted to state the location of the outermost electron. Some candidates referred to an increase in the shielding of the outer electron but omitted to identify the electrons responsible for this increase. In some cases, candidates simply stated that aluminium was in the 3s with no reference at all being made to electrons. While some candidates clearly explained the drop in ionisation energy between phosphorus and sulphur, many others vaguely attributed this deviation from the general trend to *mutual* repulsion, or to *repulsion between electrons*, without identifying the location, or the paired nature, of the electrons involved. Some vague references to the *increased stability* of the electron arrangement present were also seen.

### Q2.

Although many candidates gave a correct equation for this process, errors were not uncommon. Some candidates lost the mark for the state symbols as examiners, who strove to differentiate between (g) and (s), were unable to clearly identify the squiggles used in the equation. Other candidates omitted the state symbols completely. Other errors seen in this equation included the use of X, Z or M to represent the metal, the use of positrons, single electrons being shown on both sides of the equation, or the equation being reversed. Part (b) was quite well done although unacceptable phrases such as *an increase in the nuclear force* or *core charge* were not uncommon. Many candidates struggled with part (c). Many knew that the first ionisation energy of both aluminium and sulphur are lower than the trend would suggest but the explanations offered were frequently vague, and the specific identification of the 3p<sup>1</sup> electron, in aluminium, and the 3p<sup>4</sup> electron pair, in sulphur, were often omitted. Many candidates were aware that the outer electron in aluminium is of higher energy, better shielded or further removed from the nucleus but it was often not clear that a reference to *mutual repulsion* referred to the 3p paired electrons in sulphur. More often, explanations referred to repulsion between electron pairs, or simply to repulsion between electrons. Some candidates attempted to explain the deviation using vague references to

full or half-full shells/sub-shells having more stability.

**Q4.**

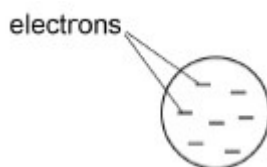
This question also discriminated very effectively. Answers to parts (a) and (b) were often correct but answers to part (c) lacked precision and in many cases did not refer to removal of an electron from a gaseous atom. Parts (d)(ii), (iii) and (iv) were not answered well. Many candidates did not appear to have read or perhaps understood the question. They were expected to compose their answers by showing how the statements were supported by evidence from the diagram. Most candidates just explained the variations in ionisation energies across the period.

### Q1.

This question is about atomic structure.

In the nineteenth century JJ Thomson discovered the electron. He suggested that negative electrons were found throughout an atom like 'plums in a pudding of positive charge'.

The diagram shows an atom of element **R** using the 'plum pudding' model.  
An atom of **R** contains seven electrons.



- (a) State **two** differences between the 'plum pudding' model and the model of atomic structure used today.

1. \_\_\_\_\_  
\_\_\_\_\_  
2. \_\_\_\_\_  
\_\_\_\_\_

(2)

- (b) Deduce the full electron configuration of an atom of element **R**.

\_\_\_\_\_

(1)

- (c) Identify **R** and deduce the formula of the compound formed when **R** reacts with the Group 2 metal in the same period as **R**.

\_\_\_\_\_

(1)

(Total 4 marks)

### Q2.

This question is about sodium fluoride (NaF).

Some toothpastes contain sodium fluoride.

The concentration of sodium fluoride can be expressed in parts per million (ppm).

1 ppm represents a concentration of 1 mg in every 1 kg of toothpaste.

- (a) A 1.00 g sample of toothpaste was found to contain  $2.88 \times 10^{-5}$  mol of sodium fluoride.

Calculate the concentration of sodium fluoride, in ppm, for the sample of toothpaste.  
Give your answer to 3 significant figures.

Concentration of sodium fluoride \_\_\_\_\_ ppm

(4)

- (b) Sodium fluoride is toxic in high concentrations.  
Major health problems can occur if concentrations of sodium fluoride are greater than  $3.19 \times 10^{-2}$  g per kilogram of body mass.

Deduce the maximum mass of sodium fluoride, in mg, that a 75.0 kg person could swallow without reaching the toxic concentration.

Mass of sodium fluoride \_\_\_\_\_ mg

(1)

- (c) The concentration of sodium fluoride in a prescription toothpaste is 2800 ppm.

Use your answer to Question (b) to deduce the mass of toothpaste, in kg, that a 75.0 kg person could swallow without reaching the toxic concentration.

Mass of toothpaste \_\_\_\_\_ kg

(1)

- (d) Identify the diagram in the figure below that shows the correct relative sizes of the ions in sodium fluoride.  
Justify your answer.

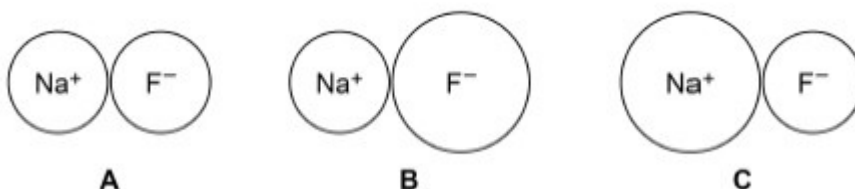


Diagram \_\_\_\_\_

Justification \_\_\_\_\_

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**Q3.**

This question is about s-block metals.

- (a) Give the full electron configuration for the calcium ion,  $\text{Ca}^{2+}$

\_\_\_\_\_  
(1)

- (b) Explain why the second ionisation energy of calcium is lower than the second ionisation energy of potassium.

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
(2)

- (c) Identify the s-block metal that has the highest first ionisation energy.

\_\_\_\_\_  
(1)

- (d) Give the formula of the hydroxide of the element in Group 2, from Mg to Ba, that is least soluble in water.

\_\_\_\_\_  
(1)

- (e) A student added  $6 \text{ cm}^3$  of  $0.25 \text{ mol dm}^{-3}$  barium chloride solution to  $8 \text{ cm}^3$  of  $0.15 \text{ mol dm}^{-3}$  sodium sulfate solution.

The student filtered off the precipitate and collected the filtrate.

Give an ionic equation for the formation of the precipitate.

Show by calculation which reagent is in excess.

Calculate the total volume of the other reagent which should be used by the student so that the filtrate contains only one solute.

Ionic equation \_\_\_\_\_

Reagent in excess \_\_\_\_\_

Total volume of other reagent \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

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(3)

- (f) A sample of strontium has a relative atomic mass of 87.7 and consists of three isotopes,  $^{86}\text{Sr}$ ,  $^{87}\text{Sr}$  and  $^{88}\text{Sr}$   
In this sample, the ratio of abundances of the isotopes  $^{86}\text{Sr} : ^{87}\text{Sr}$  is 1:1

State why the isotopes of strontium have identical chemical properties.  
Calculate the percentage abundance of the  $^{88}\text{Sr}$  isotope in this sample.

Why isotopes of strontium have identical chemical properties

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Percentage abundance of  $^{88}\text{Sr}$  \_\_\_\_\_ %

(4)

- (g) A time of flight (TOF) mass spectrum was obtained for a sample of barium that contains the isotopes  $^{136}\text{Ba}$ ,  $^{137}\text{Ba}$  and  $^{138}\text{Ba}$

The sample of barium was ionised by electron impact.

Identify the ion with the longest time of flight.

---

(1)

- (h) A  $^{137}\text{Ba}^+$  ion travels through the flight tube of a TOF mass spectrometer with a kinetic energy of  $3.65 \times 10^{-16} \text{ J}$   
This ion takes  $2.71 \times 10^{-5} \text{ s}$  to reach the detector.

$$\text{KE} = \frac{1}{2} mv^2 \quad \text{where } m = \text{mass (kg) and } v = \text{speed (m s}^{-1}\text{)}$$

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

Calculate the length of the flight tube in metres.

Give your answer to the appropriate number of significant figures.

Length of flight tube \_\_\_\_\_ m

(5)

(Total 18 marks)

**Q4.**

This question is about atomic structure.

- (a) Write the full electron configuration for each of the following species.

Cl<sup>-</sup> \_\_\_\_\_

Fe<sup>2+</sup> \_\_\_\_\_

(2)

- (b) Write an equation, including state symbols, to represent the process that occurs when the third ionisation energy of manganese is measured.

\_\_\_\_\_

\_\_\_\_\_

(1)

- (c) State which of the elements magnesium and aluminium has the lower first ionisation energy.

Explain your answer.

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

(3)

- (d) A sample of nickel was analysed in a time of flight (TOF) mass spectrometer. The sample was ionised by electron impact ionisation. The spectrum produced showed three peaks with abundances as set out in the table.

| m/z | Abundance / % |
|-----|---------------|
| 58  | 61.0          |
| 60  | 29.1          |
| 61  | 9.9           |

Give the symbol, including mass number, of the ion that would reach the detector first in the sample.

Calculate the relative atomic mass of the nickel in the sample.

Give your answer to one decimal place.

Symbol of ion \_\_\_\_\_

Relative atomic mass \_\_\_\_\_

(3)

(Total 9 marks)

**Q5.**

Which of these has the highest first ionisation energy?

**A** Na ☐

**B** Al ☐

**C** Si ☐

**D** Cl ☐

(Total 1 mark)

**Q6.**

A sample of titanium was ionised by electron impact in a time of flight (TOF) mass spectrometer. Information from the mass spectrum about the isotopes of titanium in the sample is shown in the table.

| m/z           | 46  | 47  | 48   | 49  |
|---------------|-----|-----|------|-----|
| Abundance / % | 9.1 | 7.8 | 74.6 | 8.5 |

(a) Calculate the relative atomic mass of titanium in this sample.

Give your answer to one decimal place.

Relative atomic mass of titanium in this sample \_\_\_\_\_

(2)

- (b) Write an equation, including state symbols, to show how an atom of titanium is ionised by electron impact and give the  $m/z$  value of the ion that would reach the detector first.

Equation \_\_\_\_\_

$m/z$  value \_\_\_\_\_

(2)

- (c) Calculate the mass, in kg, of one atom of  $^{49}\text{Ti}$

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

Mass \_\_\_\_\_ kg

(1)

- (d) In a TOF mass spectrometer the time of flight,  $t$ , of an ion is shown by the equation

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

In this equation  $d$  is the length of the flight tube,  $m$  is the mass, in kg, of an ion and  $E$  is the kinetic energy of the ions.

In this spectrometer, the kinetic energy of an ion in the flight tube is  $1.013 \times 10^{-13} \text{ J}$

The time of flight of a  $^{49}\text{Ti}^+$  ion is  $9.816 \times 10^{-7} \text{ s}$

Calculate the time of flight of the  $^{47}\text{Ti}^+$  ion.

Give your answer to the appropriate number of significant figures.

Time of flight \_\_\_\_\_ s

(3)

(Total 8 marks)

### Q7.

Element Q forms a sulfate with formula  $\text{QSO}_4$

Which of these could represent the electronic configuration of an atom of Q?

A [Ne]3s<sup>1</sup> ☐

B [Ne]3s<sup>2</sup> ☐

C [Ne]3s<sup>2</sup>3p<sup>1</sup> ☐

D [Ne]3s<sup>1</sup>3p<sup>2</sup>



(Total 1 mark)

**Q8.**

Bromine exists as two isotopes <sup>79</sup>Br and <sup>81</sup>Br, which are found in almost equal abundance.

Which of the statements is correct?

- A** The first ionisation energy of <sup>79</sup>Br is less than the first ionisation energy of <sup>81</sup>Br
- B** The atomic radius of <sup>79</sup>Br is less than the atomic radius of <sup>81</sup>Br
- C** The mass spectrum of C<sub>3</sub>H<sub>7</sub>Br has two molecular ion peaks at 122 and 124
- D** <sup>79</sup>Br is more reactive than <sup>81</sup>Br



(Total 1 mark)

**Q9.**

This question is about the element iodine and its compounds.

- (a) Iodine is in Group 7 of the Periodic Table.

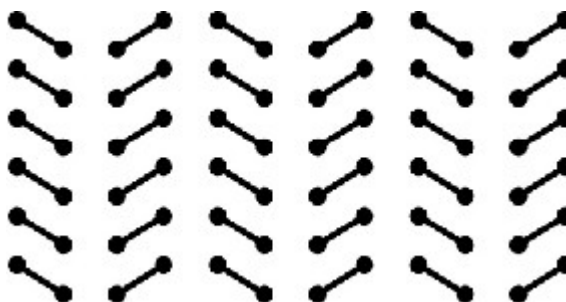
Complete the electron configuration of an iodine atom.

[Kr]

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(1)

- (b) Part of the structure of an iodine crystal is shown in the diagram.



Use your knowledge of structure and bonding to explain why the melting point of iodine is low (113.5 °C) and why that of hydrogen iodide is very low (–50.8 °C).

(6)

- (c) State why iodine does **not** conduct electricity.

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(1)

- (d) Deduce an equation for the formation of hydrogen iodide from its elements.

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(1)

- (e) The triiodide ion is formed when an iodine molecule is bonded to an iodide ion.

What is the formula of ammonium triiodide?

Tick (✓) **one** box.

$\text{NH}_3\text{I}_3$  ☐

$\text{NH}_3\text{I}_4$  ☐

$\text{NH}_4\text{I}$  ☐

$\text{NH}_4\text{I}_3$  ☐

(1)

- (f) Draw the shape of the  $\text{IF}_3$  molecule and the shape of the  $\text{IF}_4^-$  ion.  
Include any lone pairs of electrons that influence each shape.

(2)

- (g) Deduce the oxidation state of iodine in the following species.

$\text{Ba}(\text{IO}_3)_2$

---

$[\text{H}_4\text{IO}_6]^-$

---

(2)

(Total 14 marks)

### Q10.

What is the electron configuration of  $\text{Cu}^{2+}$ ?

- |          |                          |                          |
|----------|--------------------------|--------------------------|
| <b>A</b> | $[\text{Ar}]3d^94s^2$    | <input type="checkbox"/> |
| <b>B</b> | $[\text{Ar}]3d^{10}4s^1$ | <input type="checkbox"/> |
| <b>C</b> | $[\text{Ar}]3d^9$        | <input type="checkbox"/> |
| <b>D</b> | $[\text{Ar}]3d^{10}$     | <input type="checkbox"/> |

(Total 1 mark)

### Q11.

This question is about the elements in Group 2 and their compounds.

- (a) Use the Periodic Table to deduce the full electron configuration of calcium.

\_\_\_\_\_ (1)

- (b) Write an ionic equation, with state symbols, to show the reaction of calcium with an excess of water.

\_\_\_\_\_ (1)

- (c) State the role of water in the reaction with calcium.

\_\_\_\_\_ (1)

- (d) Write an equation to show the process that occurs when the first ionisation energy of calcium is measured.

\_\_\_\_\_ (1)

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

Trend \_\_\_\_\_

Explanation \_\_\_\_\_

\_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

(3)

(Total 7 marks)

**Q12.**

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  |
|----------|-------|--------|-------|--------|-------|--------|
| <b>X</b> | 648   | 1370   | 2870  | 4600   | 6280  | 12 400 |
| <b>Y</b> | 590   | 1150   | 4940  | 6480   | 8120  | 10 496 |
| <b>Z</b> | 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  $\text{NH}_4\text{VO}_3$  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  $50.0 \text{ cm}^3$  of a  $0.800 \text{ mol dm}^{-3}$  solution of  $\text{NH}_4\text{VO}_3$  reacts with  $506 \text{ cm}^3$  of sulfur(IV) oxide gas measured at  $20.0^\circ\text{C}$  and  $98.0 \text{ kPa}$ .

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  $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$ .

Oxidation state = \_\_\_\_\_

(6)

(Total 11 marks)

### Q13.

This question is about electron configuration.

- (a) Give the full electron configuration of an Al atom and of a  $\text{Cr}^{3+}$  ion.

Al atom \_\_\_\_\_

$\text{Cr}^{3+}$  ion \_\_\_\_\_

(2)

- (b) Deduce the formula of the ion that has a charge of  $2+$  with the same electron configuration as krypton.

\_\_\_\_\_

(1)

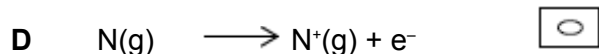
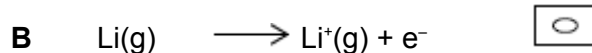
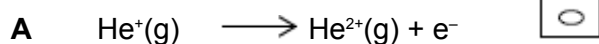
- (c) Deduce the formula of the compound that contains  $2+$  ions and  $3-$  ions that both have the same electron configuration as argon.

\_\_\_\_\_

(1)

**Q14.**

Which change requires the largest amount of energy?



(Total 1 mark)

**Q15.**

This question is about Period 3 of the Periodic Table.

- (a) Deduce which of  $\text{Na}^+$  and  $\text{Mg}^{2+}$  is the smaller ion.  
Explain your answer.

Smaller ion \_\_\_\_\_

Explanation \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

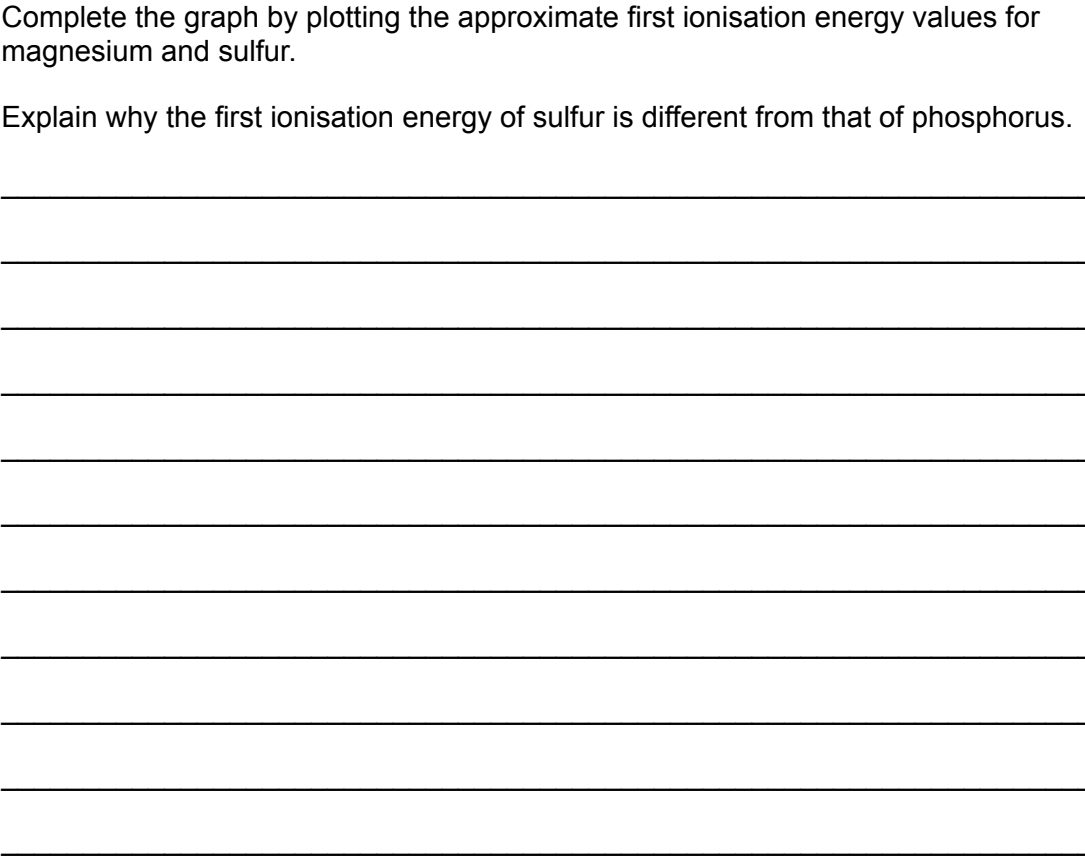
(2)

- (b) Write an equation to represent the process that occurs when the first ionisation energy for sodium is measured.

\_\_\_\_\_

(1)

- (c) The first ionisation energies of some Period 3 elements are shown in the following graph.



**(Total 7 marks)**

This question is about the periodicity of the Period 3 elements.

- (a) State and explain the general trend in first ionisation energy across Period 3.

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(4)

- (b) Give one example of an element which deviates from the general trend in first ionisation energy across Period 3.

Explain why this deviation occurs.

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(3)

- (c) The table shows successive ionisation energies of an element **Y** in Period 3.

| Ionisation number                        | 1    | 2    | 3    | 4    | 5    | 6    | 7      | 8      |
|------------------------------------------|------|------|------|------|------|------|--------|--------|
| Ionisation energy / $\text{kJ mol}^{-1}$ | 1000 | 2260 | 3390 | 4540 | 6990 | 8490 | 27 100 | 31 700 |

Identify element **Y**.

Explain your answer using data from the table.

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(2)

- (d) Identify the Period 3 element that has the highest melting point.

Explain your answer by reference to structure and bonding.

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(4)

(Total 13 marks)

**Q17.**

Ions of two isotopes of iron are



Which statement is correct?

- A** The ions of both the isotopes have the electronic configuration  $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$  ☐
- B** The ions of both the isotopes contains 26 neutrons ☐
- C**  $^{53}\text{Fe}^{2+}$  has fewer protons than  $^{56}\text{Fe}^{2+}$  ☐
- D** After acceleration to the same kinetic energy  $^{56}\text{Fe}^{2+}$  will move more slowly than  $^{53}\text{Fe}^{2+}$  ☐

(Total 1 mark)

**Q18.**

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  $\text{ClF}_3$  and  $\text{CCl}_2$

- (i) Use your understanding of electron pair repulsion to draw the shape of  $\text{ClF}_3$   
and the shape of  $\text{CCl}_2$   
Include any lone pairs of electrons that influence the shape.

Shape of  $\text{ClF}_3$

Shape of  $\text{CCl}_2$

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(2)

- (ii) Name the shape of  $\text{CCl}_2$

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(1)

- (iii) Write an equation to show the formation of one mole of  $\text{ClF}_3$  from its elements.

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**Q19.**

- (a) **Table 1** shows some data about fundamental particles in an atom.

**Table 1**

| Particle | proton                   | neutron                  | electron                 |
|----------|--------------------------|--------------------------|--------------------------|
| Mass / g | $1.6725 \times 10^{-24}$ | $1.6748 \times 10^{-24}$ | $0.0009 \times 10^{-24}$ |

- (i) An atom of hydrogen can be represented as  $^1\text{H}$

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,  $^{10}\text{B}$  and  $^{11}\text{B}$

- (i) Calculate the percentage abundance of  $^{10}\text{B}$  in this naturally occurring sample of boron.

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(2)

- (ii) State, in terms of fundamental particles, why the isotopes  $^{10}\text{B}$  and  $^{11}\text{B}$  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 / $\text{kJ mol}^{-1}$ | 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)

## Q20.

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  $\text{AlCl}_4^-$  ion.

Name the type of bond formed in this reaction. Explain how this type of bond is formed in the  $\text{AlCl}_4^-$  ion.

Type of bond \_\_\_\_\_

Explanation \_\_\_\_\_

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(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  $\text{AlCl}_4^-$  ion.

\_\_\_\_\_ (1)

- (e) Draw and name the shape of the  $\text{TlBr}_5^{2-}$  ion.

Shape of the  $\text{TlBr}_5^{2-}$  ion.

Name of shape \_\_\_\_\_ (2)

- (f) (i) Draw the shape of the  $\text{TlCl}_2^+$  ion.

(1)

- (ii) Explain why the  $\text{TlCl}_2^+$  ion has the shape that you have drawn in part (f)(i).

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

(1)

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

Tick (✓) one box.

First

☐

Second

Third

(1)

(Total 10 marks)

**Q21.**

(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).

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(1)

(b) Nickel forms the compound nickel(II) chloride ( $\text{NiCl}_2$ ).

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

\_\_\_\_\_

(1)

- (ii) Balance the following equation to show how anhydrous nickel(II) chloride can be obtained from the hydrated salt using  $\text{SOCl}_2$ .  
Identify **one** substance that could react with both gaseous products.



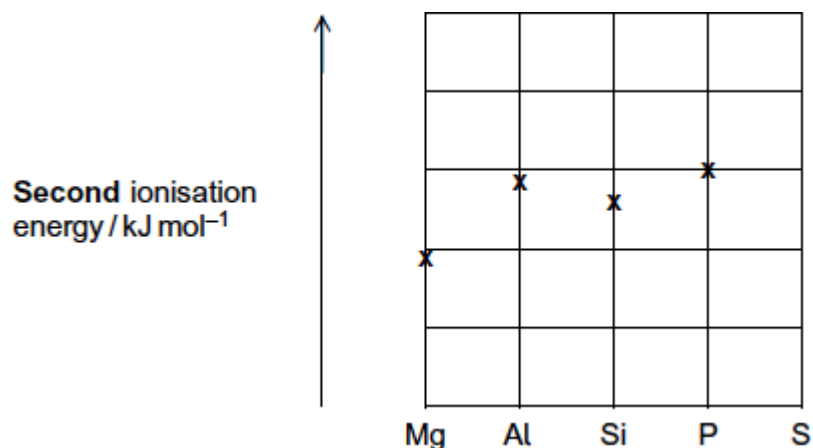
Substance \_\_\_\_\_

(2)

(Total 9 marks)

### Q22.

- (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  $\text{Al}^{2+}$  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 \_\_\_\_\_

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(2)

- (c) The following table gives the successive ionisation energies of an element in Period 3.

|                                          | First | Second | Third | Fourth | Fifth | Sixth |
|------------------------------------------|-------|--------|-------|--------|-------|-------|
| Ionisation energy / $\text{kJ mol}^{-1}$ | 786   | 1580   | 3230  | 4360   | 16100 | 19800 |

Identify this element.

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(1)

- (d) Explain why the ionisation energy of every element is endothermic.

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(1)

(Total 8 marks)

### Q23.

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.
- 
- (1)
- (d) Calcium nitride contains 81.1% by mass of the metal. Calculate the empirical formula of calcium nitride. Show your working.
- 
- 
- 
- 
- 
- 
- (3)
- (e) Write an equation for the reaction between silicon and nitrogen to form silicon nitride,  $\text{Si}_3\text{N}_4$
- 
- (1)
- (Total 7 marks)**

## Q24.

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

- (a) State the number of protons and the number of neutrons in an atom of the isotope  $^{85}\text{Rb}$
- 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 / $\text{kJ mol}^{-1}$ | 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  $^{85}\text{Rb}$  and  $^{87}\text{Rb}$  only. The isotope  $^{85}\text{Rb}$  has an abundance 2.5 times greater than that of  $^{87}\text{Rb}$

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  $^{88}\text{Sr}$  will have an atomic radius that is larger than, smaller than or the same as the atomic radius of  $^{87}\text{Rb}$ . Explain your answer.

Atomic radius of  $^{88}\text{Sr}$  compared to  $^{87}\text{Rb}$  \_\_\_\_\_

Explanation \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

(3)

(Total 16 marks)

## Q25.

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 \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

(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 \_\_\_\_\_

(3)

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

(1)

- (e) The table below gives the successive ionisation energies of an element.

|                                          | First | Second | Third | Fourth | Fifth |
|------------------------------------------|-------|--------|-------|--------|-------|
| Ionisation energy / kJ mol <sup>-1</sup> | 590   | 1150   | 4940  | 6480   | 8120  |

Deduce the group in the Periodic Table that contains this element.

(1)

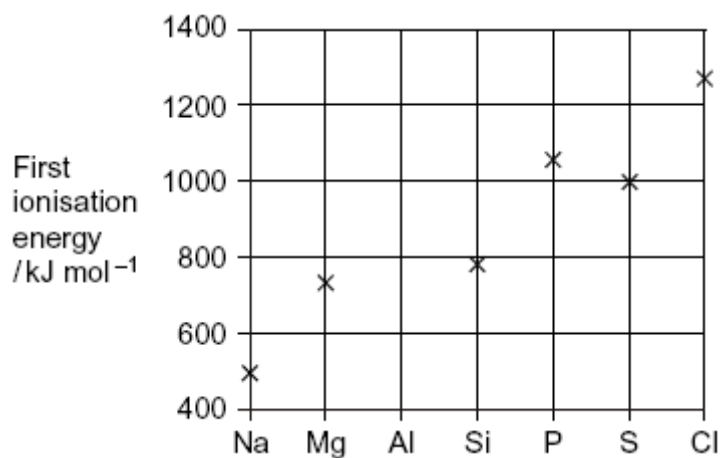
- (f) Identify the element that has a 5+ ion with an electron configuration of  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$

(1)

(Total 10 marks)

### Q26.

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.

\_\_\_\_\_ (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.

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_ (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 \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_ (3)

(Total 11 marks)

## Q27.

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 <sup>-1</sup> | 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 \_\_\_\_\_

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)**

**Q28.**

- (a) Complete the electronic configuration for the sodium ion,  $\text{Na}^+$   
 $1s^2$  \_\_\_\_\_

(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 / $\text{kJ mol}^{-1}$ | 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 \_\_\_\_\_

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

(3)

- (e) Sodium reacts with ammonia to form the compound  $\text{NaNH}_2$  which contains the  $\text{NH}_2^-$  ion. Draw the shape of the  $\text{NH}_2^-$  ion, including any lone pairs of electrons. Name the shape made by the three atoms in the  $\text{NH}_2^-$  ion.

(3)

Shape of  $\text{NH}_2^-$

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)

### Q29.

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

(2)

- (b) Complete the electron arrangement for the  $\text{Mg}^{2+}$  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  $\text{Mg}^{2+}$  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)

**Q30.**

- (a) When aluminium is added to an aqueous solution of copper(II) chloride,  $\text{CuCl}_2$ , copper metal and aluminium chloride,  $\text{AlCl}_3$ , 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.

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(4)

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

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(1)

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

*Trend* \_\_\_\_\_

*Explanation* \_\_\_\_\_

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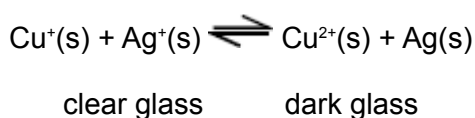
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(3)

(Total 9 marks)

### Q31.

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.



Which one of the following is a correct electron arrangement?

- A**  $\text{Cu}^+$  is  $[\text{Ar}]3\text{d}^94\text{s}^1$
- B**  $\text{Cu}$  is  $[\text{Ar}]3\text{d}^{10}4\text{s}^2$
- C**  $\text{Cu}^{2+}$  is  $[\text{Ar}]3\text{d}^84\text{s}^1$
- D**  $\text{Cu}^+$  is  $[\text{Ar}]3\text{d}^{10}$

(Total 1 mark)

### Q32.

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  $[\text{Fe}(\text{CN})_6]^{3-}$  is greater than the oxidation state of copper in  $[\text{CuCl}_2]^-$
- D The boiling point of  $\text{C}_3\text{H}_8$  is lower than that of  $\text{CH}_3\text{CH}_2\text{OH}$

(Total 1 mark)

### Q33.

The values of the first ionisation energies of neon, sodium and magnesium are 2080, 494 and 736  $\text{kJ mol}^{-1}$ , 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)

**Q34.**

Lithium hydride, LiH, is an ionic compound containing the hydride ion, H<sup>-</sup>. The reaction between LiH and aluminium chloride, AlCl<sub>3</sub>, produces the ionic compound LiAlH<sub>4</sub>.

- (a) Balance the equation below which represents the reaction between LiH and AlCl<sub>3</sub>.



(1)

- (b) Give the electronic configuration of the hydride ion, H<sup>-</sup>.

\_\_\_\_\_

(1)

- (c) Predict the shape of the  $\text{AlH}_4^-$  ion. Explain why it has this shape.

Shape \_\_\_\_\_

Explanation \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

(3)

- (d) A bond in  $\text{AlH}_4^-$  can be represented by  $\text{H} \rightarrow \text{Al}$

Name this type of bond and explain how it is formed.

Type of bond \_\_\_\_\_

Explanation \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

(3)

(Total 8 marks)

**Q35.**

- (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  $6.023 \times 10^{23} \text{ mol}^{-1}$ )

---

---

---

(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  $^{28}\text{Si}$  and also has six fewer neutrons than an atom of  $^{28}\text{Si}$ . Give the symbol, including the mass number and the atomic number, of this atom.

---

(2)

(Total 9 marks)

## Mark schemes

### Q1.

- (a) Assume current model unless otherwise stated.

Statement about the nucleus:

(Central) nucleus contains protons and neutrons.

*Allow "protons and neutrons are in the centre of the atom"*

1

Statement about electrons

Electrons are now arranged in energy levels/shells/orbitals

*Ignore "mostly empty space"*

*Ignore electrons surround / orbit nucleus*

*Allow additional statement about neutrons but must be separate from statement about nucleus to score*

*e.g.*

*no neutrons in plum pudding / neutrons now recognised*

1

- (b)  $1s^2 2s^2 2p^3$

*Ignore commas, capitals and subscripts*

*Allow  $1s^2 2s^2 2px^1 2py^1 2pz^1$*

1

- (c) (R is N (nitrogen))

Formula  $Be_3N_2$

*Accept  $Be_3R_2$  only if stated R = nitrogen*

*Accept  $N_2Be_3$*

1

[4]

### Q2.

- (a)  $M_r \text{ NaF} = 42(.0)$

*Incorrect  $M_r$  loses M1 & M4*

1

Mass NaF in 1 g =  $2.88 \times 10^{-5} \times 42.0$  (= 1.210 (1.2096)  $\times 10^{-3}$  g)

1

Mass NaF in 1 kg = 1.210 (1.2096) g

*$M3 = M2 \times 1000$  (g)*

*Units, if given, must match answer*

1

(Mass in mg = 1210 (1209.6) mg)

Concentration of NaF = 1210 (ppm)

*Allow  $1.21 \times 10^3$  ppm*

1

- (b) Toxic mass =  $3.19 \times 10^{-2} \times 75 \times 1000$   
 = 2390 mg  
 Allow 2393

1

- (c) Mass of toothpaste needed =  $\frac{2390}{2800}$   
 = 0.854 kg  
 Mark consequential to (b)  
 (b)  $\div 2800$  (to at least 2 sig fig)  
 Allow 0.85 - 0.86 kg

1

- (d) B  
 If not B, allow M2 only  
 If blank, read on.

1

Both  $\text{Na}^+$  and  $\text{F}^-$  same electron arrangement ( $1s^2 2s^2 2p^6$ ) or isoelectronic  
 Electronegativity, molecules or IMF = CE, M1 only

1

Sodium (ion) has more protons so attracts (outer) electrons closer / Sodium (ion)  
 has more protons so stronger attractions for (outer) electrons  
 Ignore shielding, higher charge density, atomic radius  
 If reference to fluorine rather than fluoride, then penalise 1  
 mark only

1

[9]

### Q3.

- (a)  $1s^2 2s^2 2p^6 3s^2 3p^6 (4s^0)$

1

- (b) **M1** In  $\text{Ca}^{(+)}$  (outer) electron(s) is further from nucleus

Or  $\text{Ca}^{(+)}$  loses electron from a higher (energy) orbital

Or  $\text{Ca}^{(+)}$  loses electron from a 4(s) orbital or 4th energy level or 4th energy  
 shell and  $\text{K}^{(+)}$  loses electron from a 3(p) orbital or 3rd energy level or 3rd  
 energy shell

Must be comparative

Allow converse arguments

1

**M2** More shielding (in  $\text{Ca}^+$ )

1

- (c) Be /Beryllium

1

- (d)  $\text{Mg}(\text{OH})_2$

1

- (e)  $\text{Ba}^{2+} + \text{SO}_4^{2-} \rightarrow \text{BaSO}_4$   
 Ignore state symbols

1

$$n \text{ BaCl}_2 (6/1000 \times 0.25) = 1.5 \times 10^{-3} \text{ and } n \text{ Na}_2\text{SO}_4 = (8/1000 \times 0.15) = 1.2 \times 10^{-3}$$

and BaCl<sub>2</sub> /barium chloride in excess

*Working required or  $3 \times 10^{-4}$  of BaCl<sub>2</sub>*

1

10 cm<sup>3</sup> (of 0.15 mol dm<sup>-3</sup> sodium sulfate)

*or 0.01dm<sup>3</sup>*

1

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

*Ignore protons and neutrons unless incorrect numbers*

*Not just electrons determine chemical properties*

1

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

*Alternative M2:*

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

1

$$\text{M3} \quad x = 10\% \text{ (or } x = 0.1)$$

$$\text{M3 } y = 8$$

1

$$\text{M4} \quad (\% \text{ abundance of 88 isotope is } 100 - 2x10) = \underline{80(.0)\%}$$

$$\text{M4 } \% \text{ of 88 isotope is } 100 - 10y = 80(.0) \%$$

*Allow other alternative methods*

1

(g) <sup>138</sup>Ba<sup>+</sup>

1

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

*Calculation of m in kg*

*If not converted to kg, max 4*

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

1

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

*For re-arrangement*

1

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

*For expression with square root*

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

1

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

*M5 must be to 3sf*

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

1

1

Alternative method

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

*M1 Calculation of m in kg*

1

**M2**  $v = d/t$

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

1

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

1

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

1

**M5**  $d = 1.53 - 1.54 \text{ (m)}$

*M5 must be to 3sf*

1

[18]

#### Q4.

(a)  $\text{Cl}^- 1s^2 2s^2 2p^6 3s^2 3p^6$

1

$\text{Fe}^{2+} 1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$

1

*If [Ne] or [Ar] used then Max 1 if both correct*

*Ignore 4s<sup>0</sup>*

*Allow subscripts*

(b)  $\text{Mn}^{2+} (\text{g}) \rightarrow \text{Mn}^{3+} (\text{g}) + \text{e}^-$

1

*States symbols are required*

*Allow  $\text{Mn}^{2+} (\text{g}) - \text{e}^- \rightarrow \text{Mn}^{3+} (\text{g})$*

*Negative charge needed on electron*

(c) Al

*Mg then CE = 0*

1

(Outer) electron in (3)p sublevel / orbital

*Not just level or shell*

1

Higher in energy / further from the nucleus  
so easier to remove OWTTE

*Both required for M3*

1

*Ignore shielding*

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

*M1 needs mass and charge – allow subscripts*

1

$$A_r = [(58 \times 61.0) + (60 \times 29.1) + (61 \times 9.9)] / 100$$

1

$$A_r = 58.\underline{9} \text{ must be to 1dp}$$

1

[9]

**Q5.**

**D**

[1]

**Q6.**

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

1

$$= 47.8$$

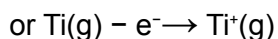
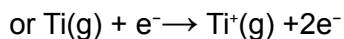
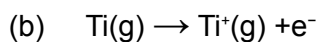
*Correct answer scores 2 marks.*

*Allow alternative methods.*

*Allow 1dp or more.*

*Ignore units*

1



*State symbols essential*

*Allow electrons without  $^-$  charge shown.*

1

46

1

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

1

(d) M1 is for re-arranging the equation

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

Allow  $t$  a square root of  $m$

1

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

Or

$$d = 1.5(47)$$

*This scores 2 marks*

*Allow this expression for M2*

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

1

$$= 9.6(14) \times 10^{-7}$$

Correct answer scores 3 marks.

1

[8]

**Q7.**

B

[1]

**Q8.**

C

[1]

**Q9.**

(a) [Kr] 5s<sup>2</sup> 4d<sup>10</sup>5p<sup>5</sup>

1

(b) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

### Level 3

All stages are covered and the explanation of each stage is correct and complete.

Answer communicates the whole explanation coherently and shows a logical progression from stage 1 to stage 2 and then stage 3.

5-6 marks

### Level 2

All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies **OR** two stages are covered and the explanations are generally correct and virtually complete.

Answer is mainly coherent and shows a progression through the stages. Some

steps in each stage may be out of order and incomplete.

3-4 marks

### Level 1

Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, **OR** only one stage is covered but the explanation is generally correct and virtually complete.

Answer includes some isolated statements, but these are not presented in a logical order or show confused reasoning.

1-2 marks

### Level 0

Insufficient correct chemistry to warrant a mark.

0 marks

### Indicative Chemistry content

#### Stage 1

$I_2$  is molecular.

$HI$  is molecular.

#### Stage 2

IMF hold the molecules together.

There are weak IMF forces hence the melting point is low in both substances.

$I_2$  bigger molecule than  $HI$  so  $I_2$  has more electrons.

#### Stage 3

Therefore stronger van der Waals between molecules in  $I_2$  that need more energy to break causing the melting point to be higher.

$HI$  also shows permanent dipole-dipole attraction between molecules but these forces are less than the vdW forces in iodine.

6

- (c) No delocalised electrons or ions

1

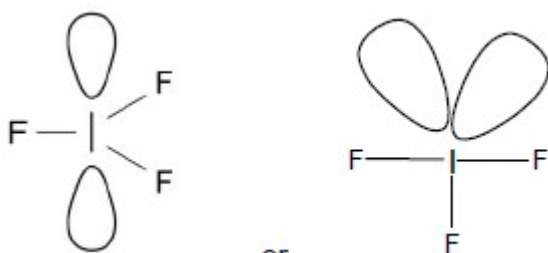
- (d)  $\frac{1}{2}H_2 + \frac{1}{2}I_2 \rightarrow HI$

Allow multiples

1

- (e)  $NH_4I_3$

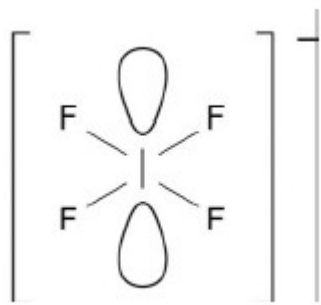
1



- (f)

Allow any shape with 3 bond pairs and 2 lone pairs

1



*Allow any shape with 4 bond pairs and 2 lone pairs (e.g. lone pairs in equatorial positions)*

1

(g) +5

1

+7

1

[14]

**Q10.**

C

[1]

**Q11.**

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

*Allow correct numbers that are not superscripted*

1

(b)  $\text{Ca(s)} + 2\text{H}_2\text{O(l)} \longrightarrow \text{Ca}^{2+}(\text{aq}) + 2\text{OH}^-(\text{aq}) + \text{H}_2(\text{g})$

*State symbols essential*

1

(c) Oxidising agent

1

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

*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]

**Q12.**(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 ( $4s^23d^3$ ) 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

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

*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

$$\text{Moles of SO}_2 = pV / RT = (98\,000 \times 506 \times 10^{-6}) / (8.31 \times 293)$$

$$= 2.04 \times 10^{-2}$$

1

**Stage 2:** moles of electrons added to  $\text{NH}_4\text{VO}_3$ 

When  $\text{SO}_2$  (sulfur(IV) oxide) acts as a reducing agent, it is oxidised to sulfate(VI) ions so this is a two electron change

1

$$\text{Moles of electrons released when SO}_2 \text{ is oxidised} = 2.04 \times 10^{-2} \times 2$$

$$= 4.08 \times 10^{-2}$$

1

**Stage 3:** conclusionBut in  $\text{NH}_4\text{VO}_3$  vanadium is in oxidation state 5

1

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

1

**[11]****Q13.**

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

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^3$  1

*If noble gas core used correctly in both then scores 1*

*Allow subscripts and capitals*

*Ignore  $4s^0$*

(b)  $Sr^{2+}$  1

*Ignore name and correct proton/mass number*

*Allow  $Sr^{+2}$*

(c)  $Ca_3P_2$  1

*Allow reversed or ionic formula*

*Ignore name*

[4]

#### Q14.

A

[1]

#### Q15.

(a)  $Mg^{(2+)}$  or Magnesium 1  
*Na<sup>+</sup> CE=0*

Because  $Mg^{2+}$  has more protons

AND

With the same shielding/screening/electron arrangement/number of electrons (or isoelectronic)

*Allow larger/stronger nuclear charge*

*Ignore atomic radius*

(b)  $Na(g) \rightarrow Na^+(g) + e^-$  1

*1 for correct species and gas phase*

*Allow e without charge*

*Allow  $Na(g) - e^- \rightarrow Na^+(g)$*

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

(c) Mg between 600-800 1

S between 800-1040

*If S not lower than P on graph then M1 only*

*If no plots on graph must state S below P to access M3 & M4*

1

e<sup>-</sup> paired in (3)p orbital in S (owtte)  
*Allow (3)p subshell/sublevel provided pair mentioned*

1

Paired e<sup>-</sup> repel (so less energy needed to remove)

1

[7]

### Q16.

(a) General increase

*If not increase then CE*

1

Greater nuclear charge / more protons

1

Same shielding / electrons added to same shell

*Allow similar*

1

Stronger attraction (from nucleus) for outer electron(s)

*Allow electron in outer shell*

1

(b) Aluminium / Al (lower than Mg)

*CE if not Al or S*

1

(Outer) electron in (3)p orbital / sub-shell (level)

*If 2p or 4p orbital lose M2 and M3*

1

(3p) higher in energy

*Allow more shielded or weaker nuclear attraction*

*M3 is dependent on M2*

1

or

Sulfur / S (lower than P)

(Outer) electrons in (3)p orbital begin to pair

Repel

*If 2p or 4p orbital lose M2 and M3*

*Allow 2 electrons in (3)p*

*M3 is dependent on M2*

(c) Sulfur / S

*CE if not S*

1

Large jump after 6<sup>th</sup> or between 6<sup>th</sup> and 7<sup>th</sup>

*Do not allow M2 if atom/ion is removed*

1

(d) Silicon

*CE if not Si*

1

Giant covalent structure / macromolecule

1

Covalent (bonds)

*Giant covalent scores M2 and M3*

1

Many / strong (covalent bonds) or

(covalent bonds) need lots of energy to break

CE for M2-M4 if molecules / metallic / ionic / IMFs mentioned

1

[13]

Q17.

D

[1]

Q18.

(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

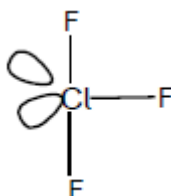
1

(c) Chlorine / Cl

Not Cl<sub>2</sub>, Not CL, Not Cl<sup>2</sup>

1

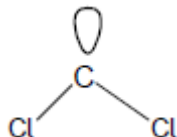
(d) (i)



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

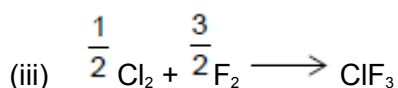
1

(ii) Bent / v shape

Ignore non-linear, angular and triangular

Apply list principle

1



No multiples

Ignore state symbols

1

[11]

### Q19.

(a) (i)  $1.6734 \times 10^{-24} \text{ (g)}$

Only.

$1.6734 \times 10^{-27} \text{ kg}$

Not  $1.67 \times 10^{-24} \text{ (g)}$ .

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  $5 \times 0.2$  divisions between 10 and 11.

1

abundance of  $^{10}\text{B}$  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

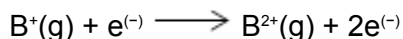
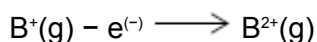
*Ignore protons unless wrong.*

1

- (c) Range between 3500 and 10 000 kJ mol<sup>-1</sup>

1

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



*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.*

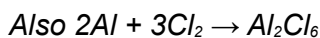
1

[8]

## Q20.

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

*Accept multiples.*



*Ignore state symbols.*

1

- (b) Coordinate / dative (covalent)

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

1

Electron pair on Cl<sup>-</sup> donated to Al(Cl<sub>3</sub>)

*QoL*

*Lone pair from Cl<sup>-</sup> not just Cl*

*Penalise wrong species.*

1

- (c)  $Al_2Cl_6$  or  $AlBr_3$

Allow  $\text{Br}_3\text{Al}$  or  $\text{Cl}_6\text{Al}_2$

Upper and lower case letters must be as shown.

Not  $2\text{AlCl}_3$

1

- (d)  $\text{SiCl}_4$  / silicon tetrachloride

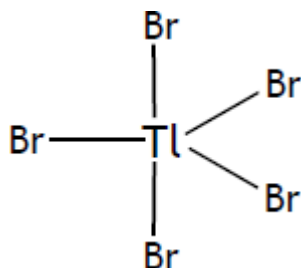
Accept silicon(4) chloride or silicon(IV) chloride.

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)  $\text{Cl} - \text{Tl} - \text{Cl}$

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]

## Q21.

- (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 delocalised / mobile / free / sea of electrons

Ignore atoms.

1

Strong attraction between them or strong metallic bonds

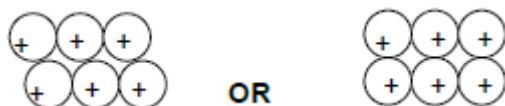
Allow 'needs a lot of energy to break / overcome' instead of 'strong'.

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<sup>+</sup> sign.

2

(iv) Layers / planes / sheets of atoms or ions can slide over one another  
QoL.

1

(b) (i) 1s<sup>2</sup> 2s<sup>2</sup> 2p<sup>6</sup> 3s<sup>2</sup> 3p<sup>6</sup> 3d<sup>8</sup> (4s<sup>0</sup>)  
Only.

1

(ii) NiCl<sub>2</sub>.6H<sub>2</sub>O + 6 SOCl<sub>2</sub> → NiCl<sub>2</sub> + 6 SO<sub>2</sub> + 12 HCl  
Allow multiples.

1

NaOH / NH<sub>3</sub> / CaCO<sub>3</sub> / CaO

Allow any name or formula of alkali or base.

Allow water.

1

[9]

## Q22.

(a) (i) Higher than P

1

(ii) 1s<sup>2</sup> 2s<sup>2</sup> 2p<sup>6</sup> 3s<sup>1</sup>

Allow any order

1

(iii) Al<sup>+</sup>(g) + e<sup>(-)</sup> → Al<sup>2+</sup>(g) + 2e<sup>(-)</sup>

OR

Al<sup>+</sup>(g) → Al<sup>2+</sup>(g) + e<sup>(-)</sup>

OR

Al<sup>+</sup>(g) - e<sup>(-)</sup> → Al<sup>2+</sup>(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<sup>+</sup>*

1

Electron (removed) from the 2<sup>nd</sup> 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]

### Q23.

- (a) N<sup>3-</sup> / N<sup>-3</sup>

1

- (b) F<sup>-</sup>/ fluoride

*Ignore fluorine/F*

*Penalise FI*

1

- (c) Li<sub>3</sub>N / NLi<sub>3</sub>

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*

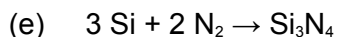
1

Ca<sub>3</sub>N<sub>2</sub>

*If Ca<sub>3</sub>N<sub>2</sub> shown and with no working award 3 marks*

If  $\text{Ca}_3\text{N}_2$  obtained by using atomic numbers then lose M1

1



Accept multiples

1

[7]

**Q24.**

(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.

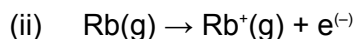
Not highly charged electrons.

1

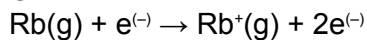
Knock out electron(s)

Remove an electron.

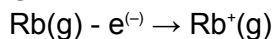
1



**OR**



**OR**



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

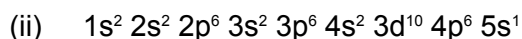
Answer should be comparative.

1

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

Only

1



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<sup>85</sup>Rb 71.4% and <sup>87</sup>Rb 28.6%*

*M2 divide by 100*

1  
1

$$\underline{85.6}$$

$$M3 = \underline{85.6}$$

1

(f) Detector

*Mark independently*

*Allow detection (plate).*

1

Current / digital pulses / electrical signal related to abundance

*Not electrical charge.*

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*

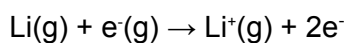
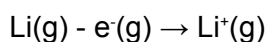
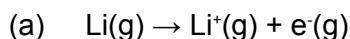
*(Outer) electron entering same shell/sub shell/orbital/same number of shells.*

*Do not allow incorrect orbital.*

1

[16]

**Q25.**



*One mark for balanced equation with state symbols*

|     |                                                                                                                                                                                                                                                             |   |
|-----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
|     | Charge and state on electron need not be shown                                                                                                                                                                                                              | 1 |
| (b) | Increases<br><i>If trend wrong then CE = 0/3 for (b). If blank mark on.</i>                                                                                                                                                                                 | 1 |
|     | Increasing nuclear charge / increasing no of protons<br><i>Ignore effective with regard to nuclear charge</i>                                                                                                                                               | 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<br><i>If not lower then CE = 0/3</i>                                                                                                                                                                                                                  | 1 |
|     | Paired electrons in a (4) p orbital<br><i>If incorrect p orbital then M2 = 0</i>                                                                                                                                                                            | 1 |
|     | (Paired electrons) repel<br><i>If shared pair of electrons M2 + M3 = 0</i>                                                                                                                                                                                  | 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<br><i>CE if molecule mentioned</i><br><i>Must be comparative answer</i><br><i>QWC</i> | 1 |
| (e) | 2 / two / II                                                                                                                                                                                                                                                | 1 |
| (f) | Arsenic / As                                                                                                                                                                                                                                                | 1 |

[10]

## Q26.

|     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |   |
|-----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| (a) | Cross between the Na cross and the Mg cross                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1 |
| (b) | $\text{Al(g)} \rightarrow \text{Al}^+(\text{g}) + \text{e}^-$<br>$\text{Al(g)} - \text{e}^- \rightarrow \text{Al}^+(\text{g})$<br>$\text{Al(g)} + \text{e}^- \rightarrow \text{Al}^+(\text{g}) + 2\text{e}^-$<br><i>One mark for state symbols consequential on getting equation correct.</i><br><i>Electron does not have to have the – sign on it</i><br><i>Ignore (g) if put as state symbol with e<sup>-</sup> but penalise state symbol mark if other state symbols on e<sup>-</sup></i> | 2 |

- (c) 2<sup>nd</sup>/second/2/II  
Only  
1
- (d) Paired electrons in (3)p orbital  
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]

**Q27.**

- (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*

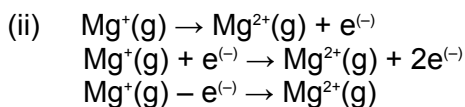
*M2 is dependent on a reasonable attempt at M1*

*Energy needed for this change*

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

*This equation alone scores one mark*

1



*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  $\text{kJ mol}^{-1}$

1

- (c) Increase

*If decrease CE = 0/3*

*If blank mark on*

1

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

*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<sub>2</sub>

1

[13]

**Q28.**

(a) 2s<sup>2</sup> 2p<sup>6</sup>;

*If ignored the 1s<sup>2</sup> given and written 1s<sup>2</sup>2s<sup>2</sup>2p<sup>6</sup> mark as correct  
Allow capitals and subscripts*

1

(b) (i) Na<sup>+</sup>(g) → Na<sup>2+</sup>(g) + e<sup>(-)</sup>;

*One mark for equation and one mark for state symbols*

Na<sup>+</sup>(g) + e<sup>(-)</sup> → Na<sup>2+</sup>(g) + 2e<sup>(-)</sup>;

*M2 dependent on M1*

*Allow Na<sup>+</sup>(g) – e<sup>(-)</sup> → Na(g)*

*Allow X<sup>+</sup>(g) → X<sup>2+</sup>(g) + e = 1 mark*

2

(ii) Na<sup>(2+)</sup> requires loss of e<sup>-</sup> from a 2(p) orbital or 2<sup>nd</sup> energy level or 2<sup>nd</sup> shell and Mg<sup>(2+)</sup> requires loss of e<sup>-</sup> from a 3(s) orbital or 3<sup>rd</sup> energy level or 3<sup>rd</sup> shell / Na<sup>(2+)</sup> 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<sup>(-)</sup> 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]

## Q29.

- (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)*

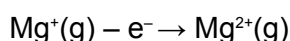
1

- (c) 's' block

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

1

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



1

- (e) Mg<sup>2+</sup> ion smaller than Ne atom / Mg<sup>2+</sup> e<sup>-</sup> closer to nucleus  
(Not 'atomic' radius fo Mg<sup>2+</sup>) 1
- Mg<sup>2+</sup> has more protons than Ne / higher nuclear charge or  
e<sup>-</sup> is removed from a charged Mg<sup>2+</sup> ion / neutral neon atom  
(accept converse arguments)  
(If used 'It' or Mg/magnesium/Mg<sup>3+</sup> etc. & 2 correct reasons,  
allow (1)) 1
- (f) (i) trend: increases  
(if 'decreases', CE = 0/3) 1
- Expl<sup>n</sup>: 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<sup>-</sup> pair in the 3p sub-level  
(penalise if wrong shell, e.g. '2p', quoted) 1
- repulsion between the e<sup>-</sup> in this e<sup>-</sup> pair  
(if not stated, 'e<sup>-</sup> pair' must be clearly implied)  
(mark M4 and M5 separately) 1

[12]

**Q30.**

- (a)  $2\text{Al} + 3\text{CuCl}_2 \rightarrow 2\text{AlCl}_3 + 3\text{Cu}$ ;  
(accept multiples/fractions)
- OR
- $2\text{Al} + 3\text{Cu}^{2+} \rightarrow 2\text{Al}^{3+} + 3\text{Cu}$ ; 1
- (b) (i) increases; 1
- (ii) lower than expected / lower than Mg / 1
- less energy needed to ionise; e<sup>-</sup> removed from (3)p sub-level; 1
- ('e<sup>-</sup> removed' may be implied)
- of higher energy / further away from nucleus / shielded by 3s e<sup>-</sup>s; 1

(c)  $\text{Al}^+(\text{g}) \rightarrow \text{Al}^{2+}(\text{g}) + \text{e}^-$ ; 1

(d) trend: increases; 1

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

1

OR

stronger metallic bonding; 1

[9]

**Q31.**

D

[1]

**Q32.**

A

[1]

**Q33.**

(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)  $\text{Mg}^+(\text{g}) \rightarrow \text{Mg}^{2+}(\text{g}) + \text{e}^-$  Equation 1

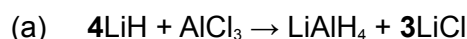
**Or**  $\text{Mg}^+(\text{g}) + \text{e}^- \rightarrow \text{Mg}^{2+}(\text{g}) + 2\text{e}^-$  State symbols (Tied to M1) 1

(c) Increased/stronger nuclear charge **or** more protons 1

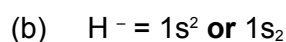
Smaller atom **or** electrons enter the same shell **or** same/similar shielding 1

(d) Electron removed from a shell of lower energy **or** smaller atom **or**  $\text{e}^-$  nearer 1

nucleus **or**  $\text{e}^-$  removed from 2p rather than from 3s  
Less shielding  
(Do not accept ' $\text{e}^-$  from inner shell')

**Q34.**

1



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  $\text{H}^-$  to Al **or** shared between H and Al  
(*tied to M2*)  
(*Not 'from H atom'*) (*Not 'to Al ion'*) (*Not 'e-s transferred'*)

1

**Q35.**

(a) (i) Atoms with the same number of protons / proton number **(1)**  
NOT same atomic number

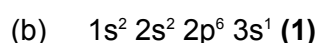
with different numbers of neutrons **(1)**  
**NOT** different mass number / fewer neutrons

(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



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)  ${}^{15}_7\text{N}$  N correct symbol **(1)**  
allow  ${}^{15}_7\text{N}$

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

2

[9]

## Examiner reports

### Q1.

- (a) Most students understood that electrons are now arranged in energy levels, although many didn't make reference to sub-atomic particles in their answer. Students did not always make a comparison and it was not always clear which model they were referring to in their responses.
- (b) Almost all students (91.3%) were able to write the correct electron configuration in terms of shells and sub-shells, although a few students made no reference to sub-shells.
- (c) Many students were able to identify that the two elements were nitrogen and beryllium but many were then unable to write the correct formula of the compound formed between them.

### Q2.

- (a) Almost all students were able to give the correct Mr for sodium fluoride but many became confused by the different units involved in this question. Students should be advised that they should explain their working for each step in a calculation. When only numbers were provided in an answer, it was not clear what students were calculating in each step.
- (b) A good number of students (39.9%) were able to determine the maximum mass of sodium fluoride that a 75.0 kg person could swallow without reaching a toxic concentration, although a few struggled with the conversion to mg.
- (c) Many students completed this calculation with the figures upside-down and so were unable to score. A surprisingly high proportion of students (16%) made no attempt whatsoever at this question.
- (d) Many students were unable to identify the correct relative sizes – many stated that both ions were the same size because they had the same number of electrons, without considering the impact of the protons. Other students did not appreciate that both ions were isoelectronic.

### Q3.

- (a) The electron configuration was well known (88.9% correct).
- (b) Only the best students gained both marks here (19%); many students focused on whether the electron was being removed from a full or partially full orbital instead of considering why the attraction between the nucleus and the electron might be different.
- (c) Less than half of the students (39.5%) could give the correct answer here; lithium was a common error.
- (d) The majority of students (76.3%) answered this correctly, although there were quite a number who gave the incorrect formula.
- (e) The ionic equation was generally correct and many students could also calculate that barium chloride was in excess. Just under a third of students managed to score all three marks.

- (f) Most students could state why isotopes have the same chemical properties. In the calculation, many students gave an algebraic equation with two unknowns and could not proceed any further. The students who gave a correct algebraic expression with one unknown could work through the calculation and generally gained full marks. Some students answered the question by trial and error and this was also given full credit. Pleasingly, 43.7% of students gained all four marks available.
- (g) Most students deduced that the mass number of the ion would be 138 but less than 30% of students could give the correct formula for the ion including its charge.
- (h) Some students answered this part very well (with 36.6% scoring full marks), but most students scored partial marks or no marks; common errors included failure to use the Avogadro constant, not converting mass to kg, and incorrect rearrangement of expressions.

#### Q4.

- (a) This was surprisingly poorly answered. Many students were unable to write the electronic configuration for  $\text{Fe}^{2+}$ .
- (b) Part (b) was generally well answered, but a significant number of answers had missing state symbols, despite the direct instruction to include them.
- (c) Part (c) was quite well answered.
- (d) The symbol including mass number was often incorrect. The calculation of  $A_r$  was straight-forward and done well by many students.

#### Q5.

69% of students scored this mark.

#### Q6.

- (a) This was generally well answered, though a few students added the abundances incorrectly.
- (b) Most students gave the correct equation, but some used the wrong state symbols or omitted them. The identity of the isotope was well known but some students lost a mark by using the symbol for the atom rather than the  $m/z$  value.
- (c) The most common error was a failure to convert from grams into kilograms.
- (d) Only the best students gained all three marks. All marks were available, even for those students who had not answered part (c), or who had the wrong answer for it. Some students were unable to re-arrange the equation. Students who appreciated that the distance travelled was common to both ions usually went on to get the correct answer, but a large number of students scored zero or one mark.

#### Q13.

Aspects of this question were well done but significant numbers were unable to write the electronic configuration of the  $\text{Cr}^{3+}$  ion. part (b) was answered well but the unfamiliar formula required in (c) proved tricky for the majority.

#### Q15.

Most of this question was answered correctly but many students failed to appreciate that the ions compared in part (a) had the same number of electrons therefore 1 mark was scored rather than 2. It was pleasing to see over half the students scoring 3 or more marks on part (c)

#### Q16.

In part (a) the trend in ionisation energy was explained well with many scoring three or four marks. Many students did not read the question carefully and explained the anomalies in the trend. Those who lost a mark usually omitted the key word 'outer' in respect of the electron being removed. In part (b) many students correctly identified and explained an element that deviated from the general trend. In part (c) most were able to recognise the large jump after the sixth ionisation energy and deduce the element as sulfur. Most students knew that silicon had the highest melting point and went on to score full marks, although aluminium was a common incorrect answer. The quality of language was not always sufficiently clear and some used chemical terms incorrectly such as covalent bonds between molecules or strong van der Waals forces between atoms.

#### Q18.

The students who selected the correct element in part (a) generally went on to score full marks. However a large number thought that argon had the highest melting point and therefore did not score any marks. In part (b) the majority of students selected argon and gave an explanation of their choice. If the answer was correct the most common problem was missing the shielding factor necessary for the third mark. Part (c) was answered correctly by most students. The shape of  $\text{ClF}_3$  was found easier to draw than  $\text{CCl}_2$  in part (d)(i) and the name of the shape in (d)(ii) was answered correctly by many students. The most common error in part (d)(iii) was to write an equation to produce two moles rather than one mole as stated in the question.

#### Q19.

The overall performance in part (a)(i) was disappointing because many students did not know the subatomic particles in the hydrogen atom. The mark in part (a)(ii) was scored by most students. Many students scored both marks in part (b)(i) but several quoted an equation involving  $x$  and  $y$  but could not progress beyond that. The majority of students answered part (b)(ii) correctly and part (c) was also generally well done. In part (d), many students used Br instead of B in their equation and some either wrote the wrong ionisation energy or failed to add state symbols. Many answers to part (e) were superficial; many students simply referred to a different proton / electron ratio or the removal of an electron from a different energy level.

#### Q20.

The equation in part (a) was given correctly by only a few students. Far too many students could not give the correct formula for aluminium chloride. The type of bonding in part (b) was well answered but many students thought that the pair of electrons originated from the Cl atom or from the Al atom. In part (e), the majority of students gave a correct structure and formula. Incorrect answers were due to the insertion of lone pairs of electrons. The linear shape in part (f) was generally answered well but the explanation of the shape often did not refer to repulsion between the bonding electron pairs. The majority of students scored the mark in part (g), realising that the outer electrons are removed first during successive ionisations.

#### Q21.

This question was generally quite well answered. In part (a)(i), most students knew the correct block in the Periodic Table although some seemed to think that the name 'Transition Metals' was enough to identify the d block. In part (a)(ii), the biggest issue was the omission of 'positive' when describing ions and 'delocalised' when describing the electrons involved in the bonding. The diagrams in part (a)(iii) generally scored highly but some were untidy and failed to show a regular arrangement of ions. Surprisingly, many students did not refer to layers of atoms / ions sliding in part (a)(iv) and therefore did not score the mark. Answers to part (b)(i) were disappointing and showed that students could not write the electron configuration of ions in the d block. Balancing the equation proved difficult but a good number of students did this well and many students could suggest a suitable substance in part (b)(ii).

## Q22.

The concept of second ionisation energy discriminated well. Good students could apply their understanding of ionisation energy and gave good answers to this question. Weaker students found much of the question difficult.

In part (a)(i), many students thought incorrectly that the cross was below phosphorus. The electron configuration in part (a)(ii) was well answered and the main error in part (a)(iii) was omitting state symbols. Answers to part (a)(iv) often failed to mention the electron being removed and there were several confused responses with inappropriate use of shell / energy level rather than sub-shell / orbital. A large number of students thought that argon had the highest second ionisation energy and therefore could not score the rest of the marks in part (b). The students who did quote sodium often found the explanation difficult. In part (c), various elements were quoted but it was evident that some students did not know which was Period 3. In part (d), many students simply stated the meaning of endothermic but did not explain why the ionisation was endothermic. Some students had the idea that a bond was broken but failed to extend this to an attraction between the nucleus and the electrons.

## Q23.

A lot of correct answers were seen in part (a) although many students found this difficult and answers giving incorrect charges ranging from  $-1$  to  $+4$  were seen. Some students lost marks by trying to write an equation rather than just stating the ion. In part (b), many students did not refer to an ion in their answer. Many students did not appreciate the  $-ide$  ending in part (c) and produced formulae such as  $\text{LiNO}_3$ . Many of those who realised that the formula contained only Li and N gave incorrect formulae such as  $\text{LiN}$ ,  $\text{LiN}_3$ ,  $\text{Li}_4\text{N}$  etc. In the empirical formula calculation in part (d), there were many students who could get no further than the 2.02 : 1.35 ratio and weaker students divided the percentage of nitrogen by 28 rather than by 14. A small number of students used incorrect fractions by dividing the relative atomic mass by the percentage and getting  $\text{Ca}_2\text{N}_3$ . The equation in part (e) proved demanding with many students writing atomic nitrogen, N and molecular silicon eg  $\text{Si}_2$ ,  $\text{Si}_8$ . A few incorrect symbols for silicon were seen ie S rather than Si.

## Q24.

Part (a) was done very well. In part (b)(i), many students stated that a positive ion was formed but failed to say how. The equation in part (b)(ii) was well done with only a few omitting the state symbols. In part (c), a number of students failed to score the mark since they referred to a rubidium molecule, showing a lack of understanding of the metals given. In part (d)(ii) there were many students who filled the 4d rather than the 5s orbitals and some gave an abbreviated electron structure even though the question asked for the full electron structure. Many students found part (e) difficult although it was pleasing to see some gain full marks. Part (f) was not well understood with many students confusing charge and current. The answers to part (g) were generally good although a few students

did not give complete explanations and lost the last mark.

### Q25.

Candidates generally attempted part (a) well although there were some candidates who failed to score the mark since the state symbols were missing or, due to unclear writing, it was impossible to distinguish if the state symbol was an 's' or 'g'. Part (b) was well answered by most candidates. In order to give a convincing answer in part (c), candidates needed to understand what an orbital is. Many incorrect answers showed that candidates confused principal energy levels and orbitals. Many answers stated that electrons repel and did not refer to repulsion of the paired electrons in the relevant p orbital. There was also confusion between paired electrons repelling and the repulsion of paired electrons that is used to explain molecular shapes. Most candidates answered part (d) well. Parts (e) and (f) discriminated quite well and a range of answers were seen.

### Q26.

Part (a) was answered well. The equation in part (b) was generally well known although many candidates lost the second mark for omitting the state symbols or having the electron on the wrong side of the equation. Part (c) was answered correctly by a good number of candidates. The explanation in part (d) was variable with much confusion over paired electrons and lone pairs of electrons. There was much inaccuracy in the use of terminology in candidates' answers. Answers to part (e) were variable and answers included almost every element in period 2. Part (f) was well done by a majority of candidates.

### Q27.

Part (a) was answered well by most candidates with some writing the electron configuration of Mg rather than the ion. Some candidates wrote subscripts for the numbers of electrons even though the  $1s^2$  was given. In part (b)(i) many candidates could not give a precise definition. The commonest errors were to mix up moles and atoms or to miss out the gaseous state. Many candidates missed the state symbols from the equation in part (b)(ii) and some gave equations showing the removal of 2 electrons. Part (b)(iii) was not well answered. There was a good attempt at part (b)(iv). In part (c) the trend was generally well known as was the increasing nuclear charge. Imprecise technical language cost several candidates a mark - "a bigger nucleus" is not the same as "a nucleus with a bigger charge". Part (d) was well answered with most candidates knowing the deviation and the explanation. Marks were lost for not stating that the paired electrons were in the p orbital and some thought they were in the 2p orbital. There were many correct answers to part (e).

### Q28.

The electronic configuration in part (a) was generally well known. In part (b)(i) the removal of 2 electrons from the neutral atom was a common incorrect answer and in (b)(ii) many candidates missed the effect of change of shielding. Often candidates referred to s and p orbitals with no reference to the number of the principal energy level. Part (b)(iii) was disappointing and showed that many candidates find it difficult to apply concepts to different situations. Part (c) was generally well known although many candidates did not score the second explanation mark. In part (d) many candidates did not realise that metallic bonding, or an explanation of it, was required in the answer. Many thought that van der Waals forces were involved or mentioned losing electrons causing ionisation. In part (e) there were many unclear diagrams and many candidates had the wrong number of lone pairs of electrons. Answers to the shape of the molecule were often incorrect or contradictory e.g. bent-linear. Part (f) was well answered.

### Q29.

Candidates tended to score a little better on this question than on question 3 but, overall, the question was not well answered. Part (a) was generally well done, although incomplete answers were quite common. The most common error was to omit reference to *gaseous atoms*.

Parts (b) and (c) were often well answered; however, in part (d) incorrect ionic charges and missing or incorrect state symbols were quite often seen.

Part (e) was poorly done. Many candidates referred to difference in the number of electron shells present in the two species despite being told in the question that they had the same number of electrons. Some candidates attributed the difference to a special stability enjoyed by neon as a consequence of it having a full outer electron shell. Clearly, the majority of candidates failed to appreciate the significance of the two species having the same number of electrons. Many answers referred to "It", magnesium or Mg, rather than correctly identifying the species being discussed.

In part (f), candidates are asked to demonstrate their understanding of a trend required in the specification. While part (f)(i) was often competently dealt with, answers in part (f)(ii) frequently lacked sufficient specific detail to be awarded credit. Often, candidates failed to identify the electron pair from which the first electron would be removed, or to explain the relatively low first ionisation energy of sulphur in terms of repulsion between the electrons in this electron pair. Vague phrases such as '*electron pairs repel*', or a reference to a more stable half-filled shell being formed, earned no credit.

### Q30.

While less able, (or less well prepared,) candidates struggled with this question, the majority coped quite well. The equation in part (a) was usually correct, although it was not unusual to see  $\text{Al}_2$ ,  $\text{Al}^{3+}$  or  $\text{Cu}_2$  in the equation, or for the equation to be incorrectly balanced. Most candidates correctly identified an increase in ionisation energy across the group; however, the explanations in part (b)(ii) were frequently vague and unconvincing. In particular, statements that the electron in aluminium was *easier to remove*, rather than making direct reference to the lower ionisation energy of aluminium, failing to specify the 3p electron as being the first electron to be removed from aluminium or vaguely referring to extra shielding, were quite common. In part (c) some candidates did not start their equation with  $\text{Al}^+$  ions and many more either omitted the state symbols completely or used the wrong one. The majority of candidates correctly identified a rising trend in the melting point of the three metals in part (d) but the explanations offered were diverse and frequently incomplete or wrong. Those candidates who did correctly attribute the trend to an increase in proton number or to the number of delocalised electrons often proceeded no further, or simply referred, without explanation, to an increase in metallic bonding. Many explanations were poor, and references to *molecules*, *ionic bonding*, *van der Waals' forces* and even *hydrogen bonding* were frequently seen.

### Q33.

This question was, in general, poorly answered. In part (a), the definition was not well known, *element* was frequently used in place of *atom*, and the requirement for gaseous conditions was often omitted. In part (b) the equation was frequently correct; however, equations showing Mg going to  $\text{Mg}^{2+}$  ions were not unusual. Again, the gaseous state symbol was often omitted. In part (c), some candidates based their argument on the stability of the full shell of the  $\text{Na}^+$  ion and the lower stability of the incomplete outer shell of the  $\text{Mg}^+$  ion. Other candidates suggested that sodium atoms *wanted to lose an electron*. These arguments earned no credit. In part (d) similar incorrect arguments to those used in part (c) were frequently seen, as well as vague references to differences in charge density

and comparisons of metallic bonding strengths.

#### Q34.

This question was, in general, also poorly answered. Of those candidates who attempted part (a), most were successful; however, a surprisingly large number of candidates made no attempt to balance the equation. Whilst, in part (b), most candidates gave the correct electronic arrangement for the hydride ion;  $1s^0$  and  $1s^12s^1$  were quite common errors.

Candidates encountered many problems in deducing the shape of the  $AlCl_4^-$  ion, with *trigonal planar*, *square planar* and *distorted tetrahedral* being the most common errors. Some candidates drew diagrams to illustrate their answer, many of which showed a lone pair on the Al atom. The explanation was frequently incomplete, or incorrectly referred to repulsions between *hydrogen atoms* or *hydride ions*, rather than between four bonding electron pairs. In part (d), many candidates were able to identify the bonding as dative/coordinate but then simply described, in general terms, the formation of such a bond. References to the donation of a lone pair from the hydride ion to the aluminium atom were relatively rare.

#### Q35.

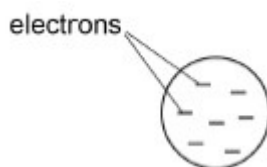
Many good answers were seen here and high marks were quite common. However, candidates frequently ignored the instruction in (a)(i) to define *isotopes* in terms of fundamental particles, and offered a definition based wholly, or in part, on mass number and atomic number. In (a)(ii), the link between chemical properties and electron configuration was well known but many candidates attempted to establish a link between proton, neutron or mass numbers and chemical properties. The calculation in (a)(iii) was often poorly done, the most common errors being to invert the expression or to multiply the mass number by  $L$ . Part (b) was generally well answered, although a few candidates gave the electron arrangement showing 23 electrons. Similarly, part (c) was generally well answered, however, some candidates referred to electrons being in the *d block*, while a small minority offered nonsense explanations. Most candidates correctly identified nitrogen as the element in part (d), but  ${}^{14}_7N$  was a common error.

### Q1.

This question is about atomic structure.

In the nineteenth century JJ Thomson discovered the electron. He suggested that negative electrons were found throughout an atom like 'plums in a pudding of positive charge'.

The diagram shows an atom of element **R** using the 'plum pudding' model.  
An atom of **R** contains seven electrons.



- (a) State **two** differences between the 'plum pudding' model and the model of atomic structure used today.

1. \_\_\_\_\_  
\_\_\_\_\_  
2. \_\_\_\_\_  
\_\_\_\_\_

(2)

- (b) Deduce the full electron configuration of an atom of element **R**.

\_\_\_\_\_

(1)

- (c) Identify **R** and deduce the formula of the compound formed when **R** reacts with the Group 2 metal in the same period as **R**.

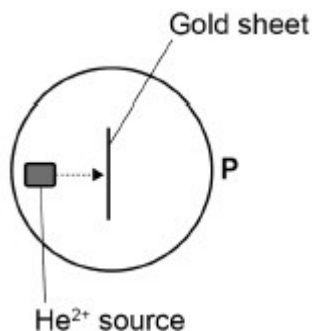
\_\_\_\_\_

(1)

(Total 4 marks)

### Q2.

In the early twentieth century the apparatus shown in the diagram was used to investigate atomic structure. When  $\text{He}^{2+}$  particles were fired at a thin sheet of gold, most of the particles were detected at point **P**.



What conclusion can be drawn from the detection of  $\text{He}^{2+}$  particles at point **P**?

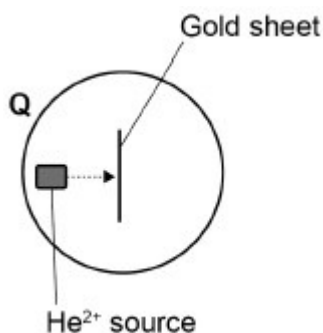
- A** Gold atoms contain electrons.
- B** Gold atoms contain protons.
- C** Gold atoms contain neutrons.
- D** Gold atoms are mainly empty space.

☐
☐
☐
☐

(Total 1 mark)

**Q3.**

When  $\text{He}^{2+}$  particles were fired at a thin sheet of gold, about 1 in 8000 of the particles were detected at point **Q**.



What conclusion can be drawn from the detection of  $\text{He}^{2+}$  particles at point **Q**?

- A** Gold atoms have a small, positive nucleus.
- B** Gold atoms have electrons in orbitals.
- C** Gold consists of ions in a sea of delocalised electrons.
- D** Gold atoms have more protons than  $\text{He}^{2+}$  particles.

☐
☐
☐
☐

(Total 1 mark)

**Q4.**

Magnesium exists as three isotopes:  $^{24}\text{Mg}$ ,  $^{25}\text{Mg}$  and  $^{26}\text{Mg}$

- (a) In terms of sub-atomic particles, state the difference between the three isotopes of magnesium.

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(1)

- (b) State how, if at all, the chemical properties of these isotopes differ.

Give a reason for your answer.

Chemical properties \_\_\_\_\_

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Reason \_\_\_\_\_

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(2)

- (c)  $^{25}\text{Mg}$  atoms make up 10.0% by mass in a sample of magnesium.

Magnesium has  $A_r = 24.3$

Use this information to deduce the percentages of the other two magnesium isotopes present in the sample.

$^{24}\text{Mg}$  percentage = \_\_\_\_\_ %       $^{26}\text{Mg}$  percentage = \_\_\_\_\_ %

(4)

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

$$\text{KE} = \frac{1}{2}mv^2 \quad \text{where } m = \text{mass (kg) and } v = \text{velocity (m s}^{-1}\text{)}$$

$$v = \frac{d}{t} \quad \text{where } d = \text{distance (m) and } t = \text{time (s)}$$

In a TOF mass spectrometer, each  $^{25}\text{Mg}^+$  ion is accelerated to a kinetic energy of  $4.52 \times 10^{-16} \text{ J}$  and the time of flight is  $1.44 \times 10^{-5} \text{ s}$ .

Calculate the distance travelled, in metres, in the TOF drift region.

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

Distance = \_\_\_\_\_ m

(4)

(Total 11 marks)

**Q5.**

Which of these correctly shows the numbers of sub-atomic particles in a  $^{41}\text{K}^+$  ion?

|          | Number of electrons | Number of protons | Number of neutrons |                          |
|----------|---------------------|-------------------|--------------------|--------------------------|
| <b>A</b> | 19                  | 19                | 20                 | <input type="checkbox"/> |
| <b>B</b> | 18                  | 20                | 21                 | <input type="checkbox"/> |
| <b>C</b> | 18                  | 19                | 22                 | <input type="checkbox"/> |
| <b>D</b> | 19                  | 18                | 23                 | <input type="checkbox"/> |

(Total 1 mark)

**Q6.**

Which species has the same number of electrons as the radical  $\bullet\text{CH}_3$ ?

|          |                 |                          |
|----------|-----------------|--------------------------|
| <b>A</b> | $\text{CH}_2$   | <input type="checkbox"/> |
| <b>B</b> | $\text{CH}_3^+$ | <input type="checkbox"/> |
| <b>C</b> | $\text{CH}_3^-$ | <input type="checkbox"/> |
| <b>D</b> | $\text{CH}_4^+$ | <input type="checkbox"/> |

(Total 1 mark)

**Q7.**

What are the numbers of neutrons and electrons in the  $^{57}\text{Fe}^{2+}$  ion?

|          | Neutrons | Electrons |                          |
|----------|----------|-----------|--------------------------|
| <b>A</b> | 31       | 24        | <input type="checkbox"/> |
| <b>B</b> | 57       | 24        | <input type="checkbox"/> |
| <b>C</b> | 31       | 26        | <input type="checkbox"/> |
| <b>D</b> | 57       | 28        | <input type="checkbox"/> |

(Total 1 mark)

**Q8.**

Which of these atoms has the largest atomic radius?

|          |    |                          |
|----------|----|--------------------------|
| <b>A</b> | Ar | <input type="checkbox"/> |
| <b>B</b> | Cl | <input type="checkbox"/> |

C Mg 

D Na 

(Total 1 mark)

**Q9.**

- (a) **Table 1** shows some data about fundamental particles in an atom.

**Table 1**

| Particle | proton                   | neutron                  | electron                 |
|----------|--------------------------|--------------------------|--------------------------|
| Mass / g | $1.6725 \times 10^{-24}$ | $1.6748 \times 10^{-24}$ | $0.0009 \times 10^{-24}$ |

- (i) An atom of hydrogen can be represented as  $^1\text{H}$

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,  $^{10}\text{B}$  and  $^{11}\text{B}$

- (i) Calculate the percentage abundance of  $^{10}\text{B}$  in this naturally occurring sample of boron.

(2)

- (ii) State, in terms of fundamental particles, why the isotopes  $^{10}\text{B}$  and  $^{11}\text{B}$  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 / $\text{kJ mol}^{-1}$ | 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)

### Q10.

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  $^{182}\text{W}$  and  $^{186}\text{W}$

(i) Deduce the number of protons in  $^{182}\text{W}$

\_\_\_\_\_

(1)

(ii) Deduce the number of neutrons in  $^{186}\text{W}$

\_\_\_\_\_

(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  $^{182}\text{W}$  and  $^{186}\text{W}$

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)

**Q11.**

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)

**Q12.**

- (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  ${}^9\text{Be}$ . Deduce the symbol, including the mass number, of this atom.
- 

(2)

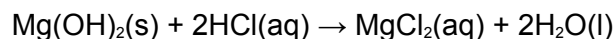
- (c) Draw the shape of a molecule of  $\text{BeCl}_2$  and the shape of a molecule of  $\text{Cl}_2\text{O}$ . Show any lone pairs of electrons on the central atom. Name the shape of each molecule.



Name of shape \_\_\_\_\_ Name of shape \_\_\_\_\_

(4)

- (d) The equation for the reaction between magnesium hydroxide and hydrochloric acid is shown below.



Calculate the volume, in  $\text{cm}^3$ , of  $1.00 \text{ mol dm}^{-3}$  hydrochloric acid required to react completely with 1.00 g of magnesium hydroxide.

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(4)  
(Total 12 marks)

**Q13.**

- (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  $^{27}\text{Al}$ . An atom of **Q** also contains 14 protons.

- (i) Give the number of protons in an atom of  $^{27}\text{Al}$ .

---

- (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.

|                        |      |      |      |
|------------------------|------|------|------|
| <i>m/z</i>             | 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.

---

---

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(2)

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

---



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(1)

(Total 10 marks)

#### Q14.

- (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  $^{34}_{16}\text{S}$ . 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,  $\text{S}^{2-}$ .

S     $1s^2$  \_\_\_\_\_

$\text{S}^{2-}$      $1s^2$  \_\_\_\_\_

(2)

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

Block \_\_\_\_\_

Explanation \_\_\_\_\_

(2)

- (e) Sodium sulphide,  $\text{Na}_2\text{S}$ , is a high melting point solid which conducts electricity when molten. Carbon disulphide,  $\text{CS}_2$ , is a liquid which does not conduct electricity.

- (i) Deduce the type of bonding present in  $\text{Na}_2\text{S}$  and that present in  $\text{CS}_2$

Bonding in  $\text{Na}_2\text{S}$  \_\_\_\_\_

Bonding in  $\text{CS}_2$  \_\_\_\_\_

- (ii) By reference to all the atoms involved explain, in terms of electrons, how  $\text{Na}_2\text{S}$  is formed from its atoms.

---

---

- (iii) Draw a diagram, including all the outer electrons, to represent the bonding present in  $\text{CS}_2$

- (iv) When heated with steam,  $\text{CS}_2$  reacts to form hydrogen sulphide,  $\text{H}_2\text{S}$ , and carbon dioxide.  
Write an equation for this reaction.

---

(7)

(Total 16 marks)

**Q15.**

- (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.

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(7)

- (7)

**(Total 14 marks)**

An atom in which the number of protons is greater than the number of neutrons is

- (Total 1 mark)**

## Mark schemes

### Q1.

- (a) Assume current model unless otherwise stated.

Statement about the nucleus:

(Central) nucleus contains protons and neutrons.

*Allow "protons and neutrons are in the centre of the atom"*

1

Statement about electrons

Electrons are now arranged in energy levels/shells/orbitals

*Ignore "mostly empty space"*

*Ignore electrons surround / orbit nucleus*

*Allow additional statement about neutrons but must be separate from statement about nucleus to score*

*e.g.*

*no neutrons in plum pudding / neutrons now recognised*

1

- (b)  $1s^2 2s^2 2p^3$

*Ignore commas, capitals and subscripts*

*Allow  $1s^2 2s^2 2px^1 2py^1 2pz^1$*

1

- (c) (R is N (nitrogen))

Formula  $Be_3N_2$

*Accept  $Be_3R_2$  only if stated  $R = \text{nitrogen}$*

*Accept  $N_2Be_3$*

1

[4]

### Q2.

D

[1]

### Q3.

A

[1]

### Q4.

- (a)  $^{24}\text{Mg}$  has 12n;  $^{25}\text{Mg}$  has 13n;  $^{26}\text{Mg}$  has 14n

**OR** They have different numbers of neutrons

1

- (b) No difference in chemical properties

1

Because all have the same electronic structure (configuration)

**OR** they have the same number of outer electrons

1

(c) If fraction with mass 24 = x

Fraction with mass 26 = 0.900 - x

Fraction with mass 25 = 0.100

1

$$A_r = 24x + (25 \times 0.100) + 26(0.900 - x)$$

1

$$24.3 = 24x + 2.50 + 23.4 - 26x$$

$$2x = 1.60$$

$$x = 0.800 \text{ i.e. percentage } ^{24}\text{Mg} = 80.0(\%) \text{ (80.0\% 3sf)}$$

1

$$^{26}\text{Mg} = 0.900 - 0.800 = 0.100 \text{ ie percentage } ^{26}\text{Mg} = 10.0(\%)$$

1

(d)  $m = \frac{25/1000}{6.022 \times 10^{23}}$

1

$$v^2 = 2ke/m \text{ or } v^2 = \frac{2 \times (4.52 \times 10^{-18}) \times (6.022 \times 10^{23})}{25/1000}$$

1

$$V = \sqrt{2.18 \times 10^{10}} = 1.48 \times 10^5 \text{ (ms}^{-1}\text{)}$$

1

$$D = vt = 1.48 \times 10^5 \times 1.44 \times 10^{-5}$$

$$D = 2.13 \text{ (m)}$$

1

[11]

**Q5.**

C

[1]

**Q6.**

D

[1]

**Q7.**

A

[1]

**Q8.**

D

[1]

**Q9.**

(a) (i)  $1.6734 \times 10^{-24} \text{ (g)}$

*Only.*

$$1.6734 \times 10^{-27} \text{ kg}$$

*Not  $1.67 \times 10^{-24} \text{ (g)}$ .*

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  $5 \times 0.2$  divisions between 10 and 11.*

1

abundance of  $^{10}\text{B}$  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.*

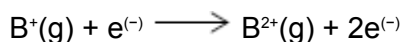
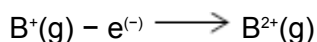
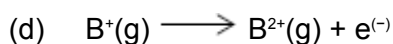
Same electronic configuration / arrangement

*Ignore protons unless wrong.*

1

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

1



*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]

### Q10.

(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

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

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

1

= 183.90; allow range from 183.90 – 184.00;

1

[12]

### Q11.

- (a) Number of protons in the nucleus

1

- (b) They may have different numbers of neutrons

1

- (c) (i) Mass spectrometer

1

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

2

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

1

$$= (82 \times 12 + 83 \times 12 + 84 \times 50 + 86 \times 26)/100 = 84.16$$

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]

## Q12.

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

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

1

electron: relative mass =  $1/1800 \rightarrow 0$ /negligible or

$5.56 \times 10^{-4} \rightarrow 0$  relative charge = -1

1

(b)  $^{17}\text{O}/\text{O}^{17}$  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  $N^\circ$  given but  $\neq 8$ , treat as 'con' for M2)

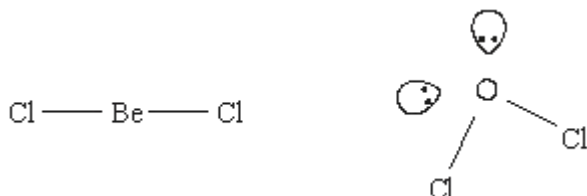
(if lp on Be, diagram = 0)

(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)  $M_r(\text{Mg}(\text{NO}_3)_2) = 58(.3)$  (if At  $N^\circ$  used, lose M1 and M2)

1

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

1

moles  $\text{HCl} = 2 \times 0.0172 = 0.0344$  or  $0.0343$  (mol) (process mark)

1

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

(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]

**Q13.**

- (a) Proton mass = 1 charge = +1  
 Electron mass  $\leq 1/1800$  Or  $\leq 5.6 \times 10^{-4}$  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  
 $1/12^{\text{th}}$  mass of atom of  $^{12}\text{C}$   
 Or Mass of 1 mole of atoms of an element (1)  
 $1/12^{\text{th}}$  mass of 1 mole of  $^{12}\text{C}$  (1)  
 Or Average mass of an atom / all the isotopes (1)  
 relative to the mass of a  $^{12}\text{C}$  atom taken as exactly 12 / 12.000 (1)  
 (Penalise 'weight' once only) (Ignore 'average' mass of  $^{12}\text{C}$ )  
 (Do not allow 'mass of average atom')

2

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

**Q14.**

- (a)

| Particle | Relative charge | Relative mass |            |
|----------|-----------------|---------------|------------|
| Proton   | +1 <b>or</b> 1+ | 1             | <b>(1)</b> |

|          |                                   |                     |     |
|----------|-----------------------------------|---------------------|-----|
| Neutron  | 0<br>or no<br>charge/neutral/zero | 1 ( <u>not</u> – 1) | (1) |
| Electron | –1 or 1–                          | 1/1800 to 1/2000    | (1) |

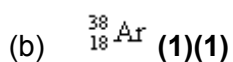
or negligible

or zero

or  $5.0 \times 10^{-4}$  to  $5.6 \times 10^{-4}$

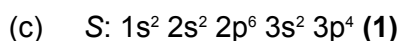
*if 'g' in mass column - wrong  
penalise once*

3

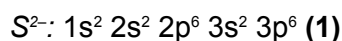


*Allow numbers before or after Ar*

2



*Allow upper case letters*



*If use subscript penalise once*

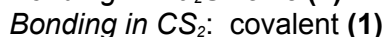
2



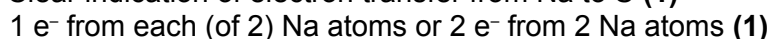
*Explanation:* Highest energy or outer orbital is (3) p

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

2

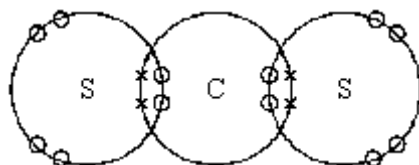


*ignore other words such as dative / polar / co-ordinate*



*QoL correct English*

(iii)



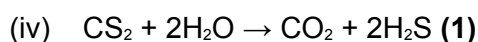
Correct covalent bonds (1)

All correct including lone pairs (1)

*Allow all •s or all x's*

*M2 tied to M1*

*NOT separate e-s in S•- 2 l p*



*Ignore state symbols even if wrong*

**Q15.**

- (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

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

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

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

**Q16.**

C

## Examiner reports

### Q1.

- (a) Most students understood that electrons are now arranged in energy levels, although many didn't make reference to sub-atomic particles in their answer. Students did not always make a comparison and it was not always clear which model they were referring to in their responses.
- (b) Almost all students (91.3%) were able to write the correct electron configuration in terms of shells and sub-shells, although a few students made no reference to sub-shells.
- (c) Many students were able to identify that the two elements were nitrogen and beryllium but many were then unable to write the correct formula of the compound formed between them.

### Q2.

For this question with a 72.6% success rate, A was the commonest incorrect response.

### Q3.

While 66.9% of students correctly identified A, there was a fairly even distribution of wrong answers between B, C and D.

### Q9.

The overall performance in part (a)(i) was disappointing because many students did not know the subatomic particles in the hydrogen atom. The mark in part (a)(ii) was scored by most students. Many students scored both marks in part (b)(i) but several quoted an equation involving  $x$  and  $y$  but could not progress beyond that. The majority of students answered part (b)(ii) correctly and part (c) was also generally well done. In part (d), many students used Br instead of B in their equation and some either wrote the wrong ionisation energy or failed to add state symbols. Many answers to part (e) were superficial; many students simply referred to a different proton / electron ratio or the removal of an electron from a different energy level.

### Q10.

In part (a) the majority of the candidates scored full marks with some losing marks by referring to a charge of + rather than +1, or putting a + (plus) or a – (minus) sign in the relative mass column. The answer to part (b) was well done with only a few writing 'Transition metals' rather than stating the block that tungsten is in. Some candidates did not score marks in part (c) since they did not look for the atomic number in the Periodic Table and some could not remember how to calculate the number of neutrons. Candidates generally answered part (d) well although a few put 'detect' as one of their answers and this was given in the stem of the question. Some tried to explain how the ions were formed but this was not asked for. Part d (ii) was well answered. In part (e) candidates lost the second mark by not knowing that the isotopes have the same electron configuration. Many answers just stated that isotopes had different numbers of neutrons and/or same number of protons. The calculation in part (f) was very well done although some candidates lost the second mark by not giving their answer to two decimal places.

### Q12.

On the whole, this question was well answered. The relative masses and charges of neutrons and electrons were generally well known but errors were not uncommon. Some candidates reversed the contents of the *mass* and *charge* columns, suggesting that they had rote learned a table with a different layout of columns.

Part (b) was quite well done but errors such as  $^{17}\text{Be}$ ,  $^{13}\text{O}$ ,  $^{17.0}\text{O}$  and  $^{16}\text{O}$  were not uncommon.

While many candidates correctly deduced the shapes of the molecules in part (c), the presence of a lone pair of electrons on the Be atom, or one/three lone pairs of electrons on the O atom, was quite common. The shape of the  $\text{BeCl}_2$  molecule was well known but there was considerable confusion regarding the shape of the  $\text{Cl}_2\text{O}$  molecule. Many candidates gave *tetrahedral* as the shape of this molecule. While the distribution of electron pairs around the oxygen atom might be described as *tetrahedral*, this is not the shape produced by the atoms in the molecule. Many candidates described the shape in appropriately by using the terms *bent*, *V-shaped* and *angular*. The use of *tetrahedral* was accepted in this examination but this may not be the case in future examinations. A significant number of candidates used the term *bent linear* when describing the shape of  $\text{Cl}_2\text{O}$  molecules; this was treated as a contradiction and so earned no credit. A significant number of candidates attempted to show the shapes of these molecules using dot-and-cross diagrams; these were not accepted.

The calculation in part (d) was correctly performed by many candidates, but errors such as the use of incorrect *Mr* values or the use of an incorrect mole ratio were quite common. A small but significant number of candidates assumed the use of a known mass of HCl and ignore the 1.00 g of  $\text{Mg}(\text{OH})_2$  stipulated in the question; such answers earned no credit.

### Q13.

The fundamental particle data required in part (a) was generally well known; however, relative charges where either the sign or the value was omitted were occasionally seen. Part (b)(i) was well answered, and the majority of candidates coped well with (b)(ii). It was quite common however to see 28.1, rather than the required 28, to be quoted as the mass number of **Q**. Part (c) simply required a standard definition for the *A<sub>r</sub>* to be quoted. Surprisingly, this question was quite poorly done, with attempts being frequently vague and incomplete. The most common error was to omit references to *mean*, *mass* and *atoms* in the definition. Also, it was not uncommon to see a ratio showing single atoms on the top and moles on the bottom. In part (d), the calculation of the *A<sub>r</sub>* of the sample of magnesium was usually correct, however, a significant number of candidates failed to quote their final answer to one decimal place. Some candidates used the sum of the *m/z* values, rather than the sum of the relative abundances (100). Part (e) was very poorly answered. Very few references to *highest m/z value* were seen.

### Q14.

Many candidates answered this question quite well but full marks were not that common. Most candidates correctly completed the table in part (a) but it was not unusual for either the signs or the values of the relative charges to be omitted. In a few instances, the values of the electron and the neutron were transposed. Success in part (b) was far from universal. Errors such as 39.9 and 36 for the mass number were quite common, as was the use of *Z* to represent the element. Part (c) was, in the main, successfully completed but the odd d level was seen, as were configurations for the  $\text{S}^{2-}$  ion showing  $3\text{p}^2$  rather than  $3\text{p}^6$  electrons, or even a  $2\text{p}^8$  arrangement. While part (d) was also generally well done, some candidates were found to be unfamiliar with this part of the specification and

the suggestion that the element was found in block 6, because it contained 6 outer electrons, was not uncommon. Some candidates incorrectly referred to the p-block or p-shell, rather than using the correct terms sub-level or sub-shell. In part (e), a surprising number of candidates identified incorrectly the bonding in  $\text{Na}_2\text{S}$  as being covalent or metallic, and the bonding in  $\text{CS}_2$  as being ionic, molecular or dative. For those candidates who did recognise the ionic nature of the bonding in  $\text{Na}_2\text{S}$ , their descriptions were often vague and they did not express clearly the transfer of electrons which takes place, and the numbers of electrons involved. Many answers could have equally well fitted the description for the formation of a covalent bond. The diagram of the bonding in  $\text{CS}_2$  was frequently flawed, with spare electrons being placed around carbon and extra lone pairs on the sulphur atoms. Some candidates showed a single bond between the sulphur and carbon atoms, whilst others only included a single sulphur atom. The equation was almost invariably correct; although, in a few cases, the equation was not balanced.

#### **Q15.**

Most candidates scored high marks for part (a) though the final part of the question, requiring an explanation why isotopes have identical chemical properties, was more demanding. Part (b) was also answered well though a considerable number of candidates wasted time by giving detailed but irrelevant information about the operation of the various parts of a mass spectrometer. Candidates were often imprecise about the information that can be obtained from a mass spectrum. Confusion between mass/charge and atomic mass or relative atomic mass was common but did not incur a heavy penalty.

**Q1.**

A sample of bromine was analysed in a time of flight (TOF) mass spectrometer and found to contain two isotopes,  $^{79}\text{Br}$  and  $^{81}\text{Br}$

After electron impact ionisation, all of the ions were accelerated to the same kinetic energy (KE) and then travelled through a flight tube that was 0.950 m long.

- (a) The  $^{79}\text{Br}^+$  ions took  $6.69 \times 10^{-4}$  s to travel through the flight tube.

Calculate the mass, in kg, of one ion of  $^{79}\text{Br}^+$

Calculate the time taken for the  $^{81}\text{Br}^+$  ions to travel through the same flight tube.

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

$$KE = \frac{1}{2} mv^2 \quad \text{where } m = \text{mass (kg) and } v = \text{speed (m s}^{-1}\text{)}$$

$$v = \frac{d}{t} \quad \text{where } d = \text{distance (m) and } t = \text{time (s)}$$

Mass of one ion of  $^{79}\text{Br}^+$  \_\_\_\_\_ kg

Time taken by  $^{81}\text{Br}^+$  ions \_\_\_\_\_ s

(5)

- (b) Explain how ions are detected and relative abundance is measured in a TOF mass spectrometer.

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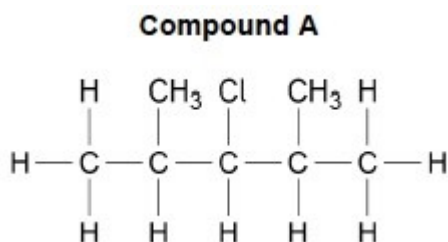
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(2)

(Total 7 marks)

**Q2.**

Compound **A** is a halogenoalkane.



- (a) Name Compound **A**.

(1)

- (b) Compound **A** has a relative molecular mass ( $M_r$ ) of 134.5  
 The main isotope of hydrogen is  $^1\text{H}$   
 The main isotope of carbon is  $^{12}\text{C}$   
 Chlorine consists of two common isotopes,  $^{35}\text{Cl}$  and  $^{37}\text{Cl}$ , of which 75% is  $^{35}\text{Cl}$   
 The mass spectrum of **A** was recorded when **A** was ionised by electron impact to form  $\text{A}^+$  ions.

Draw, on **Figure 1**, the peaks for the main molecular ions in the mass spectrum of **A**.

**Figure 1**



(2)

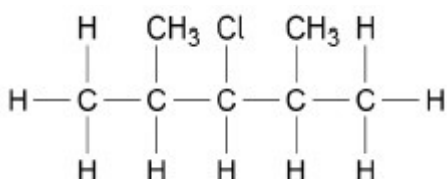
- (c) Reaction of **A** with warm, dilute aqueous sodium hydroxide forms alcohol **B**.

Name the mechanism for this reaction.

Outline the mechanism using the structure of **A** shown.  
 Include the structure of the product, alcohol **B**.

Mechanism \_\_\_\_\_

Outline of mechanism



(4)

- (d) Reaction of **A** with hot, ethanolic potassium hydroxide gives alkene **C**.

Name the mechanism for this reaction.

State the role of the hydroxide ions.

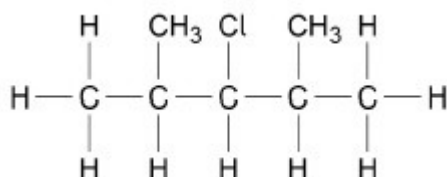
Outline the mechanism using the structure of **A** shown.

Include the structure of the product, alkene **C**.

Mechanism \_\_\_\_\_

Role of hydroxide ions \_\_\_\_\_

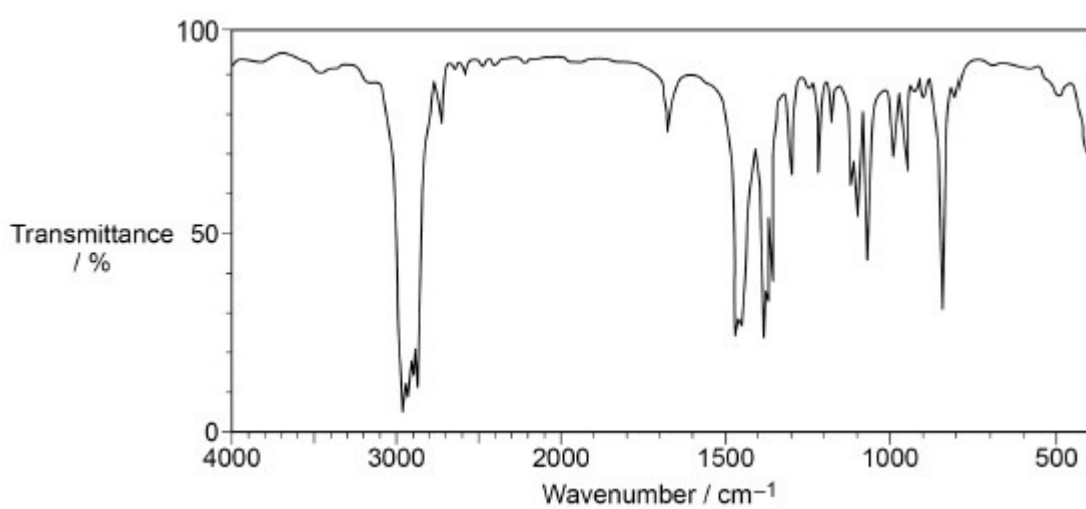
Outline of mechanism



(6)

- (e) The infrared spectrum in **Figure 2** is that of either alcohol **B** or alkene **C**.

**Figure 2**



Tick the box that shows the correct compound.

Explain your answer with reference to a bond and the wavenumber of its absorption.

Alcohol **B** ☐ Alkene **C** ☐

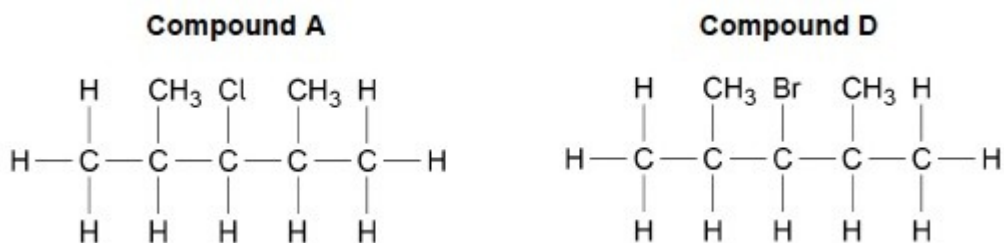
Explanation \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

(1)

- (f) Compound **D** reacts with dilute aqueous sodium hydroxide in a similar way to **A** to form alcohol **B**.



Explain why **D** reacts more quickly than **A** with dilute aqueous sodium hydroxide at the same temperature.

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(1)

(Total 15 marks)

### Q3.

A student has a 10 cm<sup>3</sup> sample of 1.00 × 10<sup>-2</sup> mol dm<sup>-3</sup> methanoic acid solution. The student is asked to dilute the methanoic acid solution to a concentration of 2.00 × 10<sup>-4</sup> mol dm<sup>-3</sup> by adding distilled water.

Which volume of water should be added?

- |                              |                       |
|------------------------------|-----------------------|
| <b>A</b> 200 cm <sup>3</sup> | <input type="radio"/> |
| <b>B</b> 490 cm <sup>3</sup> | <input type="radio"/> |
| <b>C</b> 500 cm <sup>3</sup> | <input type="radio"/> |
| <b>D</b> 510 cm <sup>3</sup> | <input type="radio"/> |

(Total 1 mark)

### Q4.

This question is about s-block metals.

- (a) Give the full electron configuration for the calcium ion, Ca<sup>2+</sup>

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(1)

- (b) Explain why the second ionisation energy of calcium is lower than the second ionisation energy of potassium.

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(2)

- (c) Identify the s-block metal that has the highest first ionisation energy.

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(1)

- (d) Give the formula of the hydroxide of the element in Group 2, from Mg to Ba, that is least soluble in water.

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(1)

- (e) A student added 6 cm<sup>3</sup> of 0.25 mol dm<sup>-3</sup> barium chloride solution to 8 cm<sup>3</sup> of 0.15 mol dm<sup>-3</sup> sodium sulfate solution.

The student filtered off the precipitate and collected the filtrate.

Give an ionic equation for the formation of the precipitate.

Show by calculation which reagent is in excess.

Calculate the total volume of the other reagent which should be used by the student so that the filtrate contains only one solute.

Ionic equation \_\_\_\_\_

Reagent in excess \_\_\_\_\_

Total volume of other reagent \_\_\_\_\_

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(3)

- (f) A sample of strontium has a relative atomic mass of 87.7 and consists of three isotopes, <sup>86</sup>Sr, <sup>87</sup>Sr and <sup>88</sup>Sr

In this sample, the ratio of abundances of the isotopes <sup>86</sup>Sr : <sup>87</sup>Sr is 1:1

State why the isotopes of strontium have identical chemical properties.

Calculate the percentage abundance of the <sup>88</sup>Sr isotope in this sample.

Why isotopes of strontium have identical chemical properties

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Percentage abundance of  $^{88}\text{Sr}$  \_\_\_\_\_ %

(4)

- (g) A time of flight (TOF) mass spectrum was obtained for a sample of barium that contains the isotopes  $^{136}\text{Ba}$ ,  $^{137}\text{Ba}$  and  $^{138}\text{Ba}$

The sample of barium was ionised by electron impact.

Identify the ion with the longest time of flight.

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(1)

- (h) A  $^{137}\text{Ba}^+$  ion travels through the flight tube of a TOF mass spectrometer with a kinetic energy of  $3.65 \times 10^{-16} \text{ J}$   
This ion takes  $2.71 \times 10^{-5} \text{ s}$  to reach the detector.

$$\text{KE} = \frac{1}{2}mv^2 \quad \text{where } m = \text{mass (kg) and } v = \text{speed (m s}^{-1}\text{)}$$

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

Calculate the length of the flight tube in metres.

Give your answer to the appropriate number of significant figures.

Length of flight tube \_\_\_\_\_ m

(5)

(Total 18 marks)

**Q5.**

This question is about atomic structure.

- (a) Write the full electron configuration for each of the following species.

Cl<sup>-</sup> \_\_\_\_\_

Fe<sup>2+</sup> \_\_\_\_\_

(2)

- (b) Write an equation, including state symbols, to represent the process that occurs when the third ionisation energy of manganese is measured.

\_\_\_\_\_  
\_\_\_\_\_

(1)

- (c) State which of the elements magnesium and aluminium has the lower first ionisation energy.

Explain your answer.

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

(3)

- (d) A sample of nickel was analysed in a time of flight (TOF) mass spectrometer. The sample was ionised by electron impact ionisation. The spectrum produced showed three peaks with abundances as set out in the table.

| m/z | Abundance / % |
|-----|---------------|
| 58  | 61.0          |
| 60  | 29.1          |
| 61  | 9.9           |

Give the symbol, including mass number, of the ion that would reach the detector first in the sample.

Calculate the relative atomic mass of the nickel in the sample.

Give your answer to one decimal place.

Symbol of ion \_\_\_\_\_

**Q6.**

Which statement about time of flight mass spectrometry is correct?

- A** The current in the detector is proportional to the ion abundance ☐
- B** Sample particles gain electrons to form positive ions ☐
- C** Particles are detected in the order of their kinetic energies ☐
- D** Ions are accelerated by a magnetic field ☐

(Total 1 mark)

**Q7.**

Chlorine exists as two isotopes  $^{35}\text{Cl}$  and  $^{37}\text{Cl}$  in the ratio 3:1

Which statement about peaks in the mass spectrum of  $\text{Cl}_2$  is correct?

- A** Peaks at  $m/z = 70$  and  $74$  in the ratio 3:1 ☐
- B** Peaks at  $m/z = 70, 72$  and  $74$  in the ratio 9:6:1 ☐
- C** Peaks at  $m/z = 70, 72$  and  $74$  in the ratio 9:3:1 ☐
- D** Peaks at  $m/z = 70$  and  $72$  in the ratio 3:1 ☐

(Total 1 mark)

**Q8.**

A sample of titanium was ionised by electron impact in a time of flight (TOF) mass spectrometer. Information from the mass spectrum about the isotopes of titanium in the sample is shown in the table.

|               |     |     |      |     |
|---------------|-----|-----|------|-----|
| $m/z$         | 46  | 47  | 48   | 49  |
| Abundance / % | 9.1 | 7.8 | 74.6 | 8.5 |

- (a) Calculate the relative atomic mass of titanium in this sample.

Give your answer to one decimal place.

Relative atomic mass of titanium in this sample \_\_\_\_\_

(2)

- (b) Write an equation, including state symbols, to show how an atom of titanium is ionised by electron impact and give the  $m/z$  value of the ion that would reach the detector first.

Equation \_\_\_\_\_

$m/z$  value \_\_\_\_\_

(2)

- (c) Calculate the mass, in kg, of one atom of  $^{49}\text{Ti}$

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

Mass \_\_\_\_\_ kg

(1)

- (d) In a TOF mass spectrometer the time of flight,  $t$ , of an ion is shown by the equation

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

In this equation  $d$  is the length of the flight tube,  $m$  is the mass, in kg, of an ion and  $E$  is the kinetic energy of the ions.

In this spectrometer, the kinetic energy of an ion in the flight tube is  $1.013 \times 10^{-13} \text{ J}$

The time of flight of a  $^{49}\text{Ti}^+$  ion is  $9.816 \times 10^{-7} \text{ s}$

Calculate the time of flight of the  $^{47}\text{Ti}^+$  ion.

Give your answer to the appropriate number of significant figures.

Time of flight \_\_\_\_\_ s

(3)

(Total 8 marks)

### Q9.

Magnesium exists as three isotopes:  $^{24}\text{Mg}$ ,  $^{25}\text{Mg}$  and  $^{26}\text{Mg}$

- (a) In terms of sub-atomic particles, state the difference between the three isotopes of magnesium.

\_\_\_\_\_

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(1)

- (b) State how, if at all, the chemical properties of these isotopes differ.

Give a reason for your answer.

Chemical properties \_\_\_\_\_

Reason \_\_\_\_\_

(2)

- (c)  $^{25}\text{Mg}$  atoms make up 10.0% by mass in a sample of magnesium.

Magnesium has  $A_r = 24.3$

Use this information to deduce the percentages of the other two magnesium isotopes present in the sample.

$^{24}\text{Mg}$  percentage = \_\_\_\_\_ %       $^{26}\text{Mg}$  percentage = \_\_\_\_\_ %

(4)

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

$$\text{KE} = \frac{1}{2}mv^2 \quad \text{where } m = \text{mass (kg) and } v = \text{velocity (m s}^{-1}\text{)}$$

$$v = \frac{d}{t} \quad \text{where } d = \text{distance (m) and } t = \text{time (s)}$$

In a TOF mass spectrometer, each  $^{25}\text{Mg}^+$  ion is accelerated to a kinetic energy of  $4.52 \times 10^{-16} \text{ J}$  and the time of flight is  $1.44 \times 10^{-5} \text{ s}$ .

Calculate the distance travelled, in metres, in the TOF drift region.

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

Distance = \_\_\_\_\_ m

(4)

(Total 11 marks)

**Q10.**

Bromine exists as two isotopes  $^{79}\text{Br}$  and  $^{81}\text{Br}$ , which are found in almost equal abundance.

Which of the statements is correct?

- A** The first ionisation energy of  $^{79}\text{Br}$  is less than the first ionisation energy of  $^{81}\text{Br}$  ☐
- B** The atomic radius of  $^{79}\text{Br}$  is less than the atomic radius of  $^{81}\text{Br}$  ☐
- C** The mass spectrum of  $\text{C}_3\text{H}_7\text{Br}$  has two molecular ion peaks at 122 and 124 ☐
- D**  $^{79}\text{Br}$  is more reactive than  $^{81}\text{Br}$  ☐

(Total 1 mark)

### Q11.

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

- (a) The mass spectrum of element **Q** has peaks with  $m/z$  values shown in the table.

|                    |    |    |    |    |
|--------------------|----|----|----|----|
| $m/z$              | 82 | 83 | 84 | 86 |
| Relative intensity | 5  | 3  | 26 | 7  |

Calculate the relative atomic mass of **Q** and give your answer to one decimal place.  
Identify the element **Q**.

Relative atomic mass of **Q** \_\_\_\_\_

Element **Q** \_\_\_\_\_

(3)

- (b) A sample of the element **Q** consists of several isotopes. All of the  $\text{Q}^+$  ions in the sample of **Q** that has been ionised in a TOF mass spectrometer have the same kinetic energy.

$$\text{kinetic energy of each ion} = \frac{1}{2}mv^2$$

where  $m$  is the mass, in kg, of one ion of an isotope and  $v$  is the velocity of an ion in  $\text{m s}^{-1}$

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

where  $d$  is the length, in m, of the flight tube and  $t$  is the time taken, in s, for an ion to reach the detector

The time of flight of a  $^{82}\text{Q}^+$  ion is  $1.243 \times 10^{-5}$  s.

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

Time of flight of the  $^{86}\text{Q}^+$  ion \_\_\_\_\_ s

(3)

**Q12.**

This question is about halogenoalkanes.

- (a) Chlorine atoms are formed in the upper atmosphere when ultraviolet radiation causes C–Cl bonds in chlorofluorocarbons (CFCs) to break.

Write **two** equations to show how chlorine atoms catalyse the decomposition of ozone.

1. \_\_\_\_\_

2. \_\_\_\_\_

(2)

- (b) Chloroethane reacts with potassium hydroxide in the presence of propan-1-ol to form ethene.

State the role of potassium hydroxide and the role of propan-1-ol in the reaction.

Role of potassium hydroxide \_\_\_\_\_

Role of propan-1-ol \_\_\_\_\_

(2)

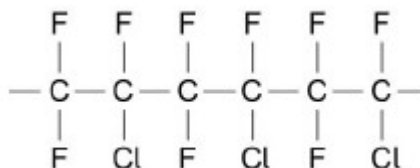
- (c) Name and outline a mechanism for the reaction in part **(b)** between chloroethane and potassium hydroxide to produce ethene.

Name of mechanism \_\_\_\_\_

Mechanism

(4)

- (d) The structure of polymer **A** is shown.



Draw the structure of the monomer used to form polymer **A**.

(1)

- (e) Chemical analysis shows that a chlorofluoroalkane, **B**, contains by mass 51.6% fluorine, 32.1% chlorine and no hydrogen.

Chlorine exists as two isotopes,  $^{35}\text{Cl}$  and  $^{37}\text{Cl}$ , in the ratio 3:1  
Fluorine only exists as one isotope,  $^{19}\text{F}$ .

A mass spectrum of **B** is obtained using electron impact ionisation. The mass spectrum shows three molecular ion peaks at  $m/z = 220$ ,  $222$  and  $224$ .

Determine the formula of each of the three molecular ions of **B**.

Predict and explain the ratio of the relative abundances of each of the three molecular ion peaks at  $m/z = 220$ ,  $222$  and  $224$ .

To gain full marks you must show all your working.

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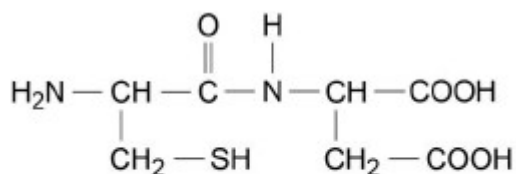
(6)

(Total 15 marks)

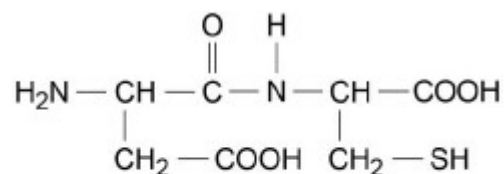
### Q13.

Chromatography is used to identify amino acid sequences in compounds.

The dipeptide cysteine-aspartic acid (cys-asp), **J**, and the dipeptide aspartic acid-cysteine (asp-cys), **K**, are shown.



**J** (cys–asp)



**K** (asp–cys)

- (a) A mixture of the two dipeptides **J** and **K** is analysed by gas chromatography followed by mass spectrometry (GC-MS).

Explain why **J** and **K** can be separated by gas chromatography and why mass spectrometry using electrospray ionisation does **not** enable you to identify them.

Gas chromatography explanation \_\_\_\_\_

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Mass spectrometry explanation \_\_\_\_\_

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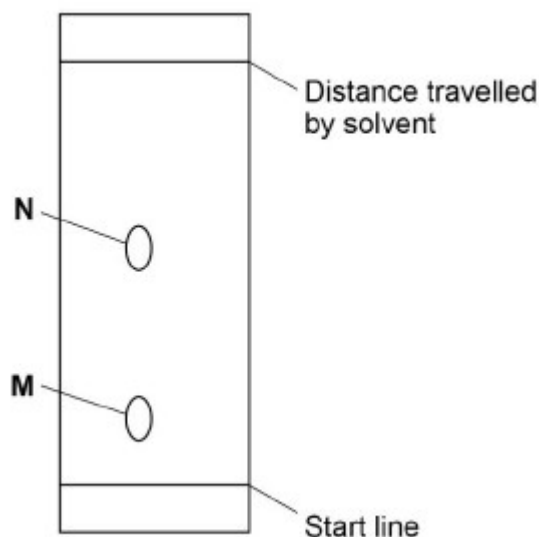
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(4)

- (b) A tripeptide, **L**, is partially hydrolysed with concentrated hydrochloric acid to produce two dipeptides and the amino acids alanine (ala), lysine (lys) and serine (ser).

The two dipeptides are separated by chromatography. The diagram below shows the chromatogram.



The table below contains the  $R_f$  values of some dipeptides.

| Dipeptide   | ala-lys | ala-ser | lys-ser | lys-ala | ser-ala | ser-lys |
|-------------|---------|---------|---------|---------|---------|---------|
| $R_f$ value | 0.55    | 0.85    | 0.10    | 0.20    | 0.15    | 0.45    |

Use the chromatogram in the diagram above and the  $R_f$  values in the table to identify the two dipeptides present in spots **M** and **N**.

Use your answers to deduce the order of the amino acids in the tripeptide **L**.

Dipeptide responsible for spot **M** \_\_\_\_\_

Dipeptide responsible for spot **N** \_\_\_\_\_

Order of amino acids in tripeptide **L** \_\_\_\_\_

(3)

(Total 7 marks)

#### Q14.

- (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)

### Q15.

Which of these atoms has the smallest number of neutrons?

A  $^3\text{H}$  ☐

B  $^4\text{He}$  ☐

C  $^5\text{He}$  ☐

D  $^4\text{Li}$  ☐

**Q16.**

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)

**Q17.**

This question is about electron configuration.

- (a) Give the full electron configuration of an Al atom and of a  $\text{Cr}^{3+}$  ion.

Al atom \_\_\_\_\_

$\text{Cr}^{3+}$  ion \_\_\_\_\_

(2)

- (b) Deduce the formula of the ion that has a charge of  $2+$  with the same electron configuration as krypton.

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(1)

- (c) Deduce the formula of the compound that contains 2+ ions and 3- ions that both have the same electron configuration as argon.

\_\_\_\_\_  
(1)  
(Total 4 marks)

**Q18.**

- (a) Explain how ions are accelerated, detected and have their abundance determined in a time of flight (TOF) mass spectrometer.

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
(3)

- (b) Calculate the mass, in kg, of a single  $^{52}\text{Cr}^+$  ion.  
Assume that the mass of a  $^{52}\text{Cr}^+$  ion is the same as that of a  $^{52}\text{Cr}$  atom.

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

\_\_\_\_\_  
\_\_\_\_\_  
(1)

- (c) In a TOF mass spectrometer the kinetic energy (KE) of a  $^{52}\text{Cr}^+$  ion was  $1.269 \times 10^{-13} \text{ J}$

Calculate the velocity of the ion using the equation.

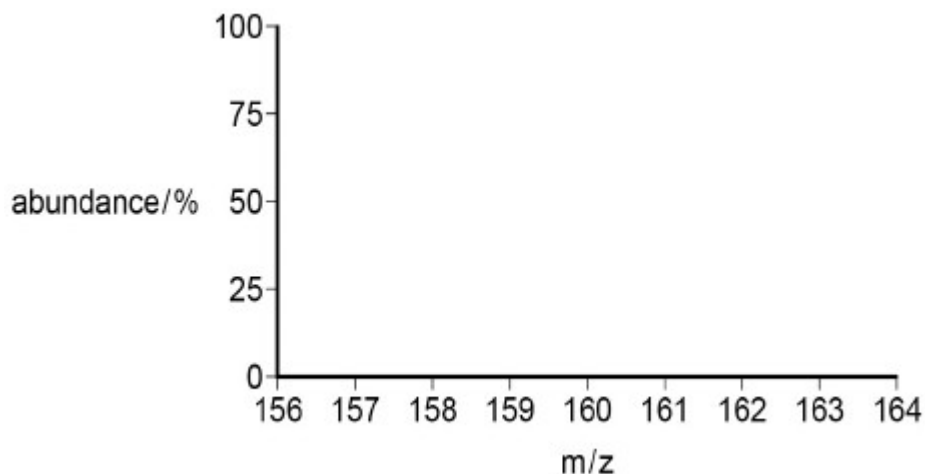
$$\text{KE} = \frac{1}{2}mv^2$$

( $m$  = mass/kg and  $v$  = velocity/ $\text{ms}^{-1}$ )

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
(2)

- (d) Bromine has two isotopes,  $^{79}\text{Br}$  and  $^{81}\text{Br}$ , in approximately equal abundance. In a TOF mass spectrometer bromine forms ions with formula  $[\text{Br}_2]^+$

Sketch the pattern of peaks you would expect to see in the mass spectrum of a sample of bromine.



(2)

- (e) A sample of xenon has  $A_r = 131.31$ . The sample consists of four isotopes. The abundances of three of the isotopes are shown in the table below. The data for one of the isotopes,  ${}^m\text{Xe}$ , is missing.

| Isotope     | ${}^{129}\text{Xe}$ | ${}^{131}\text{Xe}$ | ${}^{132}\text{Xe}$ | ${}^m\text{Xe}$  |
|-------------|---------------------|---------------------|---------------------|------------------|
| % abundance | 28.0                | 25.0                | 27.0                | To be calculated |

Use the data to calculate the abundance of isotope  ${}^m\text{Xe}$  and calculate  $m$ , the mass number of  ${}^m\text{Xe}$ . Show your working.

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(4)

(Total 12 marks)

### Q19.

Ions of two isotopes of iron are



Which statement is correct?

- A** The ions of both the isotopes have the electronic configuration  $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$  ☐
- B** The ions of both the isotopes contains 26 neutrons ☐

C  $^{53}\text{Fe}^{2+}$  has fewer protons than  $^{56}\text{Fe}^{2+}$

☐

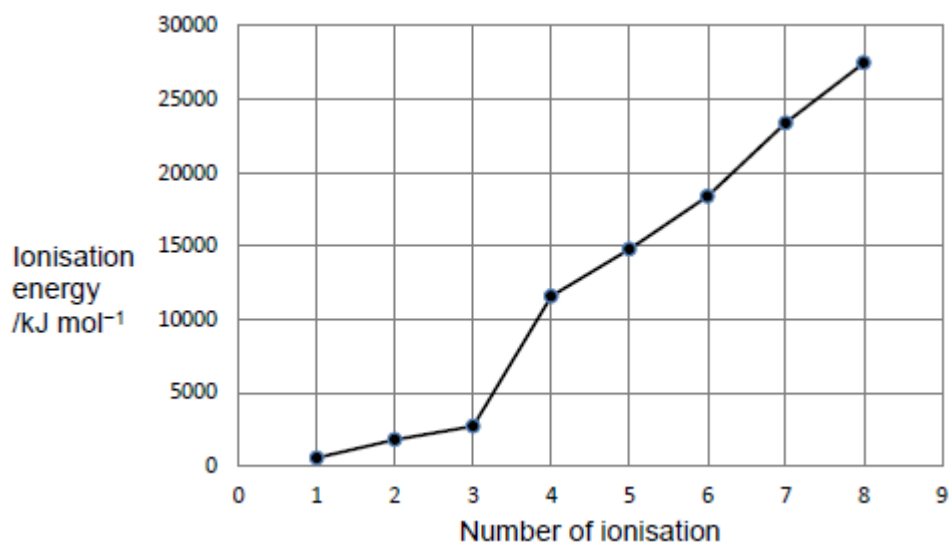
D After acceleration to the same kinetic energy  $^{56}\text{Fe}^{2+}$  will move more slowly than  $^{53}\text{Fe}^{2+}$

☐

(Total 1 mark)

### Q20.

The successive ionisation energies for element X are shown in the following graph.



Which element is X?

A Nitrogen

☐

B Phosphorus

☐

C Aluminium

☐

D Boron

☐

(Total 1 mark)

### Q21.

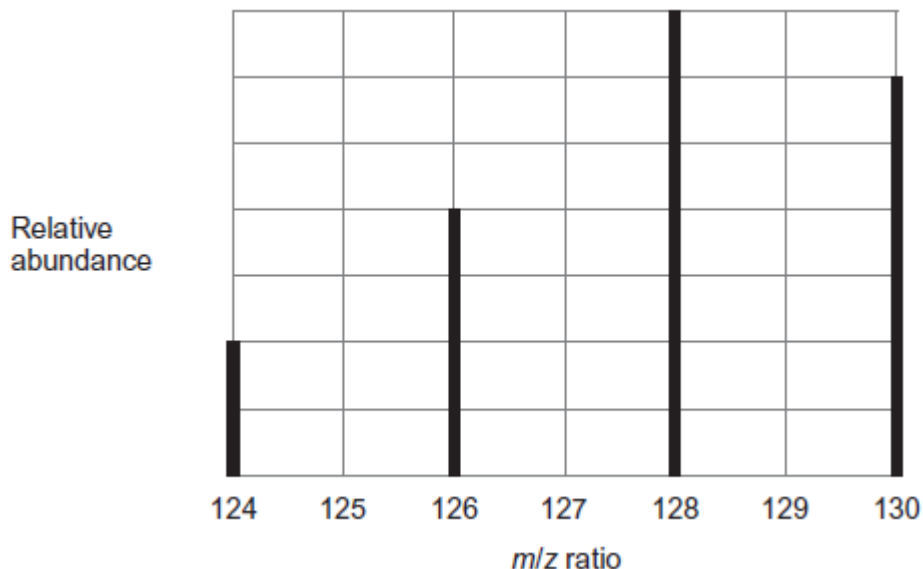
Tellurium is the element with atomic number of 52

- (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  $^{124}\text{Te}$  is larger than, smaller than or the same as the atomic radius of  $^{130}\text{Te}$   
Explain your answer.

Atomic radius of  $^{124}\text{Te}$  compared to  $^{130}\text{Te}$  \_\_\_\_\_

Explanation \_\_\_\_\_

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(2)

(Total 12 marks)

**Q22.**

- (a) **Table 1** shows some data about fundamental particles in an atom.

**Table 1**

| Particle | proton                   | neutron                  | electron                 |
|----------|--------------------------|--------------------------|--------------------------|
| Mass / g | $1.6725 \times 10^{-24}$ | $1.6748 \times 10^{-24}$ | $0.0009 \times 10^{-24}$ |

- (i) An atom of hydrogen can be represented as  $^1\text{H}$

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,  $^{10}\text{B}$  and  $^{11}\text{B}$

- (i) Calculate the percentage abundance of  $^{10}\text{B}$  in this naturally occurring sample of boron.

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(2)

- (ii) State, in terms of fundamental particles, why the isotopes  $^{10}\text{B}$  and  $^{11}\text{B}$  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  |
|------------------------------------------------------------|-------|--------|-------|--------|--------|
| <b>Ionisation energy / <math>\text{kJ mol}^{-1}</math></b> | 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)

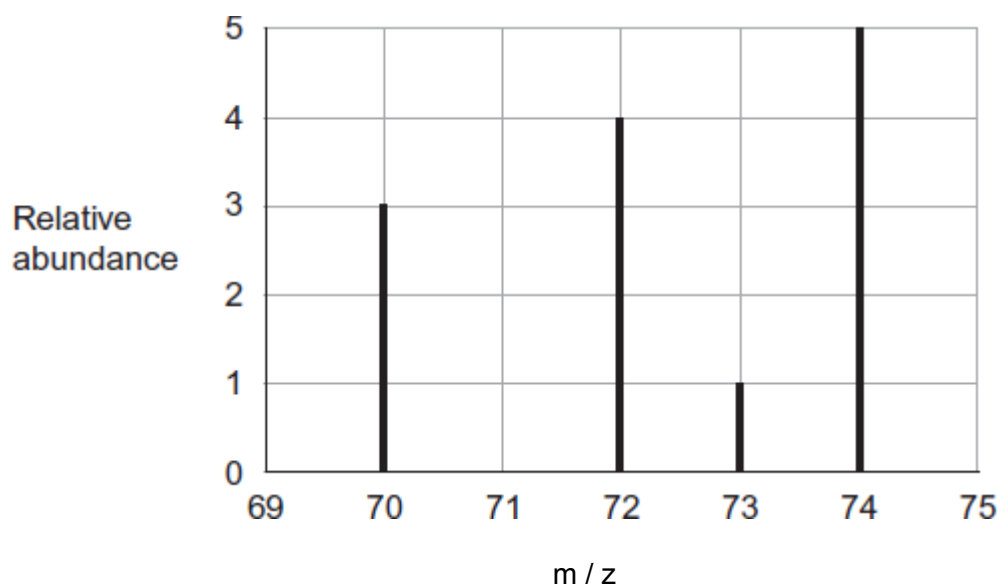
- (e) Explain why the second ionisation energy of boron is higher than the first ionisation energy of boron.

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**Q23.**

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

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(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.

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

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(1)

(Total 11 marks)

## Q24.

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

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

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 <sup>-1</sup> | 494    | 418       | 402      |

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

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
(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 <sup>85</sup>Rb and <sup>87</sup>Rb only.  
The isotope <sup>85</sup>Rb has an abundance 2.5 times greater than that of <sup>87</sup>Rb

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

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
(3)

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

Name of relevant part \_\_\_\_\_

Explanation \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

(2)

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

Atomic radius of  $^{88}\text{Sr}$  compared to  $^{87}\text{Rb}$  \_\_\_\_\_

Explanation \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

(3)

(Total 16 marks)

**Q25.**

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

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

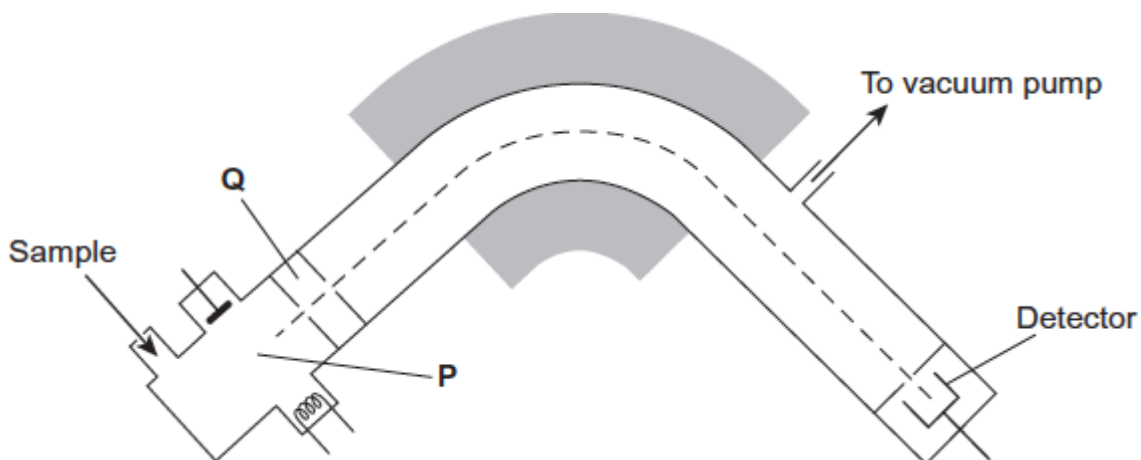
(1)

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

\_\_\_\_\_

(1)

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



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

P \_\_\_\_\_

Q \_\_\_\_\_

(2)

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

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

Measurement 1 \_\_\_\_\_

Measurement 2 \_\_\_\_\_

(2)

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

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

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

(3)

- (ii) Identify **R**.

\_\_\_\_\_

(1)

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

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

\_\_\_\_\_

\_\_\_\_\_

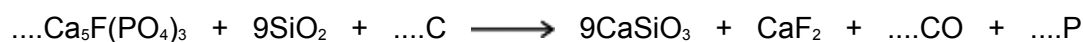
(1)

(Total 11 marks)

### Q26.

The manufacture of food grade phosphoric acid for use in cola drinks begins with the production of pure white phosphorus from the mineral fluoroapatite,  $\text{Ca}_5\text{F}(\text{PO}_4)_3$

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



(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 |
|----------|------------------------------|
| $^1H$    | 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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(1)

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

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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 \_\_\_\_\_

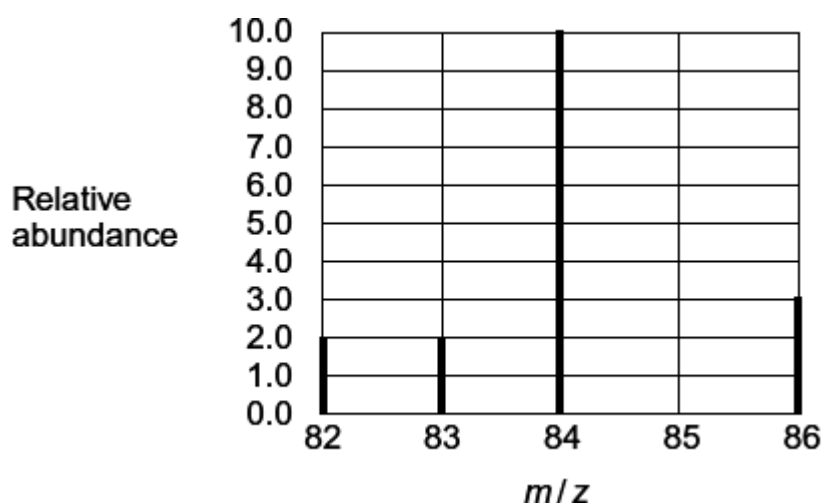
IUPAC name \_\_\_\_\_

(2)

(Total 8 marks)

### Q27.

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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(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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(5)

(Total 9 marks)

### Q28.

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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(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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(2)

(Total 12 marks)

### Q29.

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  $^{15}\text{N}$

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**Q30.**

- (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%  $^{14}\text{N}$  and 4.88%  $^{15}\text{N}$

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,  $^{14}\text{N}^+$  and  $^{15}\text{N}^+$  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  $^{15}\text{N}$  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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**Q31.**

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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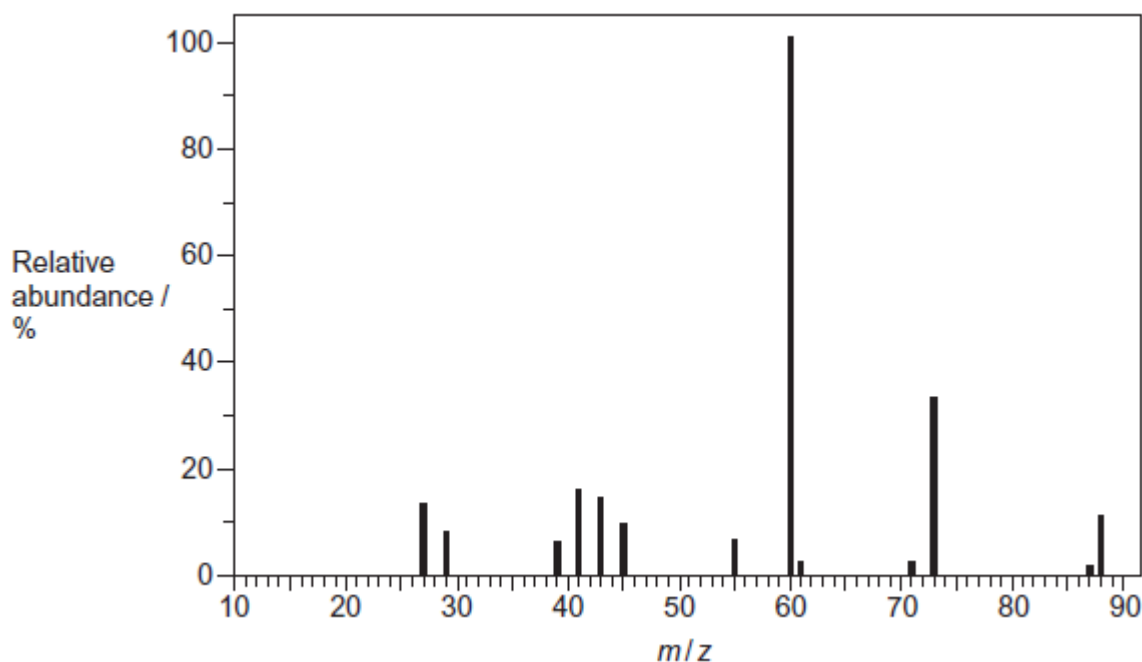
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(3)

- (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)

**Q32.**

A mass spectrometer can be used to investigate the isotopes in an element.

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

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(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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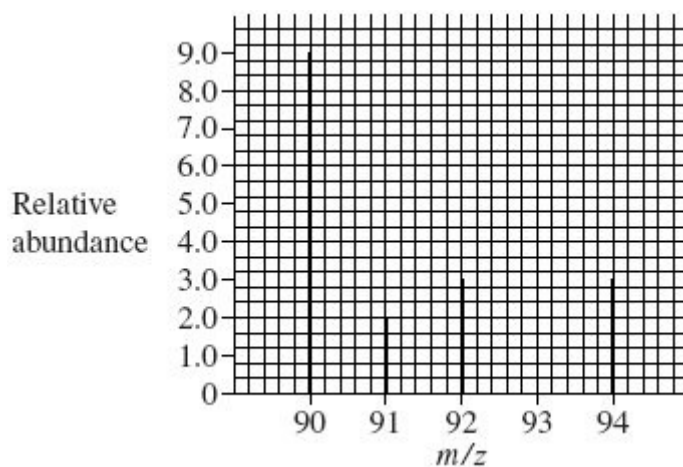
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(3)

- (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<sup>+</sup>** ions in a mass spectrometer.

State and explain which of the **Z<sup>+</sup>** 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.

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(2)  
(Total 15 marks)

**Q33.**

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.

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(1)

- (c) Isotopes of tungsten include  $^{182}\text{W}$  and  $^{186}\text{W}$

- (i) Deduce the number of protons in  $^{182}\text{W}$

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(1)

- (ii) Deduce the number of neutrons in  $^{186}\text{W}$

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(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.

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(1)

- (e) State and explain the difference, if any, between the chemical properties of the

isotopes  $^{182}\text{W}$  and  $^{186}\text{W}$

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)

### Q34.

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.

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(5)

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

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(1)

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

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(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.

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

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(4)

(Total 13 marks)

**Q35.**

(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  ${}^9\text{Be}$ . Deduce the symbol, including the mass number, of this atom.

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(2)

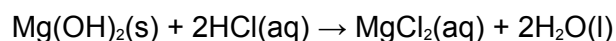
- (c) Draw the shape of a molecule of  $\text{BeCl}_2$  and the shape of a molecule of  $\text{Cl}_2\text{O}$ . Show any lone pairs of electrons on the central atom. Name the shape of each molecule.



Name of shape \_\_\_\_\_ Name of shape \_\_\_\_\_

(4)

- (d) The equation for the reaction between magnesium hydroxide and hydrochloric acid is shown below.



Calculate the volume, in  $\text{cm}^3$ , of  $1.00 \text{ mol dm}^{-3}$  hydrochloric acid required to react completely with  $1.00 \text{ g}$  of magnesium hydroxide.

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(4)

(Total 12 marks)

## Mark schemes

### Q1.

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

1

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

*Do not mix and match methods*

#### Method 1

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

$$= 1420 \text{ ms}^{-1}$$

*In method 1, M2 can be awarded in M3*

1

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

$$= \frac{1}{2} \times 1.312 \times 10^{-25} \times (1420)^2$$

$$= 1.32 \times 10^{-19} \text{ J}$$

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

1

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

$$= \sqrt{1.963 \times 10^6}$$

$$= 1.40 \times 10^3 \text{ ms}^{-1}$$

$$(\text{allow } 1.398 \times 10^3 - 1.402 \times 10^3)$$

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

1

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

$$= 6.80 \times 10^{-4} \text{ s}$$

*Mark consequential to their M4*

*Accept 6.77 – 6.80 × 10<sup>-4</sup> s*

1

#### Method 2

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

or

$$m_1 / t_1^2 = m_2 / t_2^2$$

1

$$t_2^2 = t_1^2 (m_2/m_1)$$

Or

$$t_2^2 = (6.69 \times 10^{-4})^2 \times (81/79)$$

1

$$t_2^2 = 4.59 \times 10^{-7}$$

*Mark consequential to their M3*

1

$$t = 6.77 \times 10^{-4} \text{ s}$$

*Mark consequential to their M4*

*Accept  $6.77 - 6.80 \times 10^{-4} \text{ s}$*

1

- (b) ion hits the detector / negative plate and gains an electron

1

*Not positive plate*

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

1

[7]

## Q2.

- (a) 3-chloro-2,4-dimethylpentane

*This answer only apart from slips with commas and dashes*

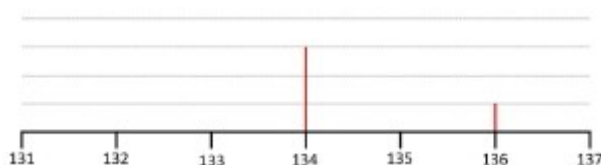
1

- (b) **M1** lines at 134 and 136

***M1** is for drawing the correct two lines (if other lines are drawn, penalise **M1** (but ignore any additional very small lines at 135 or 137))*

1

- M2** line at 134 to be three times higher than line at 136

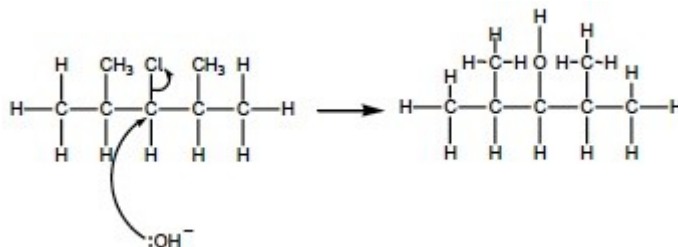


***M2** is for the line at 134 being three times as big as the one at 136 (ignore other lines)*

*Accept cross to represent top of lines; if bars drawn – they should be narrow (less than 10% of division) and clear which value they refer to.*

1

- (c) **M1** nucleophilic substitution



1

**M2** curly arrow from lone pair on O of OH<sup>-</sup> to C of C-Cl

*For SN2: penalise **M2** for any additional arrow(s) on NaOH, or for covalent NaOH; penalise **M3** for any additional arrow(s) to/from the Cl to/from anything else*

*If curly arrows represent an attempt at an elimination mechanism, cannot score **M2** or **M3***

1

**M3** curly arrow from C-Cl bond to the Cl

*Penalise **M3** for formal charge on C and/or Cl of C-Cl or incorrect partial charges on C-Cl; ignore other partial charges on uncharged atoms*

*For SN2: penalise **M2** for any additional arrow(s) on NaOH, or for covalent NaOH; penalise **M3** for any additional arrow(s) to/from the Cl to/from anything else*

*If curly arrows represent an attempt at an elimination mechanism, cannot score **M2** or **M3***

*If SN1 mechanism given (loss of Cl first followed by attack by OH<sup>-</sup>) then:*

**M2** curly arrow from C-Cl bond to the Cl

**M3** curly arrow from lone pair on O of OH<sup>-</sup> to positive C atom of correct carbocation

*penalise **M2** for any additional arrow(s) to/from the Cl to/from anything else*

*penalise **M3** for any additional arrow(s) on NaOH*

1

**M4** correct structure of alcohol (in any form)

**M4** is independent

**M4** ignore presence of non-organic products

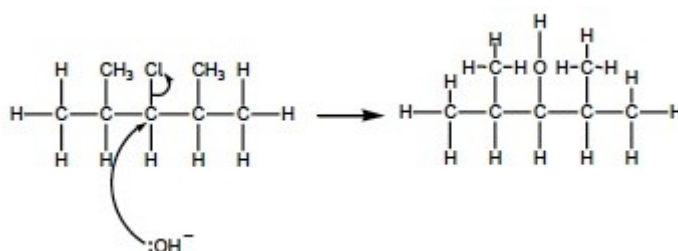
1

(d) **M1** elimination

**M1** allow base elimination (but nothing else)

1

**M2** base



**M2** allow proton acceptor

1

**M3** curly arrow from lone pair on O of OH<sup>-</sup> to H on one of the C atoms adjacent to the C–Cl

*If curly arrows represent an attempt at a substitution mechanism, cannot score **M3** or **M4***

1

**M4** curly arrow from a correct C–H bond adjacent to the C–Cl to a correct C–C bond. Only award if an arrow is shown attacking the H atom of a correct adjacent C–H bond in **M3**

*If curly arrows represent an attempt at a substitution mechanism, cannot score **M3** or **M4***

1

**M5** curly arrow from C–Cl bond to the Cl (mark is independent)  
*Penalise **M5** for formal charge on C and/or Cl of C–Cl or incorrect partial charges on C–Cl; ignore other partial charges on uncharged atoms*

1

**M6** correct structure of alkene (in any form)

***M6** is independent*

***M6** ignore presence of non-organic products*

*If E1 mechanism given (loss of Cl first followed by attack by OH<sup>-</sup>) then:*

***M3** curly arrow from C–Cl bond to the Cl*

***M4** curly arrow from lone pair of OH<sup>-</sup> to a correct H on the correct C adjacent to C<sup>+</sup> on the carbocation*

***M5** curly arrow from a correct C–H bond to a correct C–C bond*

*penalise **M3** for any additional arrow(s) to/from the Cl to/from anything else*

*penalise **M4** for any additional arrow(s) on KOH*

1

(e) C as C=C 1620-1680 cm<sup>-1</sup> OR no O–H 3230-3550 cm<sup>-1</sup>

*need the correct compound and an explanation*

*full wavenumber range or value(s) within the range*

*on this occasion candidates do not need to refer to the O–H bond being O–H alcohol as opposed to O–H acid – just reference to O–H with wavenumbers is required*

1

(f) C–Br is weaker than C–Cl or

C–Br has lower bond enthalpy than C–Cl or

C–Br breaks more easily C–Cl

*Must compare the C–Br and C–Cl bonds specifically*

*Ignore references to bond length, size of atoms, shielding, electronegativity and polarity*

*Penalise idea that bromine is more reactive than chlorine*

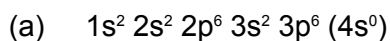
1

Q3.

B

[1]

Q4.



1

(b) **M1** In  $\text{Ca}^{(+)}$  (outer) electron(s) is further from nucleusOr  $\text{Ca}^{(+)}$  loses electron from a higher (energy) orbitalOr  $\text{Ca}^{(+)}$  loses electron from a 4(s) orbital or 4th energy level or 4th energy shell and  $\text{K}^{(+)}$  loses electron from a 3(p) orbital or 3rd energy level or 3rd energy shell*Must be comparative**Allow converse arguments*

1

**M2** More shielding (in  $\text{Ca}^{+}$ )

1

(c) Be /Beryllium

1

(d)  $\text{Mg}(\text{OH})_2$ 

1

*Ignore state symbols*

1

$$n \text{ BaCl}_2 (6/1000 \times 0.25) = 1.5 \times 10^{-3} \text{ and } n \text{ Na}_2\text{SO}_4 = (8/1000 \times 0.15) = 1.2 \times 10^{-3}$$

and  $\text{BaCl}_2$  /barium chloride in excess*Working required or  $3 \times 10^{-4}$  of  $\text{BaCl}_2$* 

1

 $10 \text{ cm}^3$  (of  $0.15 \text{ mol dm}^{-3}$  sodium sulfate)*or  $0.01 \text{ dm}^3$* 

1

(f) **M1** Same electronic configuration / same number of electrons (in outer shell) / all have 37 electrons (1)*Ignore protons and neutrons unless incorrect numbers**Not just electrons determine chemical properties*

1

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

*Alternative M2:*

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

1

**M3**  $x = 10\%$  (or  $x = 0.1$ )  
 $M3 y = 8$

1

**M4** (% abundance of 88 isotope is  $100 - 2 \times 10 = 80(.0)\%$   
 $M4$  % of 88 isotope is  $100 - 10y = 80(.0) \%$   
 Allow other alternative methods

1

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

1

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

Calculation of  $m$  in kg

If not converted to kg, max 4

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

1

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

For re-arrangement

1

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

For expression with square root

1

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

1

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

M5 must be to 3sf

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

1

Alternative method

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

M1 Calculation of  $m$  in kg

1

**M2**  $v = d/t$

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

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

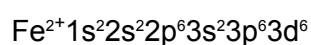
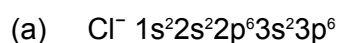
$$\text{M4} \quad d = \sqrt{\frac{KE \times 2 t^2}{m}} \quad (= \sqrt{(3.65 \times 10^{-16} \times 2 \times (2.71 \times 10^{-5})^2 / 2.275 \times 10^{-25})})$$

$$\text{M5} \quad d = 1.53 - 1.54 \text{ (m)}$$

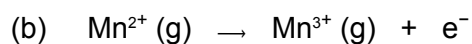
*M5 must be to 3sf*

[18]

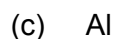
### Q5.



*If [Ne] or [Ar] used then Max 1 if both correct*  
*Ignore 4s<sup>0</sup>*  
*Allow subscripts*



*States symbols are required*  
*Allow  $\text{Mn}^{2+} (\text{g}) - \text{e}^- \rightarrow \text{Mn}^{3+} (\text{g})$*   
*Negative charge needed on electron*



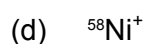
*Mg then CE = 0*

(Outer) electron in (3)p sublevel / orbital  
*Not just level or shell*

Higher in energy / further from the nucleus  
 so easier to remove OWTTE

*Both required for M3*

*Ignore shielding*



*M1 needs mass and charge – allow subscripts*

$$A_r = [(58 \times 61.0) + (60 \times 29.1) + (61 \times 9.9)] / 100$$

$$A_r = 58.9 \text{ must be to 1dp}$$

[9]

### Q6.

A

[1]

Q7.

B

[1]

Q8.

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

1

= 47.8

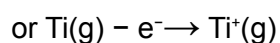
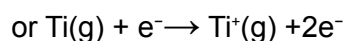
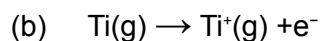
*Correct answer scores 2 marks.*

*Allow alternative methods.*

*Allow 1dp or more.*

*Ignore units*

1



*State symbols essential*

*Allow electrons without  $-$  charge shown.*

1

46

1

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

1

(d) M1 is for re-arranging the equation

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

*Allow  $t$  a square root of  $m$*

1

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

Or

$d = 1.5(47)$

*This scores 2 marks*

*Allow this expression for M2*

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

1

$$= 9.6(14) \times 10^{-7}$$

Correct answer scores 3 marks.

1

[8]

**Q9.**

- (a)  $^{24}\text{Mg}$  has 12n;  $^{25}\text{Mg}$  has 13n;  $^{26}\text{Mg}$  has 14n

**OR** They have different numbers of neutrons

1

- (b) No difference in chemical properties

1

Because all have the same electronic structure (configuration)

**OR** they have the same number of outer electrons

1

- (c) If fraction with mass 24 = x

Fraction with mass 26 = 0.900 - x

Fraction with mass 25 = 0.100

1

$$A_r = 24x + (25 \times 0.100) + 26(0.900 - x)$$

1

$$24.3 = 24x + 2.50 + 23.4 - 26x$$

$$2x = 1.60$$

$$x = 0.800 \text{ i.e. percentage } ^{24}\text{Mg} = 80.0(\%) \text{ (80.0\% 3sf)}$$

1

$$^{26}\text{Mg} = 0.900 - 0.800 = 0.100 \text{ ie percentage } ^{26}\text{Mg} = 10.0(\%)$$

1

(d)  $m = \frac{25/1000}{6.022 \times 10^{23}}$

1

$$v^2 = 2ke/m \text{ or } v^2 = \frac{2 \times (4.52 \times 10^{-18}) \times (6.022 \times 10^{23})}{25/1000}$$

1

$$V = \sqrt{2.18 \times 10^{10}} = 1.48 \times 10^5 \text{ (ms}^{-1}\text{)}$$

1

$$D = vt = 1.48 \times 10^5 \times 1.44 \times 10^{-5}$$

$$D = 2.13 \text{ (m)}$$

1

Q10.

C

[1]

Q11.

$$(a) \quad \frac{(82 \times 5) + (83 \times 3) + (84 \times 26) + (86 \times 7)}{41} = \frac{3445}{41}$$

1

84.0

1

Kr

1

$$(b) \quad 82 / (1.243 \times 10^{-5})^2 = 86 / t^2$$

$$\text{So } t^2 = 86 / 82 \times (1.243 \times 10^{-5})^2$$

1

$$t^2 = 1.6204 \times 10^{-10}$$

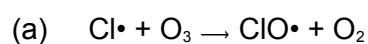
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$$t = 1.273 \times 10^{-5} \text{ (s)}$$

1

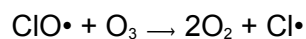
[6]

Q12.



Allow dot in free-radical on either O or Cl.

1



1

(b) (KOH acts as a) base

1

(propan-1-ol acts as a) solvent.

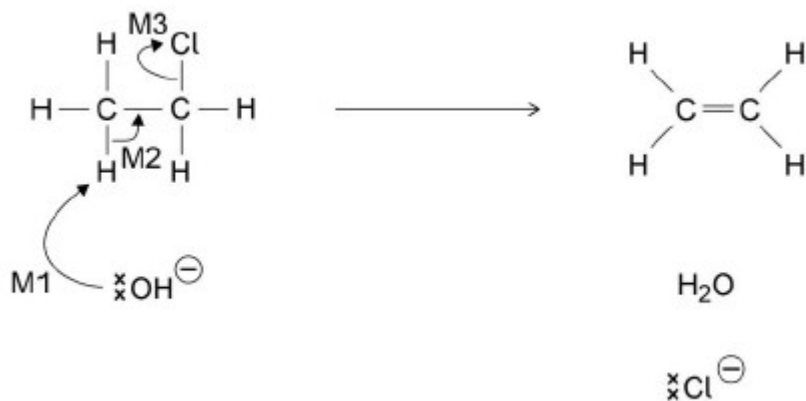
*Allow product of reaction between KOH and propan-1-ol /  
CH<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub>O<sup>-</sup> acts as base.*

1

(c) (Name of mechanism) Elimination

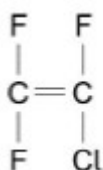
1

mechanism: 3 arrows (1 mark each).



3

(d)



1

- (e) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

### Level 3

All stages are covered & the explanation of each stage is generally correct and virtually complete. Stages 1 and 2 are supported by correct data. Answer communicates the whole process coherently and shows a logical progression from stage 1 to stage 2 and then stage 3.

Steps in stage 3 are in logical order and working is shown. If there is no working for ratio or statement of ratio then full marks cannot be awarded.

**If the formulae of the three molecular ions are not correct (2d) then the student can't access Level 3 (any incorrect chemistry drops the student to the bottom mark within the level they have achieved).**

5-6 marks

### Level 2

Stage 2 is attempted (**2a-2c** do not need to be explicitly stated) but the calculation may contain inaccuracies **OR** the explanation may be incomplete **OR** first two stages are covered and the explanations are generally correct and virtually complete. Answer is mainly coherent and shows a progression through the first two stages. Some steps in each stage may be incomplete.

**If percentage of carbon is missing or incorrect (1a) then student can't access Level 2.**

3-4 marks

### Level 1

Stage 1 needs to be attempted but may contain inaccuracies.

**OR**

Stage 3 attempted but may contain inaccuracies / molecular formula not determined.

Answer includes some isolated statements, but these are not presented in a logical order or show confused reasoning.

1-2 marks

### Level 0

Insufficient correct chemistry to warrant a mark.

0 marks

#### **Indicative Chemistry content**

##### **Stage 1 (determines empirical formula)**

**1a** 16.3% carbon

**1b** Divide by  $A_r$

**1c** Divide by smallest (0.904)

**1d** Convert ratio in simplest integer (x 2)

| C                           | Cl                          | F                           |
|-----------------------------|-----------------------------|-----------------------------|
| $\frac{16.3}{12.0} = 1.358$ | $\frac{32.1}{35.5} = 0.904$ | $\frac{51.6}{19.0} = 2.716$ |
| $\frac{1.358}{0.904}$       | $\frac{0.904}{0.904}$       | $\frac{2.716}{0.904}$       |
| 3                           | 2                           | 6                           |

##### **Stage 2 (determines formulae of three molecular ions)**

**2a** For E.F.  $M_r$  (corresponds to the molecule) = 221

**2b** since  $M_r = 221$  lies within molecular ion range 220–224

**2c** Thus empirical formula = molecular formula

**2d** Three correct formulae

**2e** Correct  $M_r$  for each of three molecules

|                     |                          |                     |
|---------------------|--------------------------|---------------------|
| $C_3^{35}Cl_2F_6^+$ | $C_3^{35}Cl^{37}ClF_6^+$ | $C_3^{37}Cl_2F_6^+$ |
| 220                 | 222                      | 224                 |

##### **Stage 3 (explains the ratio of 3 molecular ion peaks)**

**3a** Working

**2b** Correct (simplified) ratio **9:6:1**

Note: 9:3:1 will be a common incorrect answer (max 5).

Working:

|                     |                          |                     |
|---------------------|--------------------------|---------------------|
| $C_3^{35}Cl_2F_6^+$ | $C_3^{35}Cl^{37}ClF_6^+$ | $C_3^{37}Cl_2F_6^+$ |
| 220                 | 222                      | 224                 |

|                                                                |                                                                                                                                                                    |                                                                |
|----------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------|
| $^{35}\text{Cl}_2 = \left(\frac{3}{4}\right)^2 = \frac{9}{16}$ | $\begin{matrix} ^{35}\text{Cl}^{37}\text{Cl} \text{ and} \\ ^{37}\text{Cl}^{35}\text{Cl} = 2 \times \\ \frac{1}{4} \times \frac{3}{4} = \frac{6}{16} \end{matrix}$ | $^{37}\text{Cl}_2 = \left(\frac{1}{4}\right)^2 = \frac{1}{16}$ |
|----------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------|

[15]

**Q13.**

(a) **Gas chromatography explanation**

Different retention times / dipeptides appear at different times.

1

Different balance between solubility in the moving phase / gas carrier **and** retention by the stationary phase / column **OR** different relative affinity for mobile and stationary phases.

1

**Mass spectrometry explanation**

Same  $m/z$  values.

1

(Both) dipeptides / **J** and **K** have same molecular formula /  $M_r$ .

1

(b) ser-ala

1

ala-lys

1

ser-ala-lys

*This order only.*

1

[7]

**Q14.**

(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]

**Q15.**

D

[1]

**Q16.**

(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

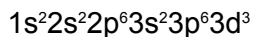
1

[6]

**Q17.**

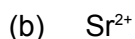
(a)  $1s^2 2s^2 2p^6 3s^2 3p^1$

1



1

*If noble gas core used correctly in both then scores 1*  
*Allow subscripts and capitals*  
*Ignore 4s<sup>0</sup>*



*Ignore name and correct proton/mass number*  
*Allow  $Sr^{+2}$*

1



*Allow reversed or ionic formula*  
*Ignore name*

1

[4]

### Q18.

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

*Mark independently*

1

Ions detected by gaining electrons

*Allow the transfer of electrons*

1

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

*Allow current is proportional to abundance*

1

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

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

1

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

*Allow correct rearrangement for V or V<sup>2</sup>*

1

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

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

1

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

*Mark independently*

1

In ratio 25%:50%:25%

*Allow approx. ratio 1:2:1*

1

- (e) % abundance  $^{m}\text{Xe} = 20(\%)$

*Working must be shown*

1

$$131.31 = (0.28 \times 129) + (0.25 \times 131) + (0.27 \times 132) + (0.20 \times m)$$

1

$$131.31 - 104.51 = 0.2m$$

1

Mass number = 134

*Answer must be an integer*

1

[12]

**Q19.**

D

[1]

**Q20.**

C

[1]

**Q21.**

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

*M1 for top line*

1

$$\frac{127.8}{19}$$

*M2 for correct denominator*

1

*127.8 with no working shown scores 3 marks*

1

Or

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

1

*Mark for 100 dependent on top line correct*

1

127.8

1

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

1

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

*Ignore state symbols*

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

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  $^{128}\text{Te}^{2+}$  = 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  $^{130}\text{Te}$*

1

[12]

## Q22.

- (a) (i)  $1.6734 \times 10^{-24}$  (g)

*Only.*

$1.6734 \times 10^{-27}$  kg

*Not  $1.67 \times 10^{-24}$  (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  $5 \times 0.2$  divisions between 10 and 11.*

1

abundance of  $^{10}\text{B}$  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<sup>-1</sup>

1

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

*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]

### Q23.

- (a) Average / mean mass of 1 atom (of an element)  
1/12 mass of one atom of  $^{12}\text{C}$

*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  $^{12}\text{C}$

**OR**

Average / mean mass of atoms of an element  $\times 12$   
mass of one atom of  $^{12}\text{C}$

**OR**

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

**OR**

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

**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.*

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

1

1

$$= \underline{72.4}$$

*72.4 only*

1

(c)  $^{72}\text{Ge}^+$  or germanium<sup>+</sup>

*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*
- (From detector / plate) to the (+) ion  
*Do not allow from a charged plate.*
- (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

1

1

[11]

## Q24.

- (a) 37  
*These answers only.*  
*Allow answers in words.*
- 48  
*Ignore any sum(s) shown to work out the answers.*
- (b) (i) Electron gun / high speed/high energy electrons  
*Not just electrons.*  
*Not highly charged electrons.*
- Knock out electron(s)  
*Remove an electron.*
- (ii)  $\text{Rb(g)} \rightarrow \text{Rb}^+(\text{g}) + \text{e}^{(-)}$   
**OR**  
 $\text{Rb(g)} + \text{e}^{(-)} \rightarrow \text{Rb}^+(\text{g}) + 2\text{e}^{(-)}$   
**OR**  
 $\text{Rb(g)} - \text{e}^{(-)} \rightarrow \text{Rb}^+(\text{g})$   
*Ignore state symbols for electron.*
- (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.*
- (d) (i) s / block s / group s  
*Only*

1

1

1

1

1

1

|      |                                                                                                                                                                                                                                             |             |
|------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|
|      |                                                                                                                                                                                                                                             | 1           |
| (ii) | $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^1$<br><i>Allow <math>3d^{10}</math> before <math>4s^2</math></i><br><i>Allow in any order.</i>                                                                                               | 1           |
| (e)  | $\frac{(85 \times 2.5) + 87 \times 1}{3.5}$<br><i>M1 is for top line</i><br><br>$= \underline{85.6}$<br><i>Only</i>                                                                                                                         | 1<br>1      |
|      | <b>OR</b><br>$\frac{(58 \times 5) + 87 \times 2}{7}$<br><i>M1 <math>^{85}\text{Rb}</math> 71.4% and <math>^{87}\text{Rb}</math> 28.6%</i><br><i>M2 divide by 100</i><br><br>$\underline{85.6}$<br><i>M3 = <math>\underline{85.6}</math></i> | 1<br>1<br>1 |
| (f)  | Detector<br><i>Mark independently</i><br><i>Allow detection (plate).</i>                                                                                                                                                                    | 1           |
|      | Current / digital pulses / electrical signal related to abundance<br><i>Not electrical <u>charge</u>.</i>                                                                                                                                   | 1           |
| (g)  | Smaller<br><i>Chemical error if not smaller, CE = 0/3</i><br><i>If blank mark on.</i>                                                                                                                                                       | 1           |
|      | Bigger nuclear charge / more protons in Sr<br><i>Not bigger nucleus.</i>                                                                                                                                                                    | 1           |
|      | Similar/same shielding<br>QWC<br><i>(Outer) <u>electron</u> entering same shell/sub shell/orbital/same number of shells.</i><br><i>Do not allow incorrect orbital.</i>                                                                      | 1           |

**Q25.**

- (a) (Total number of) protons and neutrons (in nucleus of atom)  
(number of) nucleons 1
- (b) Zn  
Do not allow  $Zn^{-1}$  or  $Zn^{+1}$  or ZN  
Ignore numbers 1
- (c) (i) P = ionise (sample)  
Allow removing an electron / forms (+) ions 1
- Q = accelerate (sample)  
Allow speeds (ions) up  
Penalise molecules / atoms 1
- (ii)  $m/z$   
Allow mass / charge 1
- (relative) abundance / (relative) intensity  
QoL  
Allow M1 + M2 in any order 1
- (d) (i)  $\frac{206 + 207 + (208 \times 2)}{4} = \frac{(829)}{4}$   
M1 = topline 1  
M2 =  $\div 4$  1  
  
= 207.3  
Only  
207.3 = 3 marks 1
- (ii) Lead / Pb  
Not PB 1
- (iii) Same number of electrons (in outer shell) / same electronic configuration  
Ignore electrons determine chemical properties  
Ignore reference to p and n if correct  
Penalise if incorrect 1
- [11]

**Q26.**

- (a)  $2Ca_5F(PO_4)_3 + 9SiO_2 + 15C \rightarrow 9CaSiO_3 + CaF_2 + 15CO + 6P$

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**

$$\begin{aligned} M_r &= 2(1.00794) + 32.06550 + 4(15.99491) \\ &= \mathbf{98.06102 \text{ or } 98.0610 \text{ or } 98.061 \text{ or } 98.06 \text{ or } 98.1} \end{aligned}$$

*Calculations not required*

**and**

$H_3PO_4$

$$\begin{aligned} M_r &= 3(1.00794) + 30.97376 + 4(15.99491) \\ &= \mathbf{97.97722 \text{ or } 97.9772 \text{ or } 97.977 \text{ or } 97.98 \text{ or } 98.0} \end{aligned}$$

1

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

**Both ideas needed**

*Ignore reference to activation energy or alternative route.*

1

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

**QoL- for the underlined words**

1

(iii) **M1**  $CH_3CH=CH_2 + H_2O \rightarrow CH_3CH(OH)CH_3$

$(C_3H_6)$

*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]

**Q27.**

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

*M1 for the top line*

*M2 is for division by 17*

1

= 84.0

*Not 84*

*No consequential marking from M1 or M2*

*Ignore units*

1

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

*Award independently*

*Comparison implied*

*Isotope(s) alone,  $M_4 = 0$*

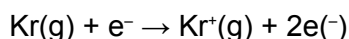
1

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

1

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

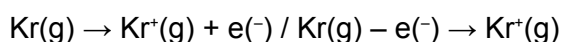
1



*State symbols must clearly be (g)*

1

**OR**



The  $^{84}\text{Kr}$  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]

**Q28.**

- (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) Average mass of 1 atom (of an element)

1/12 mass atom of  $^{12}\text{C}$

OR

Average/mean mass of atoms of an element

1/12 mass of one atom of  $^{12}\text{C}$

OR

(Average) mass of one mole of atoms

1/12 mass of one mole of  $^{12}\text{C}$

OR

(Weighted) average mass of all the isotopes

1/12 mass of one atom of  $^{12}\text{C}$

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  $\times 12$  on top line*

*This expression = 2 marks*

2

(c) (i)

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

$$= 65.6$$

*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)  $^{64}\text{Zn}^+$

*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]

## Q29.

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

*Not in a substance or compound or element*

7 protons and 7 electrons

8 neutrons

[3]

**Q30.**

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

1/12 mass of one atom of  $^{12}\text{C}$

*Accept answer in words*

*Can have top line  $\times 12$  instead of bottom line  $\div 12$*

**OR**

(Average) mass of one mole of atoms

1/12 mass of one mole of  $^{12}\text{C}$

**OR**

(Weighted) average mass of all the isotopes

1/12 mass of one atom of  $^{12}\text{C}$

**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*

= 14.05

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

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

*Not different no's of neutrons*

*Not ionisation potential*

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

- (c) No difference

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]

**Q31.**

- (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]

**Q32.**

- (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<sup>2</sup>4s<sup>2</sup>

1

*Can be written in full*

*Allow subscripts*

*3d<sup>2</sup> and 4s<sup>2</sup> can be in either order*

27

1

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

(c)

17

(= 1550)

1

(or  $\Sigma$  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  $\Sigma$  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<sup>+</sup> = 90 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]

**Q33.**

(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

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

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

1

= 183.90; allow range from 183.90 – 184.00;

1

[12]

### Q34.

(a) Number of protons in the nucleus

1

(b) They may have different numbers of neutrons

1

(c) (i) Mass spectrometer

1

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

2

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

1

$$= (82 \times 12 + 83 \times 12 + 84 \times 50 + 86 \times 26)/100 = 84.16$$

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]

**Q35.***(penalty for sig fig error = 1 mark per question)*

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

1

electron: relative mass =  $1/1800 \rightarrow 0$ /negligible or

$5.56 \times 10^{-4} \rightarrow 0$  relative charge =  $-1$

1

- (b)  $^{17}\text{O}/\text{O}^{17}$  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  $N^{\circ}$  given but  $\neq 8$ , treat as 'con' for M2)*

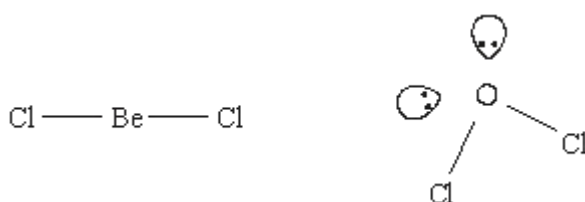
*(if lp on Be, diagram = 0)*

*(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)  $M_r(\text{Mg}(\text{NO}_3)_2) = 58(.3)$  (if At  $N^{\circ}$  used, lose M1 and M2)

1

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

1

moles  $\text{HCl} = 2 \times 0.0172 = 0.0344$  or  $0.0343$  (mol) (process mark)

1

vol  $\text{HCl} = \frac{0.0343 \times 1000}{1} = 34.3 - 34.5$  ( $\text{cm}^3$ ) (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]

## Examiner reports

### Q1.

- (a) This question proved demanding for most students. A good number were able to calculate the mass of the  $^{79}\text{Br}^+$  ion. Very few students realised that most of the quantities cancelled down during the calculation and took time to calculate the velocity of the  $^{79}\text{Br}^+$  ion in order to then work out the kinetic energy. This velocity was frequently calculated well but the remaining marks then proved a challenge for students. Some completed numerous calculation steps only to give a time for the  $^{81}\text{Br}^+$  ion that was the same as the time for the  $^{79}\text{Br}^+$  ion.
- (b) Only a few students understood that when the ion reaches the detector it gains an electron, whereas many understood that the size of the current was proportional to the abundance of the ion.

### Q2.

- (a) Most students (56.1%) could name compound **A** correctly.
- (b) This question proved to be demanding. The calculation of the  $M_r$  of individual molecules containing different isotopes was a challenge for many students. 61.8% of students either failed to score or made no attempt; 33.4% did, however, score both marks.
- (c) The nucleophilic substitution mechanism was well-answered; 45.6% of students scored full marks here.
- (d) The elimination mechanism was more challenging, and many students did not know the role of the hydroxide ion. This question discriminated particularly well.
- (e) Just under half of students could determine that the IR spectrum was of an alkene rather than an alcohol and explain this by reference to the absorption for a bond and its wavenumber range.
- (f) Students struggled to explain the relative rates of reaction of the halogenoalkanes. The most common answer incorrectly referred to the reactivity of the elements bromine and chlorine, rather than looking at the C-Br and C-Cl bond strengths. Only 28.6% of students gained this mark.

### Q3.

The most common answer, **C**, was incorrect. Students believed that 500 cm<sup>3</sup> of water should be added to the 10 cm<sup>3</sup> of solution, rather than adding 490 cm<sup>3</sup> to make the total volume 500 cm<sup>3</sup>.

### Q4.

- (a) The electron configuration was well known (88.9% correct).
- (b) Only the best students gained both marks here (19%); many students focused on whether the electron was being removed from a full or partially full orbital instead of considering why the attraction between the nucleus and the electron might be different.

- (c) Less than half of the students (39.5%) could give the correct answer here; lithium was a common error.
- (d) The majority of students (76.3%) answered this correctly, although there were quite a number who gave the incorrect formula.
- (e) The ionic equation was generally correct and many students could also calculate that barium chloride was in excess. Just under a third of students managed to score all three marks.
- (f) Most students could state why isotopes have the same chemical properties. In the calculation, many students gave an algebraic equation with two unknowns and could not proceed any further. The students who gave a correct algebraic expression with one unknown could work through the calculation and generally gained full marks. Some students answered the question by trial and error and this was also given full credit. Pleasingly, 43.7% of students gained all four marks available.
- (g) Most students deduced that the mass number of the ion would be 138 but less than 30% of students could give the correct formula for the ion including its charge.
- (h) Some students answered this part very well (with 36.6% scoring full marks), but most students scored partial marks or no marks; common errors included failure to use the Avogadro constant, not converting mass to kg, and incorrect rearrangement of expressions.

#### Q5.

- (a) This was surprisingly poorly answered. Many students were unable to write the electronic configuration for  $\text{Fe}^{2+}$ .
- (b) Part (b) was generally well answered, but a significant number of answers had missing state symbols, despite the direct instruction to include them.
- (c) Part (c) was quite well answered.
- (d) The symbol including mass number was often incorrect. The calculation of  $A_r$  was straight- forward and done well by many students.

#### Q6.

48.5% of students scored this mark; the most common wrong answer was D, showing that some students thought that a magnetic field is involved in TOF mass spectrometry.

#### Q7.

Only 26.2% of students selected the correct answer here, with all three distractors attracting significant numbers of students. Although this example is commonly taught, there are clearly not many students who can either remember the example or work out the probabilities for themselves.

#### Q8.

- (a) This was generally well answered, though a few students added the abundances incorrectly.
- (b) Most students gave the correct equation, but some used the wrong state symbols or omitted them. The identity of the isotope was well known but some students lost a

mark by using the symbol for the atom rather than the  $m/z$  value.

- (c) The most common error was a failure to convert from grams into kilograms.
- (d) Only the best students gained all three marks. All marks were available, even for those students who had not answered part (c), or who had the wrong answer for it. Some students were unable to re-arrange the equation. Students who appreciated that the distance travelled was common to both ions usually went on to get the correct answer, but a large number of students scored zero or one mark.

### Q17.

Aspects of this question were well done but significant numbers were unable to write the electronic configuration of the  $\text{Cr}^{3+}$  ion. part (b) was answered well but the unfamiliar formula required in (c) proved tricky for the majority.

### Q18.

For Question (a) many students wrote a lot of unnecessary detail about aspects of a time of flight mass spectrometer but on the whole it was quite well answered. Questions (b) and (c) proved mathematically difficult for many although consequential marking allowed large numbers to score on (c). The use of probability to predict the ratio of peaks in question (d) proved very difficult for students. Some scored 1 mark for giving three peaks but the 1:2:1 ratio was only seen from 11.3% of students. Question (e) was answered well with over 60% of students scoring all 4 marks.

### Q21.

Students found part (a) tricky and many did not realise the significance of the [Kr] given; however some students answered very well and had all the sublevels in the correct order. Part (b)(i) was answered very well by most students. Common mistakes included failed attempts to express the data as percentages and not giving the answer to the required number of decimal places. There were many confused answers to part (d)(ii) and these included references to impurities and the size of the sample rather than the fact that the Periodic Table takes into account all isotopes whereas the sample didn't. The equation in part (c) was often given the wrong way round showing that students did not understand the process occurring at the detector; many students used Tl rather than Te in their equations. In part (e) the majority of students chose the correct answer and gave a good explanation of their choice. The most common error was choosing 130 and stating that it had the biggest value. Many students thought that the atomic radius of the two isotopes in part (f) was the same but did not then give a complete explanation; many only referred to the number of protons in the nucleus.

### Q22.

The overall performance in part (a)(i) was disappointing because many students did not know the subatomic particles in the hydrogen atom. The mark in part (a)(ii) was scored by most students. Many students scored both marks in part (b)(i) but several quoted an equation involving  $x$  and  $y$  but could not progress beyond that. The majority of students answered part (b)(ii) correctly and part (c) was also generally well done. In part (d), many students used Br instead of B in their equation and some either wrote the wrong ionisation energy or failed to add state symbols. Many answers to part (e) were superficial; many students simply referred to a different proton / electron ratio or the removal of an electron from a different energy level.

**Q23.**

The definition in part (a) is still not well known. Average or mean was often omitted as was mass. Part (b) was well done although a few students still chose to divide by 100. In part (c), the charge on the ion was often missed out. The most common wrong answer in part (d) was 74 since students were obviously confusing deflection with detection. The majority who chose 70 carried on to give the correct explanation. Answers to part (e) were poor with many students not referring to electrons at all. Most students scored the mark in part (f).

**Q24.**

Part (a) was done very well. In part (b)(i), many students stated that a positive ion was formed but failed to say how. The equation in part (b)(ii) was well done with only a few omitting the state symbols. In part (c), a number of students failed to score the mark since they referred to a rubidium molecule, showing a lack of understanding of the metals given. In part (d)(ii) there were many students who filled the 4d rather than the 5s orbitals and some gave an abbreviated electron structure even though the question asked for the full electron structure. Many students found part (e) difficult although it was pleasing to see some gain full marks. Part (f) was not well understood with many students confusing charge and current. The answers to part (g) were generally good although a few students did not give complete explanations and lost the last mark.

**Q25.**

In part (a), a significant number of students struggled with a definition of mass number and many defined Ar instead. The majority of students could answer part (b) well. The answers to part (c)(i) were well known although many students gave too much detail. In some cases, this extra detail was contradictory and, therefore, lost the marks. In part (c)(ii), weaker students thought that mass and charge could be recorded separately. Answers to part (d) were generally good although many failed to read the instruction to quote the answer to 1 decimal place. Answers to part (d)(iii) were generally good although there were many irrelevant references to protons. Weaker students simply quoted that electrons determine chemical properties but did not refer to the isotopes of R.

**Q26.**

Balancing the equation in part (a) taxed some students but most were able to score at least one mark in part (b). There was a need for students to use correct chemical terminology in part (d), requiring, for example, reference to the “addition of water” in part (d)(ii). It was surprising to see how many made simple errors in the relatively straightforward part (d)(iii), for example, naming the alcohol as propanol rather than propan-2-ol.

**Q27.**

The majority of students calculated the relative atomic mass of krypton but then failed to quote their answer to the precision stated in the question. The last mark in part (a) proved more difficult with many students suggesting errors in measurements or precision. Part (b) gave a good spread of marks. The first three marks were gained by most students but some failed to give state symbols in their equation. The last two marks were more difficult and many references to the atom being split in two were seen rather than being ionised twice.

**Q28.**

Part (a)(i) was well done although many candidates gave a lot of unnecessary extra

information about protons and electrons. In part (a)(ii) there were quite a lot of answers which simply stated that a variation in neutron number had no effect on chemical properties; this approach was not an answer to the question. Answers to part (b) showed that some candidates fail to learn definitions accurately. In part (c)(i) several candidates divided by 100 rather than by 27 and a few failed to give their answer to one decimal place. There were very few correct answers to part (c)(ii). Even when zinc was identified the + sign was often missed. The most common incorrect answer was copper. Part (d) was well done but part (e) was not well understood. Electric charge was often mentioned and many thought that positive ions flowed into the computer.

#### **Q29.**

Generally well done by a large number of candidates. However the definition of mass number was often confused with relative atomic mass and a surprising number did not state the correct numbers of protons, neutrons and electrons.

#### **Q30.**

Answers to the definition in part (a) were variable as always. The most common errors were to miss out the word average/mean on the top line and 1 atom on the bottom line. The calculation was attempted well although some candidates did not give their answer to 2 decimal places. Part (b) was generally well answered. Part (c) answers were varied. Some candidates thought that natural and synthetic compounds would react differently and the ones who knew the reactions were identical often failed to qualify their answer sufficiently well to gain full marks.

#### **Q31.**

Few candidates could not make some progress in the empirical formula calculation in this part (a), but many were unable to deduce a  $M_r$  value from the spectrum in this part (b). The provision of dummy data in this part (c) allowed most candidates to score at least one of the marks.

#### **Q32.**

A substantial number of candidates were not able to produce an exact definition in part (a). Many marks were lost through the omission of vital words such as “mass” or “atom”, or mixing moles and atoms in their answer.

Part (b) was moderately well done but many candidates identified the element rather than the block it was in. The electron configuration was generally well known with the commonest errors being [Ar] 4s<sup>2</sup> 4d<sup>2</sup> and 3d<sup>4</sup>. A significant number of candidates could not calculate the number of neutrons and many gave non-integer answers such as 25.9.

In part (c) many candidates were able to calculate the relative atomic mass correctly but did not then identify the element. Weaker candidates included  $93 \times 0 = 93$  in their calculation or divided by 100. A small number used 91.2 as the atomic number and therefore identified protactinium.

The great majority of candidates scored the first 2 marks in part (d). However, many did not actually identify the isotope, often merely stating that it would be the lightest that would be deflected the most. A disappointing number misinterpreted the mass spectrum and selected 91 because it had the least abundance. A surprising number wrote that the heaviest ions would be deflected the most.

Part (e) was not well answered. Although many candidates knew that detection of ions

involved the production of a current, relatively few mentioned the relationship between the size of current and the abundance of ion. Common incomplete answers included “the more ions that hit the detector, the greater the abundance”. A very small number of candidates thought a current was produced by the ion giving electrons to the detector.

### Q33.

In part (a) the majority of the candidates scored full marks with some losing marks by referring to a charge of + rather than +1, or putting a + (plus) or a – (minus) sign in the relative mass column. The answer to part (b) was well done with only a few writing ‘Transition metals’ rather than stating the block that tungsten is in. Some candidates did not score marks in part (c) since they did not look for the atomic number in the Periodic Table and some could not remember how to calculate the number of neutrons. Candidates generally answered part (d) well although a few put ‘detect’ as one of their answers and this was given in the stem of the question. Some tried to explain how the ions were formed but this was not asked for. Part d (ii) was well answered. In part (e) candidates lost the second mark by not knowing that the isotopes have the same electron configuration. Many answers just stated that isotopes had different numbers of neutrons and/or same number of protons. The calculation in part (f) was very well done although some candidates lost the second mark by not giving their answer to two decimal places.

### Q35.

On the whole, this question was well answered. The relative masses and charges of neutrons and electrons were generally well known but errors were not uncommon. Some candidates reversed the contents of the *mass* and *charge* columns, suggesting that they had rote learned a table with a different layout of columns.

Part (b) was quite well done but errors such as  $^{17}\text{Be}$ ,  $^{13}\text{O}$ ,  $^{17.0}\text{O}$  and  $^{16}\text{O}$  were not uncommon.

While many candidates correctly deduced the shapes of the molecules in part (c), the presence of a lone pair of electrons on the Be atom, or one/three lone pairs of electrons on the O atom, was quite common. The shape of the  $\text{BeCl}_2$  molecule was well known but there was considerable confusion regarding the shape of the  $\text{Cl}_2\text{O}$  molecule. Many candidates gave *tetrahedral* as the shape of this molecule. While the distribution of electron pairs around the oxygen atom might be described as *tetrahedral*, this is not the shape produced by the atoms in the molecule. Many candidates described the shape in appropriately by using the terms *bent*, *V-shaped* and *angular*. The use of *tetrahedral* was accepted in this examination but this may not be the case in future examinations. A significant number of candidates used the term *bent linear* when describing the shape of  $\text{Cl}_2\text{O}$  molecules; this was treated as a contradiction and so earned no credit. A significant number of candidates attempted to show the shapes of these molecules using dot-and-cross diagrams; these were not accepted.

The calculation in part (d) was correctly performed by many candidates, but errors such as the use of incorrect *Mr* values or the use of an incorrect mole ratio were quite common. A small but significant number of candidates assumed the use of a known mass of  $\text{HCl}$  and ignore the 1.00 g of  $\text{Mg}(\text{OH})_2$  stipulated in the question; such answers earned no credit.

**Q1.**

Chlorine has two isotopes,  $^{35}\text{Cl}$  and  $^{37}\text{Cl}$ . The number of molecular ion peaks in the mass spectrum of a sample of  $\text{Cl}_2$  is

- A** 2
- B** 3
- C** 4
- D** 5

(Total 1 mark)

**Q2.**

- (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  $^{27}\text{Al}$ . An atom of **Q** also contains 14 protons.

- (i) Give the number of protons in an atom of  $^{27}\text{Al}$ .

---

- (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.

|                        |      |      |      |
|------------------------|------|------|------|
| <i>m/z</i>             | 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.

---

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(2)

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

---

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(1)

(Total 10 marks)

**Q3.**

- (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.

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- (iii) Calculate the mass, in grams, of a single atom of this isotope of sodium.  
(The Avogadro constant,  $L$ , is  $6.023 \times 10^{23} \text{ mol}^{-1}$ )

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(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.

---

**(Total 9 marks)**

**Q4.**

- 
- This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

(7)

-

(7)  
(Total 14 marks)

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  $\text{C}_4\text{H}_6\text{Cl}_4$ ?

- (Total 1 mark)**

## Mark schemes

**Q1.**

B

[1]

**Q2.**

- (a) Proton mass = 1 charge = +1  
 Electron mass  $\leq 1/1800$  Or  $\leq 5.6 \times 10^{-4}$  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

$1/12^{\text{th}}$  mass of atom of  $^{12}\text{C}$

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

$1/12^{\text{th}}$  mass of 1 mole of  $^{12}\text{C}$  (1)

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

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

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

*(Do not allow 'mass of average atom')*

2

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

*(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]

**Q3.**

- (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)

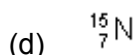
*OR d sub-shell being filled / is incomplete*

*OR highest energy sub-shell is (3)d*

*NOT transition element /  $e^-$  configuration ends at 3d*

*Q of L*

1



N correct symbol (1)

*allow  ${}^{15}_7\text{N}$*

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

2

[9]

#### Q4.

(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

average(1) mass of an atom/isotopes

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

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

**Q5.**

D

**[1]**

## Examiner reports

### Q2.

The fundamental particle data required in part (a) was generally well known; however, relative charges where either the sign or the value was omitted were occasionally seen. Part (b)(i) was well answered, and the majority of candidates coped well with (b)(ii). It was quite common however to see 28.1, rather than the required 28, to be quoted as the mass number of **Q**. Part (c) simply required a standard definition for the  $A_r$  to be quoted. Surprisingly, this question was quite poorly done, with attempts being frequently vague and incomplete. The most common error was to omit references to *mean*, *mass* and *atoms* in the definition. Also, it was not uncommon to see a ratio showing single atoms on the top and moles on the bottom. In part (d), the calculation of the  $A_r$  of the sample of magnesium was usually correct, however, a significant number of candidates failed to quote their final answer to one decimal place. Some candidates used the sum of the  $m/z$  values, rather than the sum of the relative abundances (100). Part (e) was very poorly answered. Very few references to *highest  $m/z$  value* were seen.

### Q3.

Many good answers were seen here and high marks were quite common. However, candidates frequently ignored the instruction in (a)(i) to define *isotopes* in terms of fundamental particles, and offered a definition based wholly, or in part, on mass number and atomic number. In (a)(ii), the link between chemical properties and electron configuration was well known but many candidates attempted to establish a link between proton, neutron or mass numbers and chemical properties. The calculation in (a)(iii) was often poorly done, the most common errors being to invert the expression or to multiply the mass number by  $L$ . Part (b) was generally well answered, although a few candidates gave the electron arrangement showing 23 electrons. Similarly, part (c) was generally well answered, however, some candidates referred to electrons being in the *d block*, while a small minority offered nonsense explanations. Most candidates correctly identified nitrogen as the element in part (d), but  $^{14}_7\text{N}$  was a common error.

### Q4.

Most candidates scored high marks for part (a) though the final part of the question, requiring an explanation why isotopes have identical chemical properties, was more demanding. Part (b) was also answered well though a considerable number of candidates wasted time by giving detailed but irrelevant information about the operation of the various parts of a mass spectrometer. Candidates were often imprecise about the information that can be obtained from a mass spectrum. Confusion between mass/charge and atomic mass or relative atomic mass was common but did not incur a heavy penalty.