

Questions**Q1.**

Ionisation energies provide information about the number of electrons and the arrangement of the electrons in an atom of an element.

Estimate a value for the first ionisation energy of oxygen given the data in the table.

(1)

Element	First ionisation energy / kJ mol^{-1}
carbon	1086
nitrogen	1402
oxygen

(Total for question = 1 mark)

Q2.

Answer the question with a cross in the box you think is correct ☐ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☐ .

Sulfur is a bright yellow crystalline solid at room temperature.

Sulfur forms rings of 8 sulfur atoms so the formula of the yellow solid is S₈.

A section of a periodic table showing values of first ionisation energy in kJ mol⁻¹ is shown.

N 1400	O 1310	F 1680
P 1010	S 1000	Cl 1250
As 950	Se 940	Br 1140

(i) Which equation represents the first ionisation energy of sulfur?

(1)

- ☐ A $S(s) \rightarrow S^+(g) + e^-$
- ☒ B $S_8(s) \rightarrow S_8^+(g) + e^-$
- ☐ C $S(g) \rightarrow S^+(g) + e^-$
- ☐ D $S_8(g) \rightarrow S_8^+(g) + e^-$

(ii) Explain the trend in the values of the first ionisation energies for the group containing sulfur.

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(iii) Explain why the first ionisation energy of sulfur is lower than that of chlorine.

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(iv) Explain why the first ionisation energy of sulfur is lower than that of phosphorus.

(2)

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(Total for question = 8 marks)

Q3.

Give the meaning of the term 'periodicity'.

Illustrate your answer by referring to the atomic radii of the Period 2 and Period 3 elements.
Specific values of atomic radii are not required.

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(Total for question = 3 marks)

Q4.

This question is about hydrogen, the element with atomic number $Z = 1$.

Hydrogen can be placed in several different positions in periodic tables. One is immediately above lithium in Group 1. Another is in the centre of the first row, as shown in the Periodic Table on the back cover.

Criticise the position of hydrogen immediately above lithium by giving one reason in favour and two against.

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(Total for question = 3 marks)

Q5.

* The melting temperatures of the Period 2 elements are shown.

Symbol of the element	Li	Be	B	C _(diamond)	N	O	F	Ne
Melting temperature / K	454	1551	2573	3970	63	55	53	25

Explain the trend in melting temperatures across the elements of Period 2 in terms of their structure and bonding.

(6)

(Total for question = 6 marks)

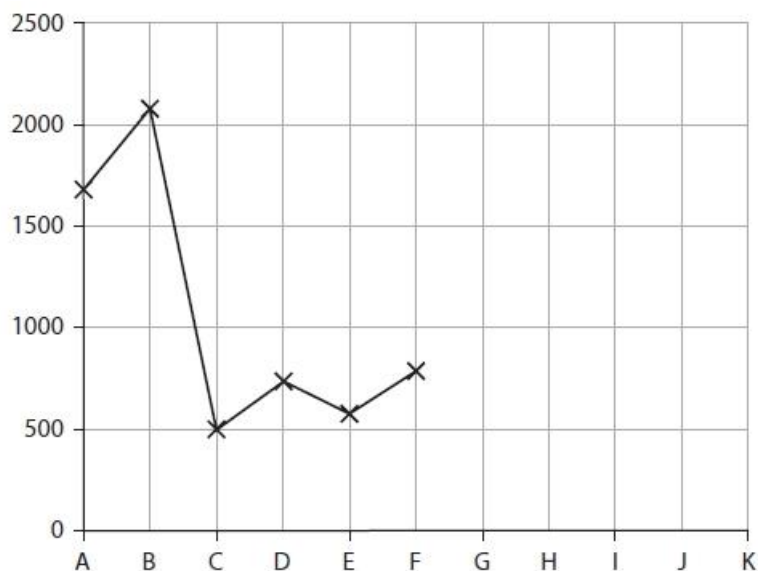
Q6.

Electrons in atoms occupy orbitals.

(i) The graph shows the first ionisation energies for a series of six consecutive elements A–F. The letters are not their chemical symbols.

Complete the graph of the first ionisation energies for the next five elements.

(3)



(ii) Explain why the value of the first ionisation energy for **D** is **greater** than for **C**.

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(iii) Explain why the value of the first ionisation energy of **E** is **less** than for **D**.

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(Total for question = 7 marks)

Q7.

This question is about trends within Group 2 of the Periodic Table.

Describe, with the aid of a labelled diagram, how you would compare the thermal stability of two different Group 2 nitrates using simple laboratory equipment.

Your answer **must** include **one** safety precaution (excluding the use of gloves, laboratory coat and eye protection).

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(Total for question = 4 marks)

Q8.

* A student suggested that the difference in the rates of reaction of strontium and barium with water is due to the difference in the sum of their first and second ionisation energies. Discuss this suggestion.

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(Total for question = 6 marks)

Q9.

A student stated that 'the elements scandium and zinc are d-block elements but are not transition metals'.

Discuss this statement, using appropriate electronic configurations to support your answer.

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(Total for question = 4 marks)

Q10.

This question is about the chemistry of elements in the d -block of the Periodic Table.

* Many of the d -block elements are also classified as transition metals.

Explain why two of the d -block elements within Period 4 (scandium to zinc) are **not** classified as transition metals.

You should include **full** electronic configurations where relevant.

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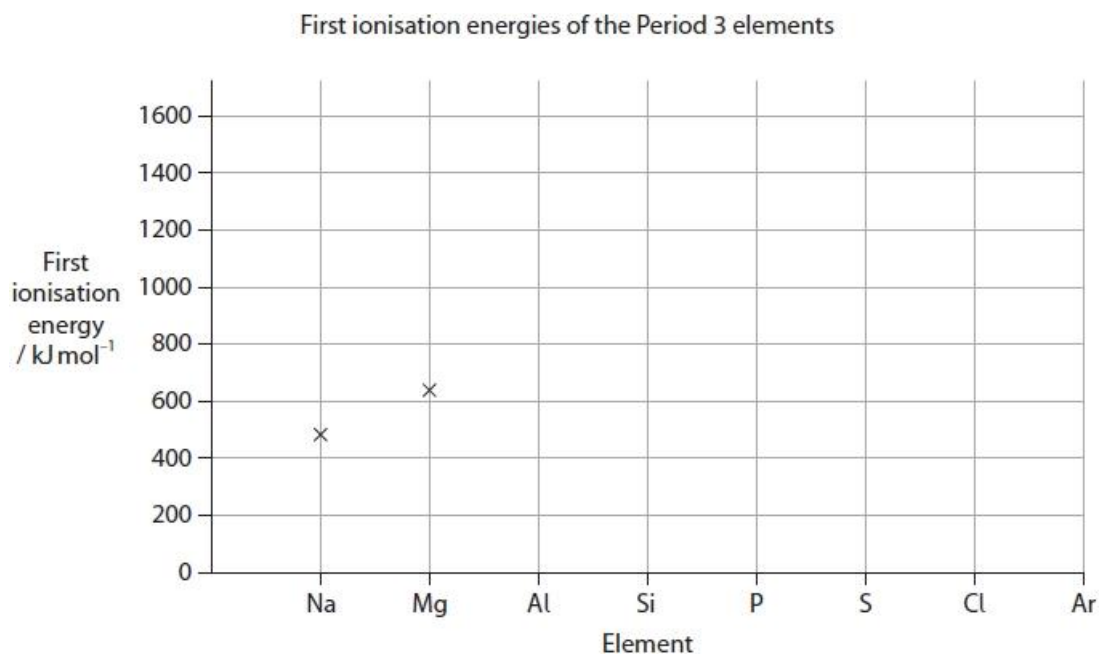
(Total for question = 6 marks)

Q11.

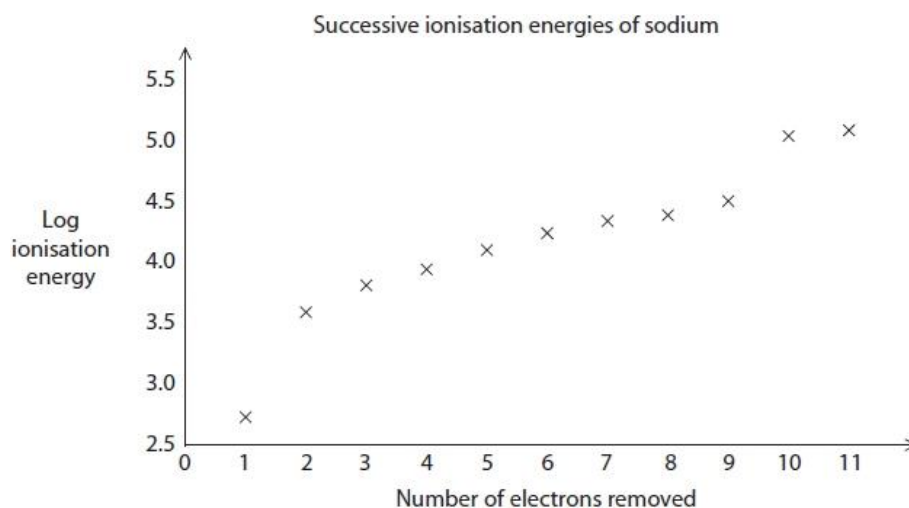
This question is about ionisation energies.

(i) Complete the graph to show how the first ionisation energies of the Period 3 elements change across the period. Precise figures are not required.

(3)



(ii) The successive ionisation energies of sodium are shown on the graph.



State what deductions can be made from this graph.

(2)

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(Total for question = 5 marks)

Q12.

This question is about hydrogen, the element with atomic number $Z = 1$.

(i) Write an equation to represent the first ionisation energy of hydrogen. Include state symbols.

(2)

(ii) The sequence of the first three elements in the Periodic Table is hydrogen, helium and then lithium.

Explain why the first ionisation energy of hydrogen is less than that of helium, but greater than that of lithium.

(4)

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(Total for question = 6 marks)

Mark Scheme

Q1.

Question Number	Answer	Additional Guidance	Mark
	An answer that includes <ul style="list-style-type: none"> (estimated value) between 1100 – 1380 (kJ mol⁻¹) 		(1)

Q2.

Question Number	Answer	Mark
(i)	The only correct answer is C ($S(g) \rightarrow S^+(g) + e^-$) <i>A is not correct because the sulfur must be in the gas phase</i> <i>B is not correct because the sulfur must be individual atoms and in the gas phase</i> <i>D is not correct because the sulfur must be individual atoms</i>	(1)

Question Number	Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to the following points: <ul style="list-style-type: none"> first ionisation energy decreases down the group because although the number of protons is increasing (1) the electron being removed is (one shell of electrons) further from the nucleus (1) (with one shell of electrons) giving more shielding from the nucleus (1) 	Allow greater repulsion between inner electron shells	(3)

Question Number	Answer	Additional Guidance	Mark
(iii)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> because in sulfur the nuclear charge / atomic number / proton number / number of protons has is less (by 1) (1) and the electron being removed is from the same sub-shell / a (3)p electron / has similar shielding / is further from the nucleus / (1) 	<p>Do not award just 'the charge has decreased (by 1) in sulfur' Allow effective nuclear charge has decreased by 1 in sulfur</p> <p>Allow has the same shielding Allow atomic radius is larger Do not award ionic radius is larger Ignore same shell</p> <p>Allow reverse arguments for chlorine</p>	(2)

Question Number	Answer	Additional Guidance	Mark
(iv)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> because in sulfur (spin) pairing has occurred (for the first time in the 3p sub-shell) or electron being removed from an orbital containing two electrons (1) (resulting in an increase in) repulsion between electrons (so the electron is lost more easily) (1) 	<p>Ignore half-filled (sub-) shell is more stable in phosphorus</p> <p>Ignore reference to shielding and distance to the nucleus</p>	(2)

Q3.

Question Number	Acceptable Answer	Additional Guidance	Mark
	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> a trend/pattern of repeating (physical and chemical) properties (with increasing atomic number) (1) atomic radii decrease from left to right/ across the period (1) the pattern /atomic radius trend is repeated in period 3 (1) 	<p>Do not award for trend in group</p> <p>Allow a sketch of the trend</p> <p>Allow even if the trend is incorrect</p>	(3)

Q4.

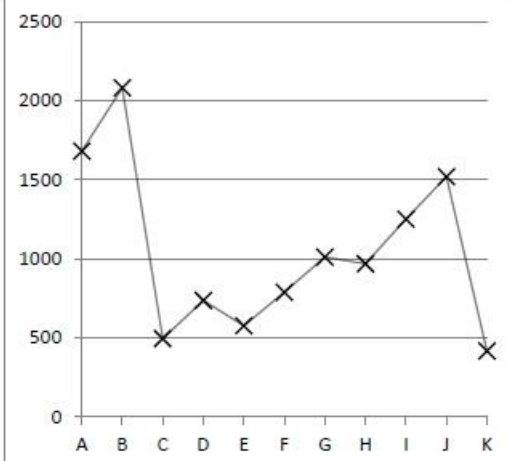
Question Number	Acceptable Answer	Additional Guidance	Mark
	<p>An answer that makes reference to the following:</p> <p>(in favour)</p> <ul style="list-style-type: none"> electronic structure of hydrogen is s^1 / $1s^1$ / has one electron in s orbital / form $1+$ ions (1) <p>(against) any two from</p> <ul style="list-style-type: none"> the rest of Group 1 are (alkali) metals / metallic (hydrogen is not) (1) hydrogen does not react in the same way as / has different reactivity to the rest of Group 1 / has different chemical properties (1) forms a H^- ion (1) 	<p>Allow 1 electron in outer shell / has 1 valence electron Do not award 'last electron is in s orbital' unless it is clear there is only one Do not award just 'single unpaired electron'</p> <p>Allow hydrogen is not a metal Ignore hydrogen is a gas but Group 1 elements are solid</p> <p>Do not award just 'different properties' or 'different behaviour' Allow hydrogen forms covalent bonds as a chemically different property Ignore trends in physical properties</p> <p>Allow hydrogen can gain one electron to form a stable ion / become stable / fill its outer shell</p>	(3)

Q5.

Question Number	Acceptable Answer	Additional Guidance	Mark																
*	<p>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.</p> <p>Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.</p> <p>The following table shows how the marks should be awarded for indicative content.</p> <table><tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr><tr><td>6</td><td>4</td></tr><tr><td>5-4</td><td>3</td></tr><tr><td>3-2</td><td>2</td></tr><tr><td>1</td><td>1</td></tr><tr><td>0</td><td>0</td></tr></table> <p>The following table shows how the marks should be awarded for structure and lines of reasoning.</p> <table><tr><th></th><th>Number of marks awarded for structure and sustained lines of reasoning</th></tr><tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning</td><td>2</td></tr></table>	Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	6	4	5-4	3	3-2	2	1	1	0	0		Number of marks awarded for structure and sustained lines of reasoning	Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning	2	<p>Guidance on how the mark scheme should be applied:</p> <p>The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points that is partially structured with some linkages and lines of reasoning, scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).</p> <p>If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</p> <p>In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning.</p> <p>If there is any incorrect chemistry, deduct mark(s) from the reasoning.</p>	(6)
Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points																		
6	4																		
5-4	3																		
3-2	2																		
1	1																		
0	0																		
	Number of marks awarded for structure and sustained lines of reasoning																		
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning	2																		

	demonstrated throughout.		<p>If no reasoning mark(s) awarded do not deduct mark(s). Comment: Look for the indicative marking points first, then consider the mark for the structure of the answer and sustained line of reasoning.</p>	
	Answer is partially structured with some linkages and lines of reasoning.	1		
	Answer has no linkages between points and is unstructured.	0		
	<p>Indicative points:</p> <ul style="list-style-type: none"> • IP1: at the start of the period / on the LHS / Li to Be the bonding is metallic • IP2: metallic bonding gets stronger as the number of delocalised electrons in a metal (atom) increases or metallic bonding gets stronger as radius of cation decreases or metallic bonding gets stronger as the charge on the cation increases • IP3 in the middle of the period / (B and) C has / have a giant structure of atoms • IP4 A lot of energy is needed to break (strong) covalent bonds, (in graphite and diamond) 		<p>Ignore statements about boron</p> <p>Allow a description of a giant structure, e.g. each C atom is bonded to 4 other (in diamond)</p>	
	<ul style="list-style-type: none"> • IP5: at the end of the period / on the RHS / N to Ne are simple molecules or N₂, O₂ and F₂ are simple molecules, • IP6: weak London forces (between molecules) 		<p>Do not award London forces</p> <p>Ignore reference / lack of reference to Ne unless incorrect</p>	

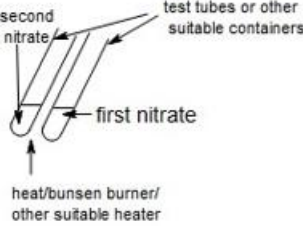
Q6.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	 <p>G above F AND H between G and F (1)</p> <p>I above H and below A AND J above I and below B (1)</p> <p>K below C (1)</p>	<p>Points which are not joined with lines are perfectly acceptable.</p> <p>Do not penalise I below G if MP1 not awarded</p>	(3)

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> D has one more proton / has a higher nuclear charge (1) the electron being removed in C and D are from the same subshell / s-subshell / (s) orbital (1) 	<p>Allow same shell / energy level Allow the electron in D is closer to the nucleus than C / atomic radius decreases</p> <p>Ignore references to shielding, and full s-orbital which is more stable.</p>	(2)

Question Number	Acceptable Answer	Additional Guidance	Mark
(iii)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none">• (the electron being removed from E) is from a new subshell / p-subshell / p-orbital (1)• which is more shielded from the nucleus than the s-subshell (from which the electron is removed in D) <p>OR</p> <ul style="list-style-type: none">• which is further from the nucleus than the s-subshell / orbital (in E) (1)	<p>Do not award 'in a new quantum shell' Allow electron removed from a higher energy level.</p> <p>Do not award clear reference to the outer electron in E being further from the nucleus than outer electron in D/atomic radius increasing from D to E</p> <p>Do not award clear reference to the outer electron in E being further from the nucleus than outer electron in D/atomic radius increasing from D to E</p>	(2)

Q7.

Question Number	Acceptable Answer	Additional Guidance	Mark
	<p>A description that makes reference to the following points:</p> <ul style="list-style-type: none"> • Workable method + time / compare (1) • Same heat applied (1) • Same amount of each nitrate in separate test tubes (1) • safety precaution: fume cupboard/hood (1) 	<p><u>Examples of workable methods</u></p> <ul style="list-style-type: none"> • First one to re-light a glowing splint / produce brown fumes. Accurate timing not essential. • Use of light sensor / meter to measure colour of gas • Use of gas syringe and measure rate of production of gas / time to produce specific volume • Bubble gas into indicator solution – time to change colour • Collection of gases over water and volume measured <p>Reward any workable alternative. e.g. use the same Bunsen Award if implied by diagram</p> <p>Award 'equal masses'.</p> <p><u>Example diagram:</u></p>  <p>Ignore well ventilated room / face mask / goggles / gloves / lab coat This is the only acceptable safety precaution.</p>	(4)

Q8.

Question Number	Acceptable Answers	Additional Guidance	Mark												
	<p>This question assesses the student’s ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.</p> <p>Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.</p> <p>The following table shows how the marks should be awarded for indicative content.</p> <table><tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr><tr><td>6</td><td>4</td></tr><tr><td>5-4</td><td>3</td></tr><tr><td>3-2</td><td>2</td></tr><tr><td>1</td><td>1</td></tr><tr><td>0</td><td>0</td></tr></table>	Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	6	4	5-4	3	3-2	2	1	1	0	0	<p>Guidance on how the mark scheme should be applied:</p> <p>The mark for indicative content should be added to the mark for lines of reasoning. For example, a response with four indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).</p> <p>If there were no linkages between the points, then the same indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and zero marks for linkages).</p>	(6)
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The following table shows how the marks should be awarded for structure and lines of reasoning		Number of marks awarded for structure of answer and sustained lines of reasoning	<p>In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning.</p> <p>Reasoning marks may be reduced for extra incorrect chemistry</p>
	Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2	
	Answer is partially structured with some linkages and lines of reasoning	1	
	Answer has no linkages between points and is unstructured	0	

	Indicative content <ul style="list-style-type: none"> the sum of the first two ionisation energies for barium is lower / barium loses (its outer) electrons more easily barium is a bigger atom/barium has a larger atomic radius/barium has more shells of electrons barium has more shielding these outweigh/exert a greater influence than barium has more proton/greater nuclear charge barium reacts faster/barium is more reactive 	<p>Allow reverse argument for strontium</p> <p>Allow max 5 IPs for reference to general trends only down group 2</p> <p>Allow any reference to single ionisation</p> <p>Do not award for barium 'molecule'</p>	

Q9.

Question Number	Answer	Additional guidance	Mark
	<p>A discussion that makes reference to the following points:</p> <ul style="list-style-type: none"> both elements / atoms have the last added electron in the d-subshell / d orbital (so are d-block elements) (1) but neither forms a (stable) ion with an incomplete d-subshell / d orbital (so are not transition metals) (1) Zn^{2+} is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$ (so d subshell is full) (1) Sc^{3+} is $1s^2 2s^2 2p^6 3s^2 3p^6$ (so d subshell is empty) (1) 	<p>Do not award just 'contains d electrons'</p> <p>Allow 'transition elements form a (stable) ion with an incomplete d-subshell / d orbital'</p> <p>Allow $[\text{Ar}]3d^{10}$</p> <p>Allow $[\text{Ar}]$</p>	(4)

Q10.

Question Number	Acceptable Answers	Additional Guidance	Mark												
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Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points														
6	4														
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		Number of marks awarded for structure of answer and sustained line of reasoning		
	Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2		
	Answer is partially structured with some linkages and lines of reasoning.	1		
	Answer has no linkages between points and is unstructured.	0		

	<p>Indicative content (IPs)</p> <p>IP1:</p> <ul style="list-style-type: none"> (transition metal) forms an ion with an incomplete <i>d</i> sub-shell <p>IP2:</p> <ul style="list-style-type: none"> scandium and zinc are not transition metals <p>IP3:</p> <ul style="list-style-type: none"> Sc^{3+} and $1s^2 2s^2 2p^6 3s^2 3p^6$ <p>IP4:</p> <ul style="list-style-type: none"> Zn^{2+} and $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$ <p>IP5:</p> <ul style="list-style-type: none"> Sc^{3+} and <i>d</i> sub-shell empty / <i>d</i>-orbitals empty <p>IP6:</p> <ul style="list-style-type: none"> Zn^{2+} and <i>d</i> sub-shell full / ALL <i>d</i>-orbitals are full 	<p>Allow 'partially-filled' for incomplete Allow <i>d</i>-orbital(s) Do not award "<i>d</i>-shell" Allow "<i>D</i>" for "<i>d</i>" throughout</p> <p>Allow if only Sc and Zn are used to illustrate <i>d</i>-block elements that are not transition metals</p> <p>Allow $4s^0$ and/or $3d^0$ Penalise use of [Ar] once only</p> <p>Allow "Sc^{3+} has no <i>d</i> sub-shell"</p> <p>Allow 'd orbital is full' if clarified by $3d^{10}$</p>	
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Q11.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> Al below Mg but above /equal to Na (1) rise from Al to Si and then to P and rise from S to Cl to Ar (1) S below P but above / equal to Si (1) 	<p><u>Example of chart</u></p> <p>First ionisation energies of the Period 3 elements</p> <p>Allow use of dots (.) or other alternatives to X</p> <p>Ignore any lines connecting the crosses (X)</p>	(3)

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> big increase/jump between 1st and 2nd electrons removed and between 9th and 10th electrons removed (1) one / first electron in the outer most / third shell and eight electrons / electron 2 - 9 in the next / second shell and two electrons / electrons 10 & 11 in the inner most/ first shell (1) 	<p>Allow answers in terms of energy levels</p> <p>Allow Na is a group 1 element</p> <p>Allow electronic configuration of Na is 2, 8, 1</p> <p>Allow an answer that relates jump in energy to existence of (new) shells</p> <p>Allow there are three shells of electrons</p>	(2)

Q12.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	<p>An answer that makes reference to the following:</p> <ul style="list-style-type: none"> equation (1) state symbol, (g), on both H and H⁺ (1) 	<p>$\text{H(g)} \rightarrow \text{H}^{\text{+}}\text{(g)} + \text{e}^{(-)}$</p> <p>or</p> <p>$\text{H(g)} - \text{e}^{(-)} \rightarrow \text{H}^{\text{+}}\text{(g)}$</p> <p>Ignore state symbol for electron</p> <p>$\text{H}_2\text{(g)} \rightarrow \text{H}_2^{\text{+}}\text{(g)} + \text{e}^{(-)}$ scores only M2</p> <p>$\text{H}_2\text{(g)} - \text{e}^{(-)} \rightarrow \text{H}_2^{\text{+}}\text{(g)}$ scores only M2</p> <p>$\text{H}_2\text{(g)} \rightarrow 2\text{H}^{\text{+}}\text{(g)} + 2\text{e}^{(-)}$ scores 0</p> <p>$\text{X(g)} \rightarrow \text{X}^{\text{+}}\text{(g)} + \text{e}^{(-)}$ scores only M2</p>	(2)

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	<p>An explanation that makes reference to the following points: <u>H < He</u>:</p> <ul style="list-style-type: none"> He more protons than H / He greater nuclear charge than H (1) in helium the outer electron is in the same shell as hydrogen (1) <p><u>H > Li</u>:</p> <ul style="list-style-type: none"> in lithium the outer electron is in a higher energy level / a new shell / further from the nucleus / in a 2s orbital (1) (and) is shielded by inner electrons / 1s² electrons (1) 	<p>Ignore references to shielding for H and He</p> <p>Ignore references to atomic radius or electrons being closer to or the same distance from the nucleus in helium</p> <p>Allow lithium has more shells of electrons</p> <p>Allow (outer electron of) lithium has more shielding than hydrogen / is shielded</p>	(4)