Q1.

The first six ionisation energies, in kJ mol^{-1}, of an element are:

1090, 2350, 4610, 6220, 37 800, 47 000

What is the element?

A Boron ⬭

B Carbon ⬭

C Nitrogen ⬭

D Oxygen ⬭

(Total 1 mark)

Q2.

Which has the electron configuration of a noble gas?

A H^+ ⬭

B O^- ⬭

C Se^{2-} ⬭

D Zn^{2+} ⬭

(Total 1 mark)

Q3.

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)

Q4.

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

	electronic configuration of element **X**	electronic configuration of element **Y**

A	$1s^1$	ls^2
B	$1s^2\ 2s^2$	$ls^2 2s^2\ 2p^1$
C	$1s^2\ 2s^2 2p^3$	$ls^2 2s^2 2p^4$
D	$1s^2\ 2s^2 2p^6$	$ls^2 2s^2 2p^6\ 3s^1$

(Total 1 mark)

Q5.

Which element has a first ionisation energy lower than that of sulfur?

A Chlorine ⬭

B Oxygen ⬭

C Phosphorus ⬭

D Selenium ⬭

(Total 1 mark)

Q6.

Which ionisation needs less energy than this process?

$$Mg(g) \rightarrow Mg^+(g) + e^-$$

A $Al(g) \rightarrow Al^+(g) + e^-$ ⬭

B $Ar(g) \rightarrow Ar^+(g) + e^-$ ⬭

C $Be(g) \rightarrow Be^+(g) + e^-$ ⬭

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

(Total 1 mark)

Q7.

Which atom in the ground state contains at least one unpaired p electron?

A Na ⬭

B Ne ⬭

C O ⬭

D Sc ⬭

(Total 1 mark)

Q8.

In which pair is the first ionisation energy of atom **Y** greater than that of atom **X**?

	Electron configuration of atom **X**	Electron configuration of atom **Y**	
A	$1s^2 2s^2$	$1s^2 2s^2 2p^1$	⬭
B	$1s^2 2s^2 2p^3$	$1s^2 2s^2 2p^4$	⬭
C	$1s^2 2s^2 2p^5$	$1s^2 2s^2 2p^6$	⬭
D	$1s^2 2s^2 2p^6$	$1s^2 2s^2 2p^6 3s^1$	⬭

(Total 1 mark)

Q9.

Which atom has the greatest first ionisation energy?

A H ⬭

B He ⬭

C Li ⬭

D Ne ⬭

(Total 1 mark)

Q10.

Which of these has the highest first ionisation energy?

A Na ⬭

B Al ⬭

C Si ⬭

D Cl ⬭

(Total 1 mark)

Q11.

Which change requires the largest amount of energy?

A $He^+(g) \longrightarrow He^{2+}(g) + e^-$ ⬭

B $Li(g) \longrightarrow Li^+(g) + e^-$ ⬭

C $Mg^+(g) \longrightarrow Mg^{2+}(g) + e^-$ ⬭

D $N(g) \longrightarrow N^+(g) + e^-$ ⬭

(Total 1 mark)

Q12.

An atom has all its electrons in their lowest energy levels.

Which atom contains only two unpaired electrons?

A Helium ⬭

B Beryllium ⬭

C Oxygen ⬭

D Iron ⬭

(Total 1 mark)

Q13.

This question is about s-block metals.

(a) Give the full electron configuration for the calcium ion, 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)

Q14.

This question is about atomic structure.

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

Cl^- _____

Fe^{2+} _____

(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)

(Total 9 marks)

Q15.

This question is about the elements in Period 3.

(a) Give the full electron configuration of the element in Period 3 with the highest first ionisation energy.

_____

(1)

(b) Give an equation, including state symbols, to represent the process that occurs when the second ionisation energy of sodium is measured.

_____

(1)

(c) The table below shows some successive ionisation energies for an element in Period 3.

Ionisation number	1	2	3	4	5	6	7	8

Ionisation energy / kJ mol^{-1}	1000	2260	3390	4540	6990	8490	27 100	31 700

Identify the Period 3 element.

Explain your answer.

Element _____

Explanation _____

_____

_____

(3)

(Total 5 marks)

Q16.

This question is about atomic structure.

(a) There is a general trend for an increase in ionisation energy across Period 3. Give **one** example of an element that deviates from this trend.

Explain why this deviation occurs.

Element _____

Explanation _____

_____

_____

_____

_____

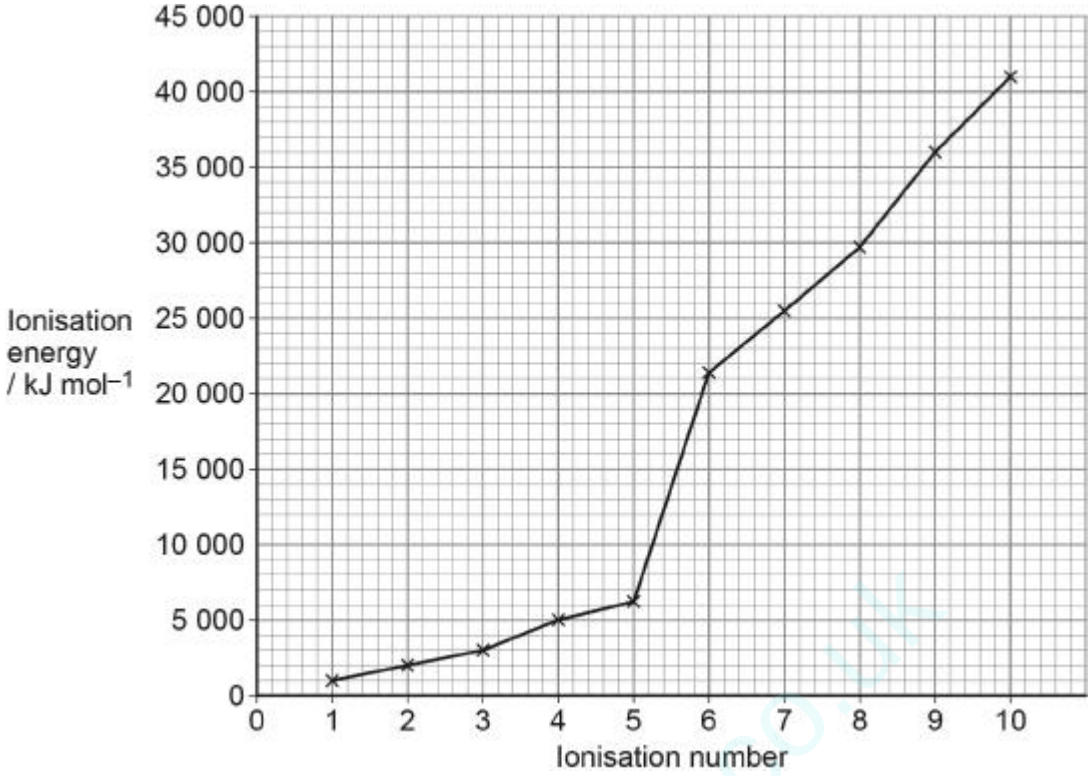
(3)

(b) Give an equation, including state symbols, to represent the process that occurs when the **third** ionisation energy of sodium is measured.

_____

(1)

(c) The graph shows the successive ionisation energies of a Period 3 element, **X**.



Identify element **X**.
Explain your choice.

Element _____

Explanation _____

_____

_____

_____

_____

_____

_____

_____

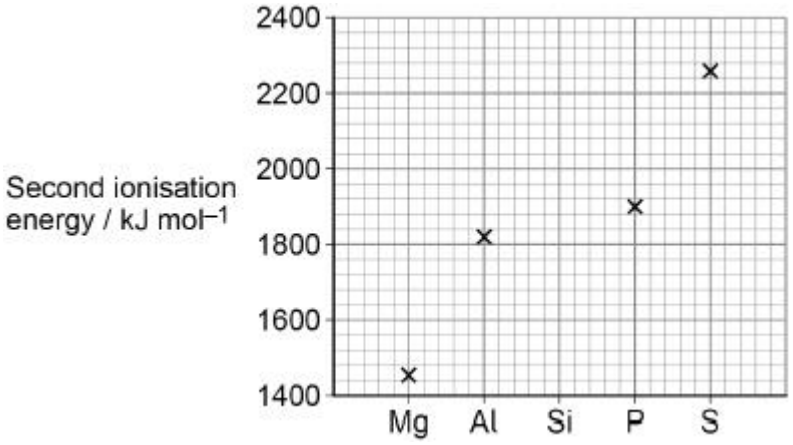
(3)

(Total 7 marks)

Q17.

This question is about Period 3 elements.

The graph shows the **second** ionisation energies of some elements in Period 3.



(a) Draw a cross (x) on the graph above to show the **second** ionisation energy of silicon.

(1)

(b) Identify the element in Period 3, from sodium to argon, that has the highest **second** ionisation energy.

Give an equation, including state symbols, to show the process that occurs when the **second** ionisation energy of this element is measured.

If you were unable to identify the element you may use the symbol **Q** in your equation.

Element _____

Equation

_____

(2)

(c) Explain why the atomic radius decreases across Period 3, from sodium to chlorine.

_____

_____

_____

_____

(2)

(d) Identify the element in Period 3, from sodium to chlorine, that has the highest electronegativity.

_____

(1)

(e) Phosphorus burns in air to form phosphorus(V) oxide.
Give an equation for this reaction.

_____

(1)

(Total 7 marks)

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 _____

_____

_____

_____

_____

(3)

(b) State the element in Period 3 that has the highest first ionisation energy.
Explain your answer.

Element _____

Explanation _____

_____

_____

_____

_____

(3)

Q19.

The first ionisation energies of the elements in Period 2 change as the atomic number increases.

Explain the pattern in the first ionisation energies of the elements from lithium to neon.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(Total 6 marks)

Q20.

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

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

_____

(1)

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

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

Substance _____

(2)

Q21.

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

_____

(1)

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

_____

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

_____

_____

_____

_____

(4)

(c) Give the equation, including state symbols, for the process which represents the

second ionisation energy of aluminium.

_____

(1)

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

Trend _____

Explanation _____

_____

_____

(3)

(Total 9 marks)

Q22.

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)

Q23.

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

_____

_____

(2)

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

1s^2 _____

(1)

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

_____

(1)

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

_____

(1)

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

Reason 1 _____

Reason 2 _____

(2)

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

(i) State and explain this general trend.

Trend _____

Explanation _____

_____

_____

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

_____

_____

_____

(5)

(Total 12 marks)

Q24.

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

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

$1s^2$ _____

(1)

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

_____

_____

_____

(2)

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

_____

(1)

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

_____

_____

_____

(1)

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

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

(1)

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

Trend _____

Explanation _____

_____

_____

(3)

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

How sulfur deviates from the trend _____

_____

Explanation _____

_____

_____

(3)

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

_____

(1)

(Total 13 marks)

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^{-1}	590	1150	4940	6480	8120

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

_____

(1)

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

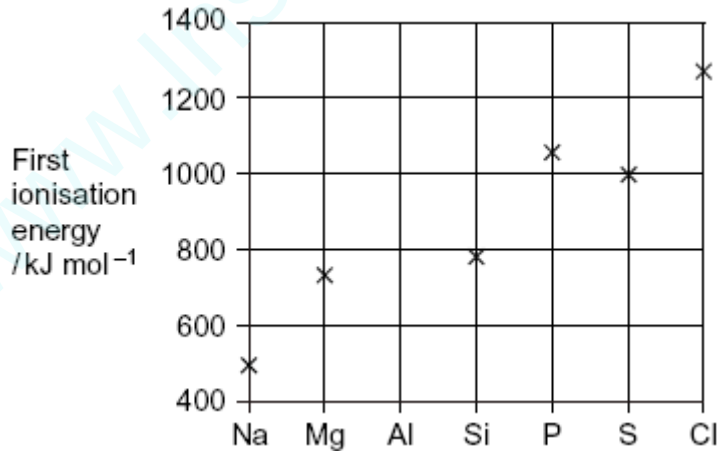
_____

(1)

(Total 10 marks)

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.

This question is about electron configuration.

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

Al atom _____

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)

(Total 4 marks)

Q28.

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

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

Number of protons _____

Number of neutrons _____

(2)

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

_____

_____

_____

_____

(2)

(ii) Write an equation, including state symbols, to show the process that occurs when the **first** ionisation energy of rubidium is measured.

_____

(1)

(c) The table shows the first ionisation energies of rubidium and some other elements in the same group.

Element	sodium	potassium	rubidium
First ionisation energy / kJ mol^{-1}	494	418	402

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

_____

_____

_____

(1)

(d) (i) State the block of elements in the Periodic Table that contains rubidium.

_____

(1)

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

_____

(1)

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

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

_____

_____

_____

_____

(3)

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

Name of relevant part _____

Explanation _____

_____

_____

(2)

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

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

Explanation _____

_____

_____

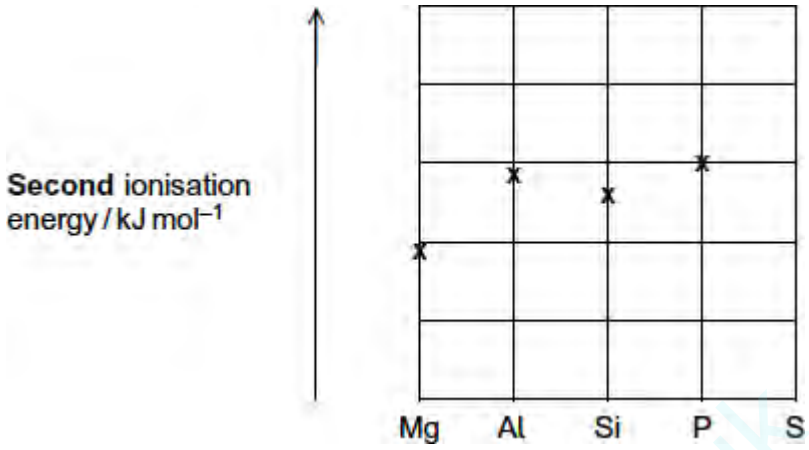
_____

(3)

(Total 16 marks)

Q29.

(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.

_____

_____

_____

(1)

(Total 8 marks)

Q30.

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.

_____

_____

_____

_____

_____

_____

_____

_____

(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.

_____

_____

_____

(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 / kJ mol^{-1}	1000	2260	3390	4540	6990	8490	27 100	31 700

Identify element **Y**.

Explain your answer using data from the table.

(2)

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

Explain your answer by reference to structure and bonding.

(4)

(Total 13 marks)

Q31.

This question is about Period 3 of the Periodic Table.

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

Smaller ion _____

Explanation _____

_____

_____

_____

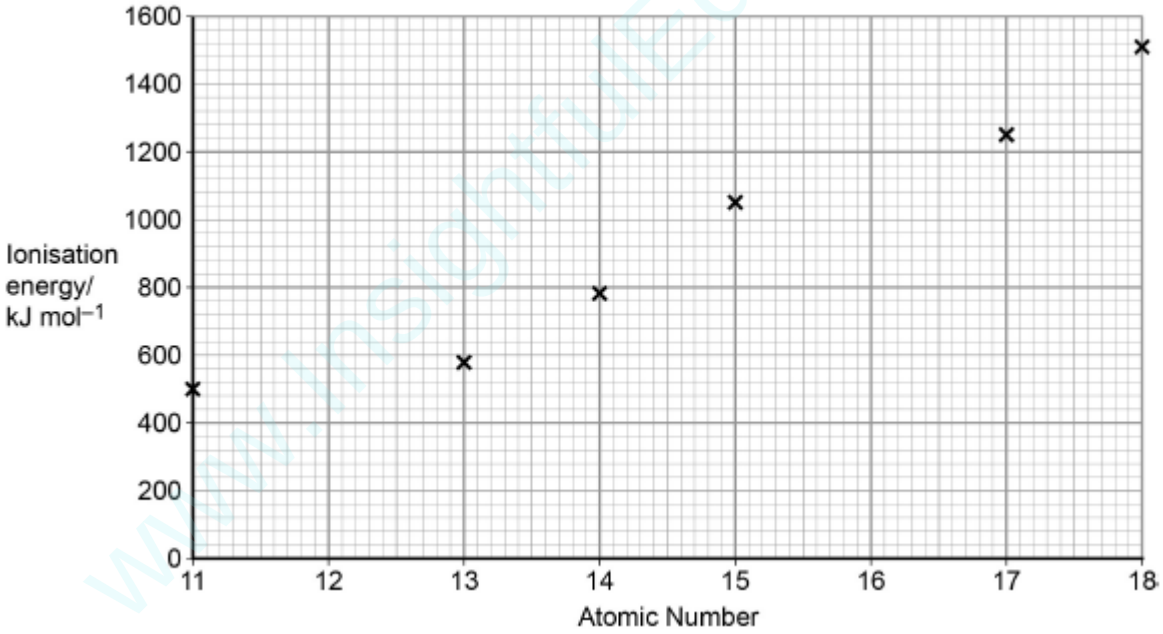
(2)

(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.



Complete the graph by plotting the approximate first ionisation energy values for magnesium and sulfur.

Explain why the first ionisation energy of sulfur is different from that of phosphorus.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(4)

(Total 7 marks)

Q32.

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

Table 1

Particle	proton	neutron	electron
Mass / g	1.6725×10^{-24}	1.6748×10^{-24}	0.0009×10^{-24}

(i) An atom of hydrogen can be represented as ^{1}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}B and ^{11}B

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

_____

(2)

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

(1)

(c) Complete **Table 2** by suggesting a value for the third ionisation energy of boron.

Table 2

	First	**Second**	**Third**	**Fourth**	**Fifth**
Ionisation energy / kJ mol^{-1}	799	2420		25 000	32 800

(1)

(d) Write an equation to show the process that occurs when the **second** ionisation energy of boron is measured. Include state symbols in your equation.

(1)

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

(1)

(Total 8 marks)

Mark schemes

Q1.

B

Carbon

[1]

Q2.

C

Se^{2-}

[1]

Q3.

B

[1]

Q4.

A

[1]

Q5.

D

Selenium

[1]

Q6.

A

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

[1]

Q7.

C

O

[1]

Q8.

C

C	$1s^2 2s^2 2p^5$	$1s^2 2s^2 2p^6$

[1]

Q9.

B

[1]

Q10.

D

[1]

Q11.

A

[1]

Q12.

C

Oxygen

[1]

Q13.

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

1

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

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

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

1

(c) Be /Beryllium

1

Q14.

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

1

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

1

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

Ignore $4s^0$

Allow subscripts

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

1

States symbols are required

Allow $Mn^{2+}\ (g) - e^- \longrightarrow Mn^{3+}\ (g)$

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

Q15.

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

1

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

Ignore state symbol on electron, even if wrong.

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

1

(c) **M1** sulfur / S

M2 large jump after the sixth electron is removed due to the 7th electron being removed / large difference between ionisation energy 6 and 7

M3 electron removed from the (2p) orbital / (second) energy level / (second) shell which is closer to the nucleus / lower in energy / has less shielding

Both ideas needed for mark

3

[5]

Q16.

(a) Aluminium / Al

*Allow **M2**/**M3** if a Group 3 element is given*

1

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

Not energy level

1

(3p) higher in energy / slightly more shielded (than 3s) / slightly further away (than 3s)

1

or

OR

Sulfur / S

*Allow **M2**/**M3** if a Group 6 element is given*

1

(Outer) electrons in (3)p orbital begin to <u>pair</u>

Do not allow just p^4 vs p^3

1

Repel

1

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

State symbols essential.

Allow
$Na^{2+}(g) + e^- \rightarrow Na^{3+}(g) + 2\ e^-$

1

(c) **M1** Phosphorus / P

Mark independently

M2 large jump in ionisation energy for the 6th ionisation energy

Large jump after the 5 e^- is removed / when the 6th e^- is removed

M3 This is when the electron is being removed from the 2nd (principle) energy level / from a lower energy level / from a lower shell / from 2p / from an energy level that is closer to the nucleus

3

[7]

Q17.

(a) Cross at 1580

Allow a cross drawn for Si that is between the values for Mg and Al

1

(b) **M1** Na

1

M2 $Na^+(g) \rightarrow Na^{2+}(g) + e^-$

***M2** Allow $Q^+(g) \rightarrow Q^{2+}(g) + e^-$*

State symbols essential

Allow correct equation consequential on their element

1

(c) The number of protons increases OR nuclear charge increases

1

Shielding is similar/same OR electrons are added to the same shell

Allow same number of shells

1

(d) Chlorine/Cl

1

(e) $4P + 5O_2 \rightarrow P_4O_{10}$ OR $P_4 + 5O_2 \rightarrow P_4O_{10}$

Allow multiples

Ignore state symbols

Do not allow equations with P_2O_5

1

[7]

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

Q19.

This question is marked using Levels of Response.	
Level 3: ALL Stages with matching justifications All stages are covered and the explanation of each stage is generally correct and virtually complete. Answer is well structured with no repetition or irrelevant points. Accurate and clear expression of ideas with no errors in use of technical terms.	5-6 marks
Level 2: TWO Stages with matching justifications OR THREE Stages with incomplete justifications. 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.	3-4 marks

Answer shows some attempt at structure Ideas are expressed with reasonable clarity with, perhaps, some repetition or some irrelevant points. Some minor errors in use of technical terms.	
Level 1: ONE Stage with matching justification OR TWO Stages with incomplete justifications 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 isolated statements but these are not presented in a logical order or show confused reasoning. Answer may contain valid points which are not clearly linked to an argument structure. Errors in the use of technical terms.	1-2 marks
Insufficient correct chemistry to gain a mark.	0 marks

Indicative Chemistry Content

Stage 1: General Trend (Li → Ne)
1a. 1st IE increases
1b. More protons/increased nuclear charge
1c. Electrons in same energy level / shell
1d. No extra/similar shielding
1e. Stronger attraction between nucleus and outer e OR outer e closer to nucleus (ignore radius decreases)

Stage 2: Deviation Be → B
2a. B lower than Be
2b. Outer electron in (2)p
2c. higher in energy than (2)s

If Al vs Mg then do not award 2a or 2b

Stage 3: Deviation N → O
3a. O lower than N
3b. 2 electrons in (2)p need to pair
3c. pairing causes repulsion (do not award if it is clear reference to repulsion is in s orbital)

If S vs P then do not award 3a or 3b

[6]

Q20.

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

1

(ii) $NiCl_2.6H_2O + \mathbf{6}\ SOCl_2 \longrightarrow NiCl_2 + \mathbf{6}\ SO_2 + \mathbf{12}\ HCl$
Allow multiples.

1

$NaOH / NH_3 / CaCO_3 / CaO$

Allow any name or formula of alkali or base.

Allow water.

1

[9]

Q21.

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

(accept multiples/fractions)

OR

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

1

(b) (i) increases;

1

(ii) lower than expected / lower than Mg /

1

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

1

('e^- removed' may be implied)

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

1

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

1

(d) trend: increases;

1

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

1

OR

stronger metallic bonding;

1

[9]

Q22.

(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]

Q23.

(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 <u>gaseous</u> atom

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

1

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

(accept capitals and subscripts)

1

(c) 's' block

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

1

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

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

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

1

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

(Not <u>'atomic'</u> radius fo Mg^{2+})

1

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

(accept converse arguments)

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

1

(f) (i) trend: increases

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

1

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

(NOT increased atomic number)

1

same shell / same shielding / smaller size

1

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

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

1

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

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

(mark M4 and M5 separately)

1

[12]

Q24.

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

$1s^2$ can be rewritten
Allow $2s^2 2p_x^2 2p_y^2 2p_z^2 3s^1$
Allow subscripts and capitals

1

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

1

OR

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

OR

Energy/enthalpy to remove one electron from one atom

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

Energy given out loses M1

M2 is dependent on a reasonable attempt at M1

Energy needed for this change
$X(g) \rightarrow X^+(g) + e^{(-)}$ = 2 marks
This equation alone scores one mark

1

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

Do not penalise MG
Not equation with X

1

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

Allow from a + particle/species
Not electron from a higher energy level/or higher sub-level
More protons = 0

1

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

1

(c) Increase

If decrease CE = 0/3
If blank mark on

1

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

QWC

1

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

If no shielding = 0
Smaller ionic radius = 0

1

(d) Lower

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

1

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

Not 2p

1

repel (each other)

M3 dependent upon a reasonable attempt at M2

1

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

1

[13]

Q25.

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

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

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

One mark for balanced equation with state symbols

Charge and state on electron need not be shown

1

(b) Increases

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

1

Increasing nuclear charge / increasing no of protons

Ignore effective with regard to nuclear charge

1

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

1

(c) Lower

If not lower then CE = 0/3

1

Paired electrons in a (4) p orbital

If incorrect p orbital then M2 = 0

1

(Paired electrons) repel

If shared pair of electrons M2 + M3 = 0

1

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

CE if molecule mentioned

Must be comparative answer

QWC

1

(e) 2 / two / II

1

(f) Arsenic / As

1

[10]

Q26.

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

1

(b) $Al(g) \rightarrow Al^+(g) + e–$

$Al(g) – e– \rightarrow Al^+(g)$

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

One mark for state symbols consequential on getting equation correct.

Electron does not have to have the – sign on it

Ignore (g) if put as state symbol with e^- but penalise state

symbol mark if other state symbols on e^-

2

(c) 2nd/second/2/II

Only

1

(d) Paired electrons 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) $1s^2 2s^2 2p^6 3s^2 3p^1$

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+}

Ignore name and correct proton/mass number
Allow Sr^{+2}

1

(c) Ca_3P_2

Allow reversed or ionic formula

Ignore name

1

[4]

Q28.

(a) 37

These answers only.

Allow answers in words.

1

48

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

1

(b) (i) Electron gun / high speed/high energy electrons

Not just electrons.

Not highly charged electrons.

1

Knock out electron(s)

Remove an electron.

1

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

OR

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

OR

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

Ignore state symbols for electron.

1

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

Answer should refer to Rb not Rb molecule

If converse stated it must be obvious it refers to Na

Answer should be comparative.

1

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

Only

1

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

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

Allow in any order.

1

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

M1 is for top line

1

1

= 85.6

Only

1

OR

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

M1 ^{85}Rb 71.4% and ^{87}Rb 28.6%

M2 divide by 100

1
1

85.6

M3 = 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]

Q29.

(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]

Q30.

(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 6th or between 6th and 7th

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]

Q31.

(a) Mg^{2+} or Magnesium

Na^+ CE=0

1

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

1

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

1 for correct species and gas phase
Allow e without charge
Allow $Na(g) - e^- \rightarrow Na^+(g)$
$Na(g) + e^- \rightarrow Na^+(g) + 2e^-$

1

(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^- paired in (3)p orbital in S (owtte)
Allow (3)p subshell/sublevel provided pair mentioned

1

Paired e^- repel (so less energy needed to remove)

1

[7]

Q32.

(a) (i) 1.6734×10^{-24} (g)
Only.

1.6734×10^{-27} kg
Not 1.67×10^{-24} (g).

1

(ii) **B**

1

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

OR ratio 10:11 = 1:4 **OR** 20:80 etc
Allow idea that there are 5 × 0.2 divisions between 10 and 11.

1

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

OR

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

$10x + 1100 - 11x = 1080$

$\therefore x = 1100 - 1080 = 20\%$
Correct answer scores M1 and M2.

1

(ii) Same number of electrons (in outer shell or orbital)
Ignore electrons determine chemical properties.

Same electronic configuration / arrangement
Ignore protons unless wrong.

1

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

1

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

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

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

Ignore state symbol on electron even if wrong.

1

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

Must imply removal of an electron.

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

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

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

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

Ignore 'more protons than electrons'.

Not 'greater nuclear charge'.

Ignore 'greater effective nuclear charge'.

Ignore shielding.

1

[8]