# Mark scheme – Periodicity

<table>
<tr><th colspan="3">Question</th><th>Answer/Indicative content</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>1</td><td></td><td></td><td>Refer to marking instructions on page 5 of mark scheme for guidance on marking this question.<br><br>Level 3 (5–6 marks)<br>Explains all three melting point values and conductivities in terms of structure, bonding, particles and relative strengths of the forces.<br><br>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.<br><br>Level 2 (3–4 marks)<br>Attempts to explain all three melting point values and conductivities in terms of the structure, bonding, particles of all three substances, but explanations may be incomplete or may contain only some correct statements or comparisons.<br>OR<br><br>Correctly explains two of the melting point values and conductivities in terms of the structure, bonding, particles.<br>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.<br><br>Level 1 (1–2 marks)<br>Identifies only some of the structures, forces and particles<br>AND<br>Attempts to explain the melting point values OR conductivities in terms of the structure, bonding, particles<br><br>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.<br><br>0 marks<br>No response or no response worthy of credit.</td><td>6<br>(AO 1.1×3)<br>(AO 2.1×3)</td><td>Indicative scientific points may include:<br><br><u>Structure and bonding</u><br><br>Magnesium<br>• Structure: giant lattice<br>• Metallic bonding<br>• Delocalised electrons<br><br>Bromine<br>• Structure: simple molecular<br>• induced dipole dipole forces (London forces)<br>• (Between) molecules<br>DO NOT ALLOW (between) atoms<br><br>Magnesium bromide<br>• Structure: giant lattice<br>• Ionic bonding<br>• (Between) oppositely charged ions<br><br><u>Comparison of bond strengths</u><br>• Metallic and ionic bonds are stronger than London forces<br>OR Metallic and Ionic bonds need more energy to break than London forces<br><br><u>Conductivity</u><br>• Magnesium: conducts due to delocalised electrons can move/mobile.<br>IGNORE ‘Carry’ charge for movement<br>• Magnesium bromide: In solid IONS cannot move; in solution IONS can move.<br>DO NOT ALLOW electrons.<br>• Bromine: Does not conduct as no mobile charge carriers.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>6</td><td></td></tr>
<tr><td>2</td><td>a</td><td></td><td>Ca: metallic bonding OR giant metallic lattice ✓</td><td>5<br>(AO1.1×2)</td><td>ALLOW Metallic structure<br>DO NOT ALLOW reference to molecules or intermolecular forces for calcium</td></tr>
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| | | | Br2: simple molecular **OR** simple covalent ✓<br><br>Induced dipole(–dipole) forces/interactions<br>**OR** London forces ✓<br><br>**Conductivity linked to mobile electrons**<br>In Ca electrons are mobile<br>**OR** electrons are delocalised<br>**OR** electrons can move<br>**AND** in $Br_2$ charge carriers/electrons are not mobile ✓<br><br>**Melting point linked to bond strengths**<br>Metallic bonds are strong<br>**AND** London forces are weak<br>**OR**<br>Metallic bonds need a large amount of energy to break<br>**AND** London forces need little energy to break ✓ | (AO2.1×1)<br><br>(AO3.2×2) | **ALLOW** 'are molecules'<br><br>**IGNORE**<br>• permanent dipole(–dipole) forces<br>• IDID and LDF<br>• van der Waals<br><br>**DO NOT ALLOW** 'free electrons' for mobile electrons<br><br>**ALLOW** comparison, e.g.<br>• Metallic bonds are stronger than London forces<br>**OR**<br>• Metallic bonds need more energy to break than London forces ✓<br><br>**ALLOW** intermolecular forces instead of London forces for this mark<br><br>**<u>Examiner's Comments</u>**<br><br>More able candidates scored well in this question, setting out their answers in a logical order. They often first discussed Ca and its bonding and structure, linking this to the physical properties and then doing the same for Br.<br><br>A number of candidates discussed the chemical properties of Ca and Br, such as their ability to bond with other elements, ionisation energy and their reactivity based on their position in the periodic table. Some candidates gave a good description of metallic bonding but then went on to discuss melting point in terms of intermolecular forces.<br><br>**AfL**<br><br>A number of students still referred to Van der Waals forces in their answers. Van der Waals forces are a collective term for several different intermolecular forces (https:/goldbook.iupac.org/terms/view/V06597), so when students intend to refer to specific |

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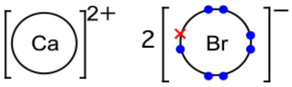
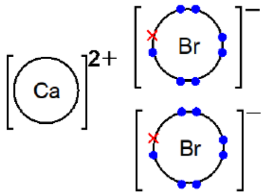
| | | | | | intermolecular forces their specific names should be used. |
| | b | i | <br><br>Ca shown with either 8 or 0 electrons<br>**AND**<br>Br shown with 8 electrons with 7 crosses and 1 dot (or vice versa) ✓<br><br>Correct charges on both ions ✓ | 2<br><br>(AO1.2×1)<br><br>(AO2.5×1) | **ALLOW** separate Br– ions, i.e.<br><br>For first mark, if eight electrons are shown around Ca, the 'extra' electrons around Br must match the symbol chosen for the electrons for Na.<br><br>**IGNORE** inner shells<br><br>Circles or brackets not required<br><br>**__Examiner's Comments__**<br><br>Most candidates were able to give the correct diagrams for ionic bonding, although care needs to be taken that diagrams are well drawn with both charges given. Some gave diagrams for covalent bonding. |
| | | ii | **Atomic radius**<br><br>Ba has a **greater** atomic radius than Ca<br>**OR** Ba has **more** shells<br>**OR** Ba has **more** shielding ✓<br><br>**Attraction**<br><br>Nuclear attraction is less in Ba<br>**OR** (outer) electrons in Ba are less attracted (to nucleus)<br>**OR** Increased distance / shielding in Ba outweighs increased nuclear charge ✓<br><br>**Ionisation energy**<br><br>Ionisation energy of Ba is less<br>**OR** (outer) electrons in Ba are less attracted (to nucleus)<br>**OR** easier to remove (outer) electrons in Ba ✓ | 3<br><br>(AO1.1×1)<br><br>(AO2.3×2) | Comparison required throughout<br>**ORA** throughout<br><br>For **more** shells, **ALLOW** higher energy level<br>**IGNORE** more orbitals **OR** more sub-shells<br>**IGNORE** 'different shell' or 'new shell'<br><br>**ALLOW** Ba has less nuclear pull'<br>**OR** 'Ba electrons are less tightly held'<br><br>**IGNORE** less effective nuclear charge'<br>**IGNORE** 'nuclear charge' for 'nuclear attraction'<br><br>**ALLOW** easier to oxidise Ba<br><br>**__Examiner's Comments__**<br><br>It was important to answer the question asked. A number of responses lost marks for describing the general trend down group 2 without making reference at all to calcium and barium. Most candidates managed to score at least one mark here but a considerable proportion missed the second marking point explaining that nuclear attraction was less in Ba. |
| | | | **Total** | **10** | |
| 3 | | | **Bonding and structure** | 5<br>(AO1.1× | **Diagram must have at least two rows and a minimum of two ions per row (allow $Sr^{+}$ or** |

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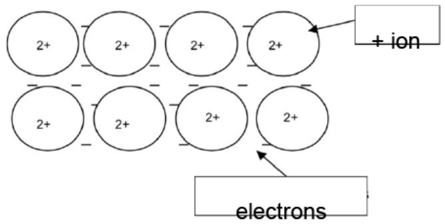
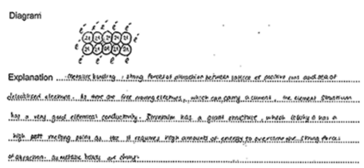
| | | | <br>**Metallic bonding diagram**<br>Regular arrangement of **labelled** + ions ✓<br>scattering of **labelled** electrons **between** other species ✓<br>**Properties linked to explanation**<br>metallic bond or attraction between the electrons and the positive ions/cations ✓<br>bonds are strong/require a lot of energy to break **AND** high melting point ✓<br>Delocalised electrons move **AND** good conductivity ✓ | 3)<br>(AO2.1× 2) | **$Sr^{2+}$)**<br>**ALLOW** for labels: + ions, positive ions, cations<br>**ALLOW** $e^-$ **OR** e as label for electron<br>**DO NOT ALLOW** intermolecular forces<br>**ALLOW** mobile electrons<br>**<u>Examiner's Comments</u>**<br>In general, the diagrams were poorly drawn or inadequately labelled. Many candidates lost marks as they did not specify the **movement** of electrons as the reason why metals conduct electricity. Too many candidates wrote "delocalised electrons carry the charge" or negated the metallic bonding description with "intermolecular forces" in their responses.<br>**Exemplar 1**<br><br>This candidate scored 3 marks for the description but lost 2 marks as the electrons were not throughout the structure, merely drawn around the ions, and the positive ions were not labelled.<br>**Exemplar 2** |

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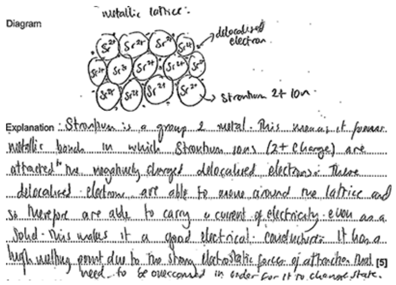
| | | | | | <br>This candidate scored 5 marks for the excellent description with a well drawn and labelled diagram, clearly showing the electrons throughout the structure in-between the ions. |
| | | | **Total** | **5** | |
| 4 | | | s-block<br>**AND** highest energy **or** outer **electron** is in a s orbital **or** s sub–shell ✓ | 1<br>(AO 1.1) | **ALLOW** 'outer' or 'valence' for 'highest energy'<br>**IGNORE** electron configurations<br>**DO NOT ALLOW** s shell / energy level<br><br>**<u>Examiner's Comments</u>**<br><br>Many candidates knew the block magnesium belonged but only very few could explain this was because magnesium's highest energy electron was in a s sub-shell or s orbital. |
| | | | **Total** | **1** | |
| 5 | | | **Type of lattice 2 marks**<br><br>• **$SiO_2$**: Giant (covalent lattice) ✓<br>• **$CO_2$**: Simple molecular/covalent (lattice) ✓<br><br>-------------------------------------<br>**Explanation 2 marks**<br>**1. Forces in $CO_2$**<br><br>• Induced dipole–dipole interactions / London forces ✓<br><br>______________________________<br>**2. Comparison of forces with strength / melting point**<br><br>• (Covalent) bonds in $SiO_2$ are stronger **THAN intermolecular** forces in $CO_2$<br>**OR**<br>• More energy to break (covalent) bonds in $SiO_2$ **THAN intermolecular** forces in $CO_2$ ✓ | 4<br><br>AO1.1×2<br><br>AO1.1×1<br><br>AO2.1×1 | **Throughout, IGNORE** 'ionic' for $SiO_2$<br><br>**FOR $SiO_2$, IGNORE** macromolecular<br>**DO NOT ALLOW** giant **metallic**<br>Mark explanation independently on type of lattice<br><br>i.e. no **ECF** from incorrect lattice<br><br>For $CO_2$<br>**IGNORE**<br><br>• covalent bonds<br>• van der Waals' forces<br>• idid<br>• LDF<br><br>**DO NOT ALLOW** hydrogen bonds<br>**OR** permanent dipole interactions<br><br>______________________________<br>For $SiO_2$,<br>comparison needs just 'bonds' **OR** 'forces'<br><br>For intermolecular, **ALLOW** 'between molecules' |

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| | | | **ORA** | | For comparison,<br>**ALLOW** strong in $SiO_2$ **AND** weak in $CO_2$<br><br>**DO NOT ALLOW** responses containing intermolecular forces in $SiO_2$<br><br>**IGNORE** 'More bonds'<br><br>**Examiner's Comments**<br><br>A good understanding of structure and bonding continues to be difficult for candidates, demonstrated by many explanations seen for the different melting points.<br><br>Most candidates obtained two relatively easy marks for identifying the giant and simple molecular/covalent structures of $SiO_2$ and $CO_2$ respectively.<br><br>The explanation proved to be much more difficult as candidates showed some misconceptions. Many identified that $CO_2$ had London forces but their action between molecules was often omitted. Many candidates realised that the forces broken on melting are much stronger in $SiO_2$ than in $CO_2$, but then went on to erroneously compare the strength of London forces or intermolecular forces in **both** $SiO_2$ and $CO_2$. |
| | | | **Total** | **4** | |
| 6 | | | Highest energy electron(s) in a p orbital/p sub-shell ✓ | **1** | **ALLOW** outer electron(s) in a p orbital/sub-shell **BUT IGNORE** p **shell**<br><br>**ALLOW** electron configuration ends in p **OR** the last electron is in a p orbital<br><br>**ALLOW** valence electron(s) in p orbital/sub-shell<br><br>**Examiner's Comments**<br>Candidates were expected to identify that a p-block element has its highest energy electron(s), or outer electrons, in a p orbital or sub-shell. Lower ability candidates often omitted 'electrons' in their responses and just repeated the information in the question. |
| | | | **Total** | **1** | |
| 7 | a | i | Hydrogen/H ✓ | 1 | **ALLOW** $H_2$<br><br>**Examiner's Comments** |

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| | | | | | Most candidates were credited this straightforward mark and identified that hydrogen would gain an electron to form a 1− ion. Some candidates opted for lithium, able to form an ion with the same electron configuration as helium, but with a 1+ rather than a 1− charge.<br><br>Candidates are recommended to look closely at the requirements of the question set. |
| | | ii | Helium/He ✓ | 1 | **Examiner's Comments**<br><br>This part required candidates to recall their knowledge of trends in first ionisation energy. Candidates found this part harder than 1(a)(i) with only the higher ability candidates choosing the correct response of 'helium'.<br><br>Many candidates instead chose another noble gas, with neon and argon commonly seen. Other common incorrect responses were hydrogen and fluorine. |
| | | iii | Magnesium/Mg ✓ | 1 | **Examiner's Comments**<br><br>Most candidates did correctly select magnesium, but many other elements were seen, especially aluminium, silicon, beryllium and calcium.<br><br>To identify the element's group, candidates needed to analyse the data to find the large increase in ionisation energy corresponding to a change in shell. From the responses, some candidates did not make use of 'Period 3' in the stem. |
| | | iv | Sulfur/S ✓ | 1 | **ALLOW** sulphur; $S_8$<br><br>**Examiner's Comments**<br><br>Most candidates selected sulfur as the correct response, recalling their knowledge of molecular shapes encountered early in the course. There was no real pattern for incorrect responses, suggesting that they were guesses. |
| | | v | Chlorine/Cl **OR** fluorine/F ✓ | 1 | **ALLOW** $Cl_2$ OR $F_2$<br><br>**Examiner's Comments**<br><br>Most candidates chose the correct response of chlorine, although hydrogen was a common incorrect response, presumably by linking to the acidic properties of $H^+$ ions. Other candidates focused on 'reacts with water' and chose sodium |

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| | | | | | (which does form a solution with water, but on that is alkaline rather than acidic). |
| | | vi | Phosphorus/P ✓ | 1 | **ALLOW** $P_4$<br><br>**<u>Examiner's Comments</u>**<br><br>Almost all candidates correctly responded with phosphorus and this was the easiest part of 1(a). |
| | | vii | Carbon/C ✓ | 1 | **ALLOW** silicon/Si<br><br>**<u>Examiner's Comments</u>**<br><br>Most candidates correctly selected carbon. From their A Level studies, candidates would expect hydrogen to have an oxidation number of +1 and to form compounds with carbon ($CH_4$) and silicon ($SiH_4$) in which the element has an oxidation number of −4. Although hydrogen is actually slightly less electronegative than carbon, hydrogen is slightly more electronegative than silicon. Therefore, in the case of $SiH_4$, silicon has an oxidation number of +4. A response of silicon still indicates a correct understanding of oxidation number rules and was also credited |
| | | viii | Oxygen/O ✓ | 1 | **ALLOW** $O_2$<br><br>**<u>Examiner's Comments</u>**<br><br>This proved to be the hardest part of 1(a) with only the higher ability candidates selecting oxygen. Sulfur proved to be the key distractor, having the same molar mass as $O_2$. Most candidates did not consider that the element was gaseous and could not be sulfur. |
| | b | | **NaC*l* OR MgC*l*$_2$** **2 marks**<br><br>Giant **ionic OR ionic** lattice ✓<br><br>**Ions** are **mobile** in **liquid** state ✓<br><br>---<br><br>**SiC*l*$_4$ OR PC*l*$_3$ OR SC*l*$_2$** **2 marks**<br><br>(Simple) molecular **OR** simple covalent (lattice) ✓ | 5 | **IGNORE** aqueous/dissolved ions are mobile<br>**IGNORE** 'free ions'<br>**AND** 'ions are free to carry current'<br><br>---<br><br>**ALLOW** 'are molecules'<br><br>**IGNORE**<br><br>• permanent dipole(−dipole) forces |

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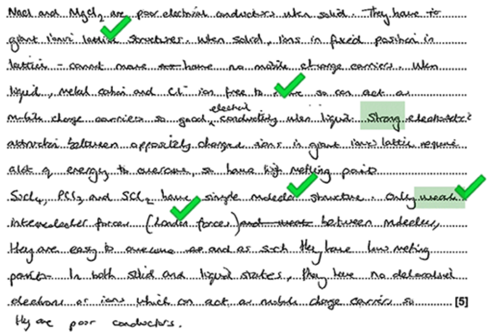
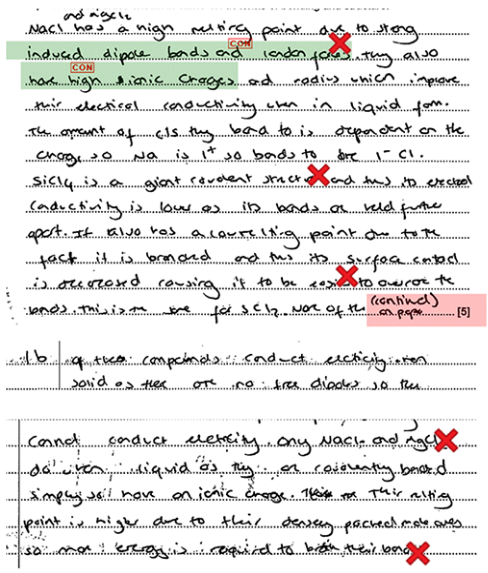
| | | | Induced dipole(−dipole) forces/interactions **OR** London forces ✓<br><br>---<br><br>**Comparison of bond strengths 1 marks**<br><br>• Ionic bonds are stronger than London forces **OR**<br>• Ionic bonds need more energy to break than London forces ✓ | | • IDID and LDF<br>• van der Waals<br><br>---<br><br>**ALLOW** attraction between ions for ionic bonds<br>**ALLOW** intermolecular forces for London forces<br>**ALLOW** overcome for break<br><br>**ALLOW** indirect comparison, i.e.<br><br>• Ionic bonds are strong **AND** London forces are weak **OR**<br>• Ionic bonds need a large amount of energy to break **AND** London forces need little energy to break<br><br>**<u>Examiner's Comments</u>**<br><br>This part required candidates to determine the structure and bonding of unfamiliar compounds from their melting points and electrical conductivities.<br><br>This part discriminated very well. Candidates with a good knowledge and understanding of structure and bonding, often produced concise, clear responses which were credited with a high mark, as shown in the Exemplar 1.<br><br>Poor understanding often showed up with contradictions and it was common to see ionic lattices with strong intermolecular forces and able to release mobile electrons (rather than mobile ions) in the liquid state. Weaker candidates often wrote extensive answers, although the extra length did not lead to more marks as correct responses were then often contradicted. Exemplar 2 shows part of a very muddled and rambling response in which NaCl is described as having both ionic bonding and London forces.<br><br>The best responses identified NaCl and $MgCl_2$ as having giant ionic lattices with strong forces between their ions. This structure was then compared with the simple molecular structures of $SiCl_4$, $PCl_3$ and $SCl_2$ with weak London forces between their molecules. A common error was for $SiCl_4$ to have a giant covalent lattice, presumably linking with the structure of elemental silicon and not using the low boiling point in the supplied data. |

**Exemplar 1**



**Exemplar 2**



| | | | | Marks | |
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| | | | **Total** | **13** | |

**8**

| | $Na_2S$ | Na | S |
|---|---|---|---|
| Melting point / °C | 1180 | 98 | 113 |
| Type of structure | **giant** | **giant** | **simple** |
| Conductivity of solid | **poor** | **good** | **poor** |
| Conductivity of liquid | **good** | **good** | **poor** |
| | ✓ | ✓ | ✓ |

One mark for **each correct column**

Marks: 3

Mark by **COLUMN**

**<u>Examiner's Comments</u>**

The majority of candidates obtained 2 or 3 marks on this question. Many candidates seemed unaware that sodium was a metal.

| | | | | Marks | |
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| | | | **Total** | **3** | |

**9**

*Increasing size:*

Atomic radius increases
**OR**
more shells
**OR**

Marks: 3

**FULL ANNOTATIONS WITH TICKS, CROSSES, CON, etc MUST BE USED**

**IGNORE** more orbitals **OR** more sub-shells
*Alternative must refer to shells*

**ALLOW** Energy levels for shells

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| | | | more (electron) shielding ✓<br><br>*Attraction*<br>Nuclear **attraction** decreases<br>**OR**<br>(outer) electron(s) experience less **attraction** ✓<br><br>*Ionisation energy*<br>Ionisation **energy** decreases<br>**OR**<br>less **energy** needed to remove electron(s) ✓ | | **ALLOW more** electron repulsion between shells<br>**IGNORE** just 'shielding' *(more / greater needed)*<br>**IGNORE** 'nuclear shielding'<br><br>**IGNORE** 'pull' for attraction<br>**IGNORE** 'electrons less tightly held'<br>**IGNORE** 'nuclear charge' for 'nuclear attraction'<br><br>**IGNORE** 'easier to remove electron'<br>***Energy is required***<br><br>**ALLOW** less energy to oxidise<br><br>**Examiner's Comments**<br>This question was another one based upon the AS part of the specification, and most candidates secured the first two marking points. The third mark, based upon the idea of less energy needed to remove electron(s) as the group is descended, was not scored by many. Instead, candidates loosely talked about an increasing ease of electron removal. |
| | | | **Total** | **3** | |
| 10 | | | **Observations linked to anion identifications**<br><br>Bubbles/effervescence/fizzing/gas **AND** carbonate ✓<br><br>(white **OR** precipitate) **AND** sulfate ✓<br><br>**Use of molar mass in reasoning**<br><br>Molar mass used **ONCE** with carbonate **OR** sulfate ✓<br><br>**Identification**<br><br>**B:** $K_2CO_3$ ✓ | **5** | **FULL ANNOTATIONS WITH TICKS, CROSSES, CON, etc MUST BE USED**<br><br>For bubbles, **BUT** ALLOW carbon dioxide/$CO_2$ **DO NOT ALLOW** hydrogen/$H_2$<br><br>For carbonate, **ALLOW** $CO_3$<br>For sulfate, **ALLOW** $SO_4$<br><br>e.g. Carbonate: 140 − (12 + 48); 140 − 60<br>Sulfate: 140 − (32.1 + 64); 140 − 96.1<br>$K_2CO_3$ = 138.1<br>$Na_2SO_4$ = 142.1<br><br>**ALLOW ONE** of the two identification marks for:<br>• Correct names: **B** potassium carbonate **AND C** sodium sulfate<br>• Incorrect formulae i.e. **B** $KCO_3$ **AND C** $NaSO_4$<br>*Communicates the same as names* |

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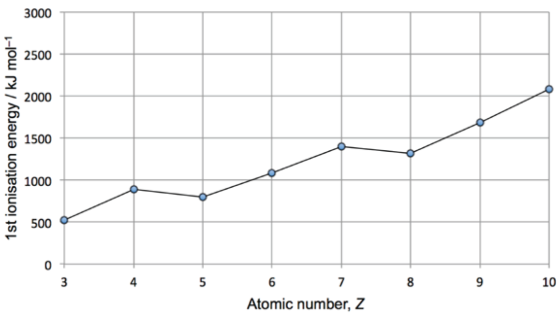
| | | | **C:** $Na_2SO_4$ ✓ | | **Examiner's Comments**<br>This was a challenging question that discriminated extremely well. The more able candidates derived the anions from the two chemical tests and identified the cations using the molar masses of the salt and the anions.<br><br>Weak candidates seemed to have little idea on how to approach such a question and they often achieved no credit.<br><br>It was disappointing that many candidates were unable to identify a carbonate and sulfate from their chemical tests. Common errors included incorrectly identifying the gas with dilute acid as hydrogen, and identifying the white precipitate with barium ions as characteristic of a chloride.<br><br>Candidates who used the provided molar mass of 140 usually went on to show that the cations contributed masses of approximately 80 for the carbonate and 44 for the sulfate. Candidates then needed to divide each value by 2 to obtain formulae of $K_2CO_3$ and $Na_2SO_4$. Many did not divide by 2 and instead concluded that the compounds were $RbCO_3$, $KSO_4$ or $CaSO_4$.<br><br>Strangely, some candidates thought they were identifying Group 1 metals and not salts. |
| | | | **Total** | **5** | |
| 11 | | i | <br>Increase from 5–7 (B→N) **AND** 5 below 4 but above 3 ✓<br><br>8(O) below 7 and 9 **AND** above 6 ✓ | 2 | **ALLOW** if points correct but straight lines not drawn |
| | | ii | Trend described down group<br><br>*Atomic radius* | 3 | ***FULL ANNOTATIONS MUST BE USED***<br>........................................................<br><br>**ALLOW ORA** but comparison should be used for each mark. |

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| | | | larger atomic radius<br>**OR**<br>more shells ✓<br><br>*Effect of nuclear charge/shielding*<br>Increased nuclear charge is outweighed by increased distance/shielding<br>**OR**<br>**more**/**increased** shielding ✓<br><br>*Reactivity **AND** Nuclear attraction*<br>Reactivity increases<br>**AND**<br>less nuclear attraction<br>**OR**<br>less attraction on electrons ✓ | | **ALLOW** 'more/higher energy levels' **ALLOW** 'electrons further from nucleus' **ALLOW** 'different shell' **OR** 'new shell'<br><br>**IGNORE** more orbitals **OR** more sub-shells<br><br>**ALLOW more** electron repulsion from inner shells<br>**IGNORE** responses with no comparison e.g. 'is shielding'<br>Mark requires statement that reactivity increases **AND** reason<br><br>**IGNORE** nuclear charge/effective nuclear charge<br><br>**ALLOW** 'less nuclear pull'<br>**OR** 'electrons held less tightly' |
| | | | **Total** | **5** | |
| 12 | a | | Periodicity ✓ | 1 | **Examiner's Comments**<br><br>The term 'periodicity' was known to all but a very small minority of candidates. |
| | b | | Sodium **OR** Na ✓<br>Silicon OR Si ✓<br>Neon **OR** Ne ✓ | 3 | **Examiner's Comments**<br><br>The periodic properties of elements were not fully known. Most realised that sodium had the lowest first ionisation energy, less were aware that silicon had the lowest fourth ionisation energy and fewer still were unable to deduce that neon had the lowest boiling point. |
| | c | | *M1 Number of bonding electrons mark*<br>Magnesium has more outer **OR** bonding electrons ✓<br><br>*M2 Ionic charge mark*<br>Magnesium **ions** have a greater (positive) charge (density) ✓ | 3 | **ALLOW** reverse argument throughout<br>**ALLOW** 'more delocalised electrons' for 'more outer electrons'<br>**DO NOT ALLOW** 'Magnesium molecules' for M1<br><br>**ALLOW** $Mg^{2+}$ ion **OR** Mg ion for 'magnesium ion'<br>**ALLOW** $Mg^{2+}$ **and** $Na_+$ for M2 (may be seen in a diagram)<br>**IGNORE** magnesium has a greater charge but |

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| | | | | | **ALLOW** magnesium has a greater ionic charge<br>**IGNORE** nuclear charge<br>**DO NOT ALLOW** 'atoms' or 'molecules' having a greater charge for M2 |
| | | | *M3 Attraction mark*<br>Magnesium has a greater attraction between ions and delocalised electrons ✓ | | **ALLOW** 'stronger metallic bonds' **only** when a clear description of metallic bonding is given. Eg 'The attraction of positive (metal) ions to delocalised electrons'<br><br>QWC 'delocalised/delocalized' spelled correctly at least once in context of M3 (may be seen in M1 but used in M3)<br><br>'delocalised' need not be directly next to electrons eg Mg has more delocalised electrons and the ions have a greater attraction to these electrons would secure M3<br><br>**Examiner's Comments**<br><br>This question proved to be a good question in terms of distinguishing candidates. Good candidates were able to secure three marks with succinct, but well-explained answers. Weaker candidates were confused as to why the strength of metallic bonding increased from Na to Mg. |
| | | | **Total** | **7** | |
| 13 | a | | Phosphorus has<br>more electrons ✓ | 1 | **ALLOW ORA** but comparison should be used for the all marks<br>**DO NOT ALLOW** Phosphorus has more electrons in the outer shell or larger electron cloud.<br><br>**IGNORE** Phosphorus molecules are bigger or have greater $M_r$.<br><br>**Examiner's Comments**<br><br>It as pleasing to see that the vast majority of candidates were able to use the terms London forces or induced dipole–dipole interactions rather than van der Waals as used in the legacy specification. Unfortunately, many candidates also chose to discuss how the strength of the covalent bonds increased melting points rather than just considering the intermolecular forces. Answers were either very good or very poor. Where a candidate only scored two marks it was |

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| | | | | | mainly due to not discussing the influence the number of electrons has on the strength of the force. |
| | | | Stronger London forces<br>**OR**<br>Stronger induced dipole(-dipole) interactions ✓ | 1 | **ALLOW** 'more' for 'stronger'<br>**ALLOW** stronger van der Waals' / vdW forces |
| | | | More energy required to break the intermolecular forces / bonds **OR** London forces ✓ | 1 | **DO NOT ALLOW** attraction between atoms-or that covalent bonds are broken |
| | b | | **Magnesium**<br>metallic (bonds) ✓ | 1 | **ALLOW** the (electrostatic) attraction between cations / positive ions and delocalised electrons for both Mg marks ✓✓ |
| | | | cations/positive ions/$Mg^{2+}$<br>**AND**<br>**delocalised** electrons ✓ | 1 | **DO NOT ALLOW** molecules for second mark<br>**IGNORE** 'sea of electrons' |
| | | | **Silicon**<br>covalent ✓ | 1 | **ALLOW** the attraction between a shared pair of electrons and the nuclei of the (bonded) atoms for both marks ✓✓ |
| | | | between atoms ✓ | 1 | **DO NOT ALLOW** any intermolecular forces in marking points 2 and 4 or silicon molecules<br><br>**Examiner's Comments**<br><br>The best answers linked the type of bonding with the correct particles in just a few statements to score all four marks. Those candidates who attempted to fill the answer space often contradicted correct answers by discussing the intermolecular forces between the particles. Some very able candidates did not include that the particles in silicon are atoms whereas others gave answers which suggested that silicon was made up of molecules. |
| | | | **Total** | **7** | |
| 14 | | i | $Sr^{+}(g) \rightarrow Sr^{2+}(g) + e^{-}$ ✓ | 1 | **ALLOW** $Sr^{+}(g) - e^{-} \rightarrow Sr^{2+}(g)$<br><br>**ALLOW** e for electron (i.e. charge omitted)<br><br>**IGNORE** states on the electron<br><br>**Examiner's Comments**<br><br>The equation for the second ionisation energy of strontium proved no difficulty for the most able candidates who provided both the correct state symbols and charges. It was surprising however that 40% of candidates failed to score what was meant to be a straightforward mark. |
| | | ii | | 3 | **FULL ANNOTATIONS MUST BE USED**<br>……………………………………………… |

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| | | | *Atomic radius*<br>larger atomic radius<br>OR<br>more shells ✓<br><br>*Effect of nuclear charge / shielding*<br>Increased nuclear charge outweighed by increased distance / shielding<br>**OR**<br>more / increased shielding ✓<br><br>*Nuclear attraction*<br>less nuclear attraction<br>**OR**<br>less attraction on electrons ✓ | | .<br>**ALLOW ORA**: comparison needed for each mark.<br><br>**ALLOW** 'more / higher energy levels'<br>**ALLOW** 'electrons further from nucleus'<br>**ALLOW** 'extra / new shell'<br><br>**IGNORE** more orbitals OR more sub-shells<br>**OR** different shell<br><br>**ALLOW** more electron repulsion from inner shells<br>**IGNORE** responses with no comparison<br><br>**IGNORE** nuclear charge / effective nuclear charge<br>**ALLOW** 'less nuclear pull'<br>**OR** 'electrons held less tightly'<br><br>**Examiner's Comments**<br><br>This descriptive question was well answered with the vast majority of candidates picking up two of the three available marks. Where a candidate scored two marks it was often due to the omission of any comment about the reduction in attraction between the nucleus and the electron as the group was descended. A common error was to discuss the reduction in nuclear charge rather than nuclear attraction. |
| | | | **Total** | **4** | |
| 15 | | | The attraction (between nuclei and outermost electrons) increases (across the period)<br>**AND**<br>The nuclear charge increases<br>**OR**<br>The number of protons increase ✓<br><br>(Outer) electrons are in the same shell<br>**OR**<br>(Outer) electrons experience similar shielding<br>**OR**<br>Same number of shells<br>**OR**<br>Atomic radius decreases ✓ | 2 | **ALLOW** There is no change in shielding<br>But **DO NOT ALLOW** 'there is no shielding'<br><br>**DO NOT ALLOW** electrons are at the same distance<br><br>**Examiner's Comments**<br><br>This question was well answered. |
| | | | **Total** | **2** | |

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| 16 | | i | $Al^{2+}(g) \rightarrow Al^{3+}(g) + e^-$✓ | 1 | State symbols required (ignore states on electrons)<br>**ALLOW** $Al^{2+}(g) - e^- \rightarrow Al^{3+}(g)$<br>**ALLOW** e for $e^-$<br><br>**Examiner's Comments**<br><br>This was well answered. The most common error was to omit the state symbols. Only occasionally did candidates attempt to ionise Al directly to $Al^{3+}$. |
| | | ii | All (thirteen) ionisation energies show an increase ✓<br><br>The two largest increases are between the third and fourth<br>**AND**<br>the eleventh and twelfth ionisation energies ✓ | 2 | **IGNORE** line if drawn<br>**IGNORE** 0 if included<br><br>**ALLOW** one mark for three lines (no crosses) showing an increase between:<br>first and third; fourth and eleventh; twelfth and thirteenth<br>**AND**<br>Largest increases between each line<br><br>**ALLOW** crosses outside grid<br><br>**Examiner's Comments**<br><br>Candidates made a good attempt at this question. For the first mark, successive ionisation energies had to increase. The most common error was to confuse the plot with that for the first ionisation energy against atomic number and so show step drops after the 3rd and 11th values.<br><br>For the second mark the candidates had to show major increases after the 3rd and 11th values. Here the most common error was to reverse the plot and so show these after the 2nd and 10th values as clearly the candidates were thinking about removing the electrons in the pattern of the configuration (2:8:3). |
| | | | **Total** | **3** | |
| 17 | a | | Giant covalent (lattice) ✓ | 1 | **ALLOW** 'Giant lattice with covalent bonds'<br>**ALLOW** 'Giant covalent bonds'<br>**IGNORE** 'Giant molecular' or 'macromolecular'<br>**DO NOT ALLOW** 'Covalent bonds between molecules'<br><br>**Examiner's Comments**<br><br>This question allowed many candidates to achieve the mark but only the more succinct wrote the expected response of 'giant covalent'. Candidates unfamiliar with the concept of |

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| | | | | | structure and bonding thought that the requirement to give the structure meant that they had to describe the geometry of the Si atom in $SiO_2$. |
| | b | | *Conductivity of Na mark*<br>M1: Sodium conducts in the solid and molten states ✓<br><br>*Reason for conductivity of Na mark*<br>M2: Sodium has delocalised electrons (in both solid and liquid state) ✓<br><br>*Conductivity of $Na_2O$ mark*<br>M3: $Na_2O$ conducts when molten and not when solid ✓<br><br>*Reason for conductivity of $Na_2O$ marks*<br>M4: Molten $Na_2O$ has **ions** which are mobile ✓<br><br>M5: Solid $Na_2O$ has **ions** which are fixed (in position) **OR ions** are held (in position) **OR ions** are not mobile<br>**AND**<br>in an (ionic) lattice **OR** structure ✓ | 5 | Quality of written communication<br>'delocalis(z)ed spelled correctly once and used in context for second marking point<br><br>**ALLOW** 'carries charge' for conducts for M1 and M3<br>**IGNORE** 'charge carriers' for electrons **OR** ions for M2, M4 and M5<br><br>**DO NOT ALLOW** M2 if incorrect bonding is seen for Na<br>**DO NOT ALLOW** ions move for solid Na for M2<br>**IGNORE** ions move for molten Na for M2<br><br>**ALLOW** solid $Na_2O$ is a poor conductor for M3<br>**IGNORE** references to aqueous $Na_2O$ for M3<br><br>**IGNORE** references to aqueous $Na_2O$ for M4<br>**IGNORE** 'delocalised ions' **OR** 'free ions' for 'mobile ions' for M4<br>**DO NOT ALLOW** M4 **AND** M5 if incorrect bonding is seen in $Na_2O$<br><br>**DO NOT ALLOW** any mention of electrons moving for M4<br>**DO NOT ALLOW** suggestion that it is only positive or only negative ions move for M4<br>**IGNORE** 'there are no delocalised electrons' for M5<br>**ALLOW** first and second statements of M5 to be unlinked in separate sentences<br>**ALLOW** 'ions fixed in position by ionic bonds' for M5<br><br>**Examiner's Comments**<br><br>This extended writing question gave weaker candidates problems, often resulting from a weakness in the ability to arrange their answer in a cogent, non-repeating manner. The more able candidates were able to rattle off excellent answers but weaker candidates dropped marks by leaving out key points; in the worst cases failing to discuss the conductivity of sodium at all. Of the possible errors that candidates made, the most common remained the suggestion that conductivity in molten $Na_2O$ relies on mobile electrons. Within the better answers it was common for candidates to say that the ions were unable to move in solid $Na_2O$, but not to |

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| | | | | | give the required explanation of why they lacked mobility.<br>Centres are recommended to advise candidates, particularly weaker ones, that the use of bullet points often helps as a form of response that allows candidates to check that all aspects of the answer have been addressed. |
| | | | **Total** | **6** | |
| 1<br>8 | | | M1 *Trend **AND** nuclear charge mark*<br>(from Li to F) atomic radius decreases<br>**AND**<br>nuclear charge increases or number of protons increases ✓<br><br>M2 *same shell / shielding mark*<br>(outer) electrons are in same shell<br>**OR**<br>(outer) electrons experience similar or same shielding ✓<br>**OR**<br>same number of shells<br><br>M3 *nuclear attraction mark*<br>Greater **nuclear** attraction on (outer) **electrons** or **shells**<br>**OR**<br>(Outer) **electrons** or **shells** are attracted more strongly to the **nucleus** ✓ | 3 | **ALLOW ORA** throughout if it is clear that the Period is being crossed right to left<br><br>**ALLOW** 'proton number increases'<br>**IGNORE** 'atomic number increases'<br>**IGNORE** 'nucleus gets bigger'<br>**IGNORE** 'effective nuclear charge increases'<br>**DO NOT ALLOW** 'charge increases' without reference to nuclear'<br><br>**IGNORE** there is shielding<br>**DO NOT ALLOW** sub-shells **OR** orbitals<br>**DO NOT ALLOW** 'electrons are at a similar distance' This will also contradict M1<br>**ALLOW** 'there is no change in shielding'<br>**IGNORE** 'shielding has no effect'<br>**DO NOT ALLOW** 'there is no shielding'<br><br>Quality of written communication<br>'nucleus' **OR** 'nuclear' spelled correctly once and used in context for third marking point<br><br>**ALLOW** pull for attraction<br>**IGNORE** for M3, 'electrons are pulled closer to nucleus' as this is a re-statement of the trend mark.<br>**DO NOT ALLOW** 'greater nuclear charge' for 'greater nuclear attraction' for M3<br><br>**Examiner's Comments**<br><br>Of the three marks on offer, the mark most commonly awarded was the one for the correct statement of the trend linked to an increase in each atom's nuclear charge. The next most popular mark was given for identifying that this increase in proton number would increase the attractive forces operating on the outer shell electrons, although a number of candidates did not get this as they rushed the answer and so just referred vaguely to increased attraction, without describing it in the required level of detail. The mark related to shielding, or the fact that each subsequent electron is being accommodated in the same shell was awarded the least of the three, with a significant number |

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| | | | | | of candidates omitting to mention this at all. Candidates should be aware that using incorrect statements such as 'there is no shielding' could lead to correct statements being contradicted. |
| | | | **Total** | **3** | |
| 1<br>9 | | | Potassium (atoms) have one more proton (than argon) | 1 | |
| | | | **Total** | **1** | |
| 2<br>0 | | | $HgBr_2$ conducts when molten but not when solid (1)<br><br>… because **ions** are mobile in molten $HgBr_2$ (1)<br><br>… but are fixed in a lattice in solid $HgBr_2$ (1)<br><br>Mercury conducts in both the solid and molten states … (1)<br><br>… because delocalised electrons move (in both solid and liquid state) (1) | 5 | Explanations **must** be included for 2nd and 3rd marks.<br><br>**ignore** references to aqueous $HgBr_2$<br><br>**ignore** 'delocalised ions' **OR** 'free ions' for 'mobile ions'<br><br>**do not allow** any mention of electrons moving<br><br>**do not allow** any mention of + ions moving |
| | | | **Total** | **5** | |
| 2<br>1 | | | *Please refer to the marking instruction point 10 for guidance on how to mark this question.*<br><br>**Level 3 (5–6 marks)**<br>Explains trend in melting point across Period 3 in terms of structure, particles and the relative strengths of the forces **AND** identifies that the high melting point of arsenic suggests a giant structure<br><br>*There is a detailed explanation of the different melting points which is clear and logically structured.*<br><br>**Level 2 (3–4 marks)**<br>Attempts to explain all three main points but the explanations may be incomplete or may contain only some correct statements or comparisons<br>**OR**<br>Correctly explains two of the three main points with most elements included.<br><br>*There is an explanation of the different melting points which is mostly clear and logically structured.*<br><br>**Level 1 (1–2 marks)**<br>Explains the trend in melting point across Period 3 | 6 | **Indicative scientific points may include:**<br><br>**1. Structure and bonding / forces in Period 3**<br>**Si:**<br>• **Structure**: giant covalent<br>• **Forces**: Covalent bonding<br>• **Particles:** atoms<br><br>**P–S–Cl:**<br>• **Structure**: simple molecular<br>• **Forces**: induced dipole-dipole interactions (London forces) **OR** van der Waals' forces<br>• **Particles:** molecules<br><br>**2. Comparison of strength in Period 3**<br>• Covalent bonds in Si are much stronger than London forces in P–ArCl<br>• P–ArCl: London forces greatest with larger molecules (more electrons), i.e.$S_8 > P_4$ |

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| | | | but identifies only some of the structure, forces and particles<br>**AND**<br>attempts to compare strengths but does not compare correct forces.<br><br>*The explanation is basic and communicated in an unstructured way. The response lacks fine detail.*<br><br>**0 marks:**<br>No response or no response worthy of credit. | | • (The stronger the force, the higher the melting point)<br><br>**3. Period 4**<br><br>• Ge, Se and Br have **similar** trend<br>• As has much **higher melting point** (than P) suggesting giant (covalent) structure<br>• (Ge has lower melting point suggesting weaker covalent bonds) |
| | | | **Total** | **6** | |
| 22 | a | | $Cl(g) \rightarrow Cl^{+}(g) + e^{-}$<br><br>Correct species, balanced **AND** correct state symbols | 1 | **allow** $Cl(g) - e^{-} \rightarrow Cl^{+}(g)$<br>**ignore** state symbols after electron |
| | b | | **Group**: 2 (1)<br><br>**Justification**:<br>Large increase between 2nd and 3rd ionisation energy values. (1) | 2 | **allow** alkaline earth<br><br>**No ecf** for justification (dependent on correct group) |
| | | | **Total** | **3** | |
| 23 | | i | $Na^{6+}(g) \rightarrow Na^{7+}(g) + e^{-}$<br><br>*State symbols must be included* | 1 | **ALLOW** $Na^{6+}(g) - e^{-} \rightarrow Na^{7+}(g)$<br>**ALLOW** e for electron (i.e. charge omitted)<br><br>**IGNORE** state with $e^{-}$ |
| | | ii | radius decreases<br>**AND**<br>attraction between (the remaining) electrons and nucleus increases | 1 | **ALLOW** same number of protons attract fewer electrons<br>**ALLOW** electron removed from increasing + ion<br><br>**IGNORE**: atomic / ionic before radius<br>electron shielding / repulsion decreases<br>effective nuclear charge increases |
| | | iii | large difference / increase / rise shows a different / new shell<br><br>large difference / increase / rise between 1st and 2nd IEs<br>**AND**<br>9th and 10th IEs | 2 | **ALLOW** energy level for shell<br>**DO NOT ALLOW** sub-shell or orbital for 1st mark<br><br>**ALLOW** a response that clearly shows where there is a large difference / increase, e.g. 'after 1st IE; before 2nd IE' |
| | | iv | Mg has (outer) electron in (3)s sub-shell<br>**AND**<br>Al has (outer) electron in (3)p sub-shell<br><br>(3)p sub-shell has higher energy than (3)s sub-shell | 2 | **ALLOW** Mg and Al has (outer) electron in different sub-shells |
| | | | **Total** | **6** | |