# Atomic Structure Test

Answer ALL Questions. Max 50 marks. To Pass the Atomic Structure Test you will need to achieve a score of greater than 70%.

**1.** A naturally occurring sample of the element boron has a relative atomic mass of 10.8. In this sample, boron exists as two isotopes, $^{10}B$ and $^{11}B$

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

.....

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.....

**(2)**

(ii) State, in terms of fundamental particles, why the isotopes $^{10}B$ and $^{11}B$ have similar chemical reactions.

.....

.....

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**(1)**
**(Total 3 marks)**

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

.....

.....

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**(1)**

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

.....

**(1)**

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

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

Measurement 1 .....

Measurement 2 .....

**(2)**

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

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

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.....

.....

**(3)**

(ii) Identify **R**.

.....

**(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 9 marks)**

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

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

.....

.....

.....

.....

**(2)**

(b) Element **X** has a relative atomic mass of 47.9

Identify the block in the Periodic Table to which element **X** belongs and give the electron configuration of an atom of element **X**.

Calculate the number of neutrons in the isotope of **X** which has a mass number 49

.....

.....

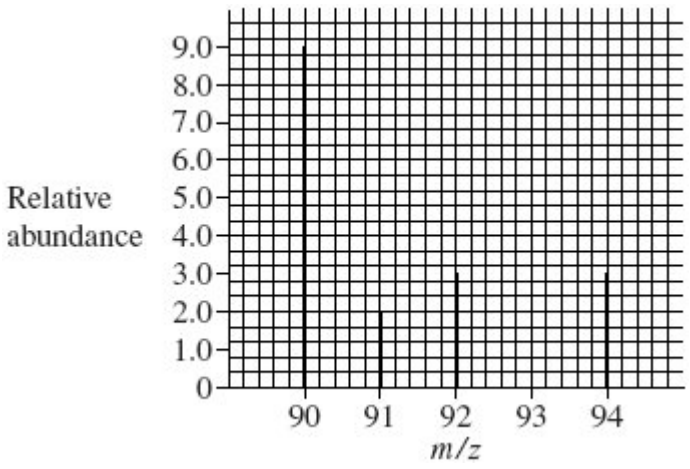
.....

**(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 $\mathbf{Z}^+$ ions in a mass spectrometer.

State and explain which of the $\mathbf{Z}^+$ ions formed from the isotopes of **Z** in part (c) will be have the shortest time of flight 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)**

**4.** The element rubidium exists as the isotopes $^{85}Rb$ and $^{87}Rb$

(a) State the number of protons and the number of neutrons in an atom of

the isotope $^{85}Rb$

Number of protons .....

Number of neutrons .....

**(2)**

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

.....

.....

.....

.....

**(2)**

(c) (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)**

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

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

.....

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.....

**(3)**

(e) 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)**
**(Total 11 marks)**

**5.** 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)**
**(Total 2 marks)**

**6.** Lithium hydride, LiH, is an ionic compound containing the hydride ion, $H^-$
Give the electronic configuration of the hydride ion, $H^-$

.....

**(1)**
**(Total 1 marks)**

**7.**

**7.** 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)**

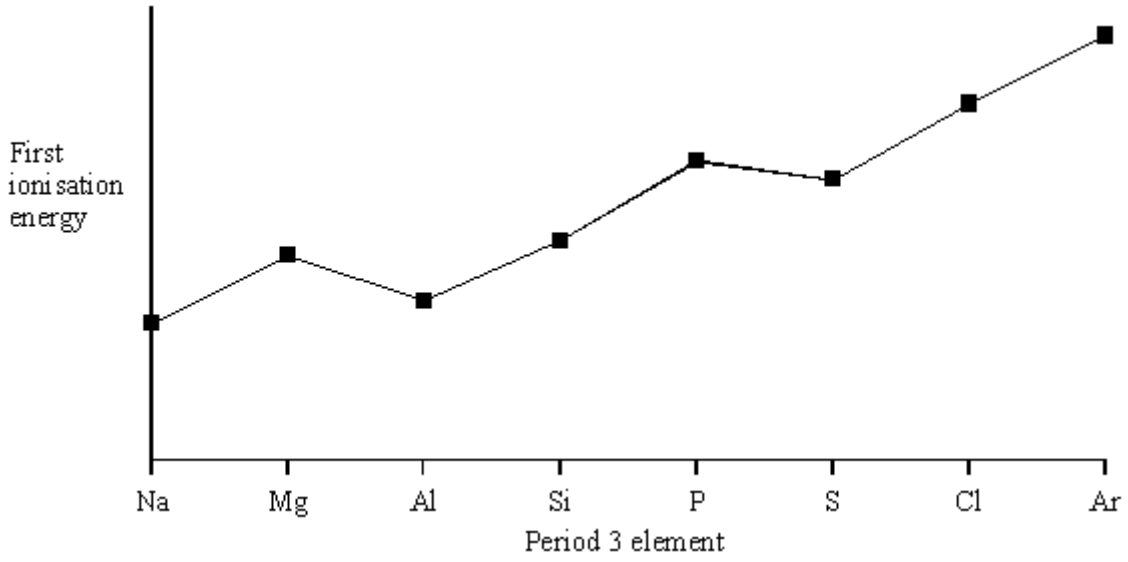
**8.** (a) What is meant by the term *first ionisation energy*?

.....

.....

**(2)**

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




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

.....

.....

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

.....

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

.....

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

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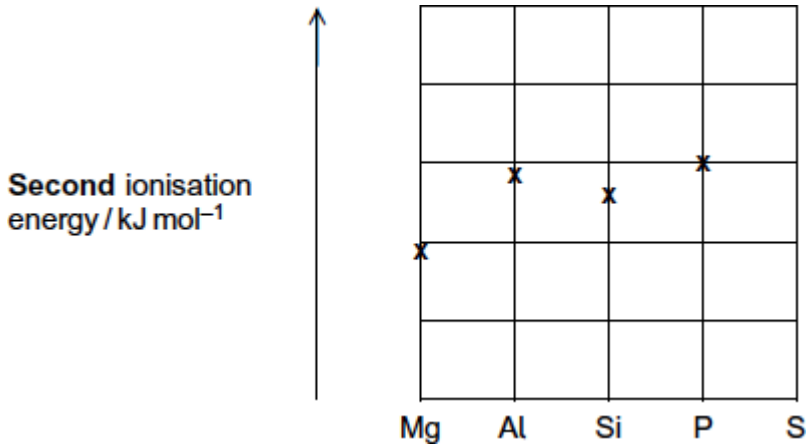
**(5)**
**(Total 7 marks)**

**9.** (a) Use your knowledge of electron configuration and ionisation energies to answer this question.

The following diagram shows the **second** ionisation energies of some Period 3 elements.




(i) Draw an '**X**' on the diagram to show the **second** ionisation energy

of sulfur.

**(1)**

(ii) Write the full electron configuration of the $Al^{2+}$ ion.

.....

**(1)**

(iii) Write an equation to show the process that occurs when the **second** ionisation energy of aluminium is measured.

.....

**(1)**

(iv) Give **one** reason why the **second** ionisation energy of silicon is lower than the **second** ionisation energy of aluminium.

.....

.....

.....

**(1)**

(b) Predict the element in Period 3 that has the highest **second** ionisation energy.
Give a reason for your answer.

Element .....

Reason .....

.....

.....

**(2)**

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

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

Identify this element.

.....

**(1)**

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

.....

.....

.....

*(Extra space)* .....

.....

**(1)**

**(Total 8 marks)**

**10.** (a) Complete the electronic configuration for the sodium ion, $Na^+$

$1s^2$ .....

**(1)**

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

.....

**(2)**

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

.....

.....

.....

.....

**(3)**

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

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

Deduce the identity of element **X**.

.....

**(1)**

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

Trend .....

Explanation .....

.....

.....

**(3)**
**(Total 10 marks)**

**11.** Which one of the following is a correct electron arrangement?

**A** $Cu^+$ is $[Ar]3d^94s^1$

**B** Cu is $[Ar]3d^{10}4s^2$

**C** $Cu^{2+}$ is $[Ar]3d^84s^1$

**D** $Cu^+$ is $[Ar]3d^{10}$

**(Total 1 mark)**

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

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

**(Total 1 mark)**

**13.** 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)**

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

| | electronic configuration of element **X** | electronic configuration of element **Y** |
|---|---|---|
| **A** | $1s^1$ | $1s^2$ |
| **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)**

**ANSWERS**

## ATOMIC STRUCTURE ANSWERS

**1.** (i) $\frac{10x + 11y}{x + y} = 10.8$

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

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

**1**

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

**OR**

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

$10x + 1100 - 11x = 1080$

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

*Correct answer scores M1 and M2.*

**1**

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

*Ignore electrons determine chemical properties.*

Same electronic configuration / arrangement

*Ignore protons unless wrong.*

I

**[3]**

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

*(number of) nucleons*

I

(b) Zn

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

I

(c) <u>m / z</u>

*Allow mass / charge*

I

(relative) <u>abundance</u> / (relative) <u>intensity</u>

*QoL*
*Allow M1 + M2 in any order*

I

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

*M1 = topline*

I

*M2 = ÷ 4*

I

= <u>207.3</u>

*Only*
*207.3 = 3 marks*

I

(ii) <u>Lead / Pb</u>

*Not PB*

I

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

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

I

**[9]**

**3.** (a) <u>Average/mean mass of (1) atom(s) (of an element)</u>
1/12 mass of one atom of $^{12}C$

I

*If moles and atoms mixes Max = 1*

I

***OR***

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

***OR***

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

***OR***

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

*This expression = 2 marks*

(b) d block

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

I

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

I

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

27

I

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

(= 1550)

I

(or ∑ their abundances)

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

I

= 91.2

*91.2 = 3 marks provided working shown.*

I

Zr/Zirconium

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

I

(d) High voltage supply

I

Removes electron(s) (to form ions)

I

$Z^+$ = <u>90</u> has shortest TOF

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

I

since lowest mass/lowest m/z

*Allow lightest*

I

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

*QWC*

I

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

*Implication that current depends on the number of ions*

I

**[15]**

**4.** (a) 37

*These answers only.*
*Allow answers in words.*

I

48

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

I

(b) Dissolved in volatile solvent/passed through hollow needle

I

Subjected to high voltage

I

(c) (i) s / block s / group s

*Only*

I

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

*Allow $3d^{10}$ before $4s^2$*
*Allow in any order.*

I

(d) $\underline{(85 \times 2.5) + 87 \times 1}$ 3.5

*M1 is for top line*

I
I

$= \underline{85.6}$

*Only*

I

***OR***

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

*M1 $^{85}Rb$ 71.4% and $^{87}Rb$ 28.6%*
*M2 divide by 100*

I
I

$\underline{85.6}$

*M3 = <u>85.6</u>*

I

(e) Detector

*Mark independently*
*Allow detection (plate).*

I

Current / digital pulses / electrical signal related to abundance

*Not electrical <u>charge</u>.*

I

**[11]**

**5.** (a) $N^{3-}$ / $N^{-3}$

**1**

(b) $F^-$/ fluoride

*Ignore fluorine/F*

*Penalise Fl*

**1**

**[2]**

**6.** $H^- = 1s^2$ **or** $1s_2$

**1**

**[1]**

**7.** (a) $Na(g) \rightarrow Na^+(g) + e^-$
OR $Na(g) + e^- \rightarrow Na^+(g) + 2e^-$

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

**2**

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

*Explanation* : Increased nuclear charge or proton number **(1)**
Stronger attraction (between nucleus and (outer) $e^-$) **(1)**

*Trend <u>wrong</u>*
*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 <u>3s</u> electrons **(1)**

*Allow $e^-$ is further away*

Mark independently

*Explanation for S*: $e^-$ removed from (3)p electron <u>pair</u> **(1)**
repulsion between paired $e^-$ (reduces energy required) **(1)**

*Mark separately*
*If deviation <u>wrong</u> 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]**

**8.** (a) 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**

(b) (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**

**[7]**

**9.** (a) (i) Higher than P

**1**

(ii) $1s^2\ 2s^2\ 2p^6\ 3s^1$
*Allow any order*

**1**

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

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

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

**1**

(iv) Electron in Si (removed from) (3)p orbital / electron (removed)

from higher energy orbital or sub-shell / electron in silicon is more shielded

*Accept converse arguments relating to Al*
*Penalise incorrect p-orbital*

**1**

(b) Sodium / Na

*Allow $Na^+$*

**1**

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

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

**1**

(c) Silicon / Si

*Not SI*

**1**

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

*Not breaking bonds*

*QoL*

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

**1**

**[8]**

**10.** (a) $2s^2\ 2p^6$;

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

**1**

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

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

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

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

**2**

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

energy level or 3rd shell / $Na^{(2+)}$ loses e from a lower (energy) orbital/ or vice versa;

*Not from 3p*

I

Less shielding (in Na);

*Or vice versa for Mg*

I

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

*M3 needs to be comparative*

I

(iii) Aluminium /Al;

I

(c) Decreases;

*If not decreases CE = 0*
*If blank, mark on*

I

Increasing nuclear charge/ increasing number of protons;

I

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

I

**[10]**

**11.** D **[1]**

**12.** D **[1]**

**13.** D **[1]**

**14.** A **[1]**