1. This question is about trends in the periodic table.

Which trend is correct?

A. melting point decreases from lithium to carbon
B. boiling point decreases from fluorine to iodine
C. first ionisation energy decreases from lithium to caesium
D. first ionisation energy increases from nitrogen to oxygen

Your answer

[1]

2. Which particles are attracted in metallic bonding?

A. anions and delocalised electrons
B. cations and delocalised electrons
C. oppositely charged ions
D. protons and electrons

Your answer

[1]

3. Which statement is **not** correct for Group 2 metals?

A. An unpaired electron is present in an s-orbital.
B. Chemical reactivity increases with increasing atomic number.
C. The first ionisation energy decreases with increasing atomic number.
D. Atomic radius increases with increasing atomic number.

Your answer

[1]

4. A chemist determines some properties of two substances, **C** and **D**.

The results are shown in the table.

	C	**D**
Melting point / °C	660	801
Electrical conductivity when solid	Yes	No
Electrical conductivity when molten	Yes	Yes
Solubility in water	No	Yes

Which row correctly identifies the bonding and structure in **C** and **D**?

	C	**D**
A	giant ionic	giant metallic
B	giant ionic	giant ionic
C	giant metallic	giant metallic
D	giant metallic	giant ionic

Your answer ☐

[1]

5. The 1st to 8th successive ionisation energies, in kJ mol^{-1}, of an element in period 3 are:

1012 1903 2912 4957 6274 21,269 25,398 29,855

What is the element?

A. Al
B. Si
C. P
D. S

Your answer ☐

[1]

6. Which element contains atoms with the largest radius?

A. Na
B. K
C. Mg
D. Ca

Your answer

[1]

7. Successive ionisation energies provide evidence for electron structure.

Sodium has eleven successive ionisation energies, shown in **Table 16.1**.

Ionisation number	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th
Ionisation energy / kJ mol^{-1}	496	4562	6910	9543	13354	16613	20117	25496	28932	141362	159075

Table 16.1

i. Write the equation for the **seventh** ionisation energy of sodium.

Include state symbols.

[1]

ii. Why do successive ionisation energies increase with ionisation number?

[1]

iii. Explain how the successive ionisation energies in **Table 16.1** provide evidence for the electron shells in sodium atoms.

[2]

iv. The trend in first ionisation energies across periods gives further details of electron structure. The first ionisation energies of magnesium and aluminium are shown below.

Element	Mg	Al
First ionisation energy / kJ mol^{-1}	738	578

Explain how the first ionisation energies of magnesium and aluminium give further details of electron structure.

[2]

8(a). Ionisation energies can provide evidence for electron structure.
Write an equation for the first ionisation energy of chlorine.
Include state symbols.

[1]

(b). The following data shows the first eight successive ionisation energies of an element.

Ionisation energy	1st	2nd	3rd	4th	5th	6th	7th	8th
Energy / kJ mol^{-1}	590	1145	4912	6474	8144	10 496	12 320	14 207

In which group of the periodic table would this element be found?

Use the data to justify your choice.

group:

justification:

[2]

9. * This question is about elements in Periods 3 – 4 of the periodic table.

The table shows the melting points of elements in Groups 14 – 17.

Phosphorus and sulfur exist as P_4 and S_8 molecules respectively.

	Group	**14**	**15**	**16**	**17**
Period 3	**Element** **Melting point / °C**	Si 1414	P 44	S 115	C*l* −102
Period 4	**Element** **Melting point / °C**	Ge 938	As 817	Se 221	Br −7

- Explain the trend in melting point from Si to C*l* across Period 3.
- Comment, with reasons, on the similarities and differences in the trends across Period 3 and Period 4.

Use the information in the table in your answer.

[6]

10. Bromine and mercury are the only two naturally occurring elements that are liquids at room temperature and pressure. Some physical properties of these two elements are given below.

	Appearance at room temperature	Melting point / °C	Boiling point / °C	Electrical conductivity of the liquid
Bromine	dark orange liquid	−7.2	58.8	very low
Mercury	shiny silver liquid	−38.8	356.7	good

Mercury and bromine react together to form mercury(II) bromide, $HgBr_2$.

Describe and explain how electrical conductivity occurs in mercury(II) bromide and mercury, in both solid and molten states.

[5]

11. Give chemical explanations for the following statements.

Potassium is placed immediately after argon in the periodic table.

[1]

12. Antimony, Sb, has atomic number 51.

Complete the table below to show where antimony is found in the Periodic Table.

Period	Block

[1]

13(a). Silicon dioxide, SiO_2, has the same structure and bonding as diamond.

State the structure and bonding in SiO_2.

[1]

(b). Describe and explain the electrical conductivity of sodium oxide, Na_2O, and sodium in their solid and molten states.

In your answer you should use appropriate technical terms, spelled correctly.

[5]

14. The Periodic Table is arranged in periods and groups.

Elements in the Periodic Table show a periodic trend in atomic radius.

State and explain the trend in atomic radius from Li to F.

In your answer you should use appropriate technical terms, spelled correctly.

trend ....

explanation ....

[3]

15. Aluminium has 13 successive ionisation energies.

i. Write the equation for the **third** ionisation energy of aluminium.

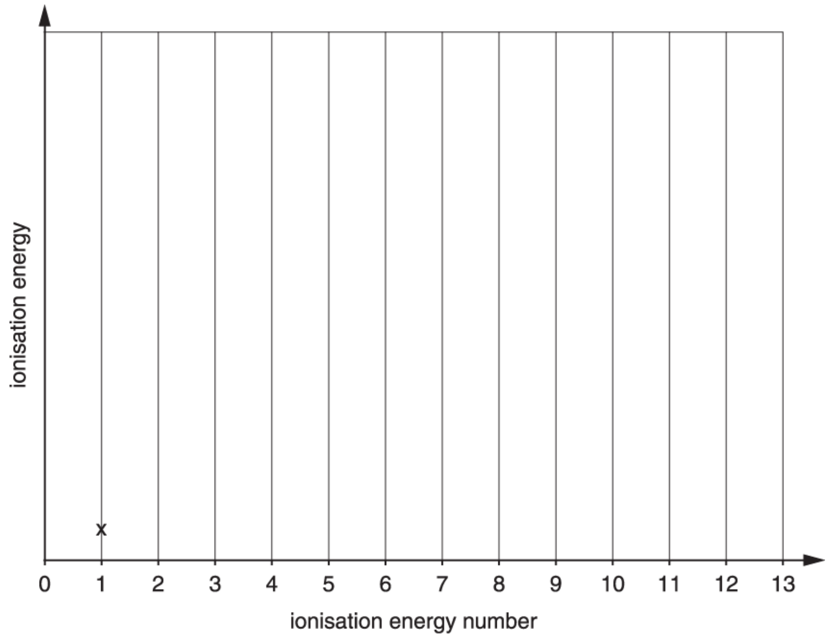
Include state symbols.

[1]

ii. On the axes below, add crosses to show the 13 successive ionisation energies of aluminium.

The value for the first ionisation energy has been completed for you.

You do not have to join the crosses.



[2]

16. This question is about the attraction between particles.

State how and explain why the attraction between nuclei and outermost electrons in gaseous atoms varies across Period 3.

[2]

17. The trend in the first and second ionisation energies of Group 2 elements can be linked to the increase in chemical reactivity down the group.

The first and second ionisation energies of calcium and strontium are given in the table.

Element	First ionisation energy / $kJmol^{-1}$	Second ionisation energy / $kJmol^{-1}$
Ca	590	1145
Sr	550	1064

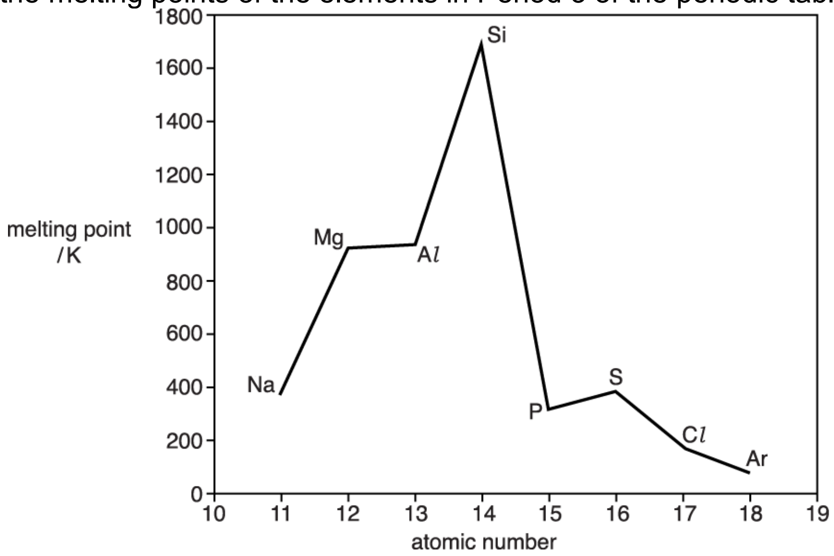
i. Write an equation, including state symbols, to represent the **second** ionisation energy of strontium.

[1]

ii. Explain why the first ionisation energy of strontium is less than the first ionisation energy of calcium.

[3]

18(a). The graph shows the melting points of the elements in Period 3 of the periodic table.



Phosphorus and chlorine have simple molecular structures.
More information about phosphorus and chlorine is given in the table below.

Element	Molecular formula
phosphorus	P_4
chlorine	Cl_2

Explain the differences in the melting points of phosphorus and chlorine.

[3]

(b). Magnesium and silicon have different types of giant structures.

Describe the bonding in magnesium and in silicon.

Include the names of the particles and describe the forces between the particles in the structures.

[4]

19(a). The elements of Period 2 and Period 3 of the Periodic Table are shown in **Table 3.1**.

Group	1	2	3	4	5	6	7	0
Period 2	Li	Be	B	C	N	O	F	Ne
Period 3	Na	Mg	A*l*	Si	P	S	C*l*	Ar

Table 3.1

The elements in these two periods show a repeating pattern in chemical and physical properties.

What is the name given to this repeating pattern of properties?

[1]

(b). State the element in **Table 3.1** with:

- the lowest first ionisation energy ....
- the lowest fourth ionisation energy ....
- the lowest boiling point ....

[3]

(c). The melting points of the Period 3 metals sodium and magnesium are shown below.

Metal	**Melting point / °C**
sodium	98
magnesium	649

Explain the differences in the melting points of sodium and magnesium, using the model of metallic bonding.

In your answer you should use appropriate technical terms spelled correctly.

[3]

20. What is the shape around the carbon atoms in graphene?

A linear
B pyramidal
C tetrahedral
D trigonal planar

Your answer

[1]

21. Electron configurations for atoms of different elements are shown below.

Which electron configuration represents the element with the largest first ionisation energy?

A $1s^2 2s^2$
B $1s^2 2s^2 2p^4$
C $1s^2 2s^2 2p^6$
D $1s^2 2s^2 2p^6 3s2$

Your answer

[1]

22. Successive ionisation energies of four elements in Period 3 are shown below.

Which letter could represent magnesium?

	Ionisation energy / kJ mol^{-1}				
	1st	**2nd**	**3rd**	**4th**	**5th**
A	1251	2298	3822	5159	6542
B	738	1451	7733	10543	13630
C	496	4563	6913	9544	13352
D	578	1817	2745	11577	14842

Your answer

[1]

23. Ionisation energies have been used to develop a model for electron configuration.

i. **Fig. 16.1** shows the first ionisation energies for Li, Be, F and Ne.

Add points for the missing elements across Period 2.

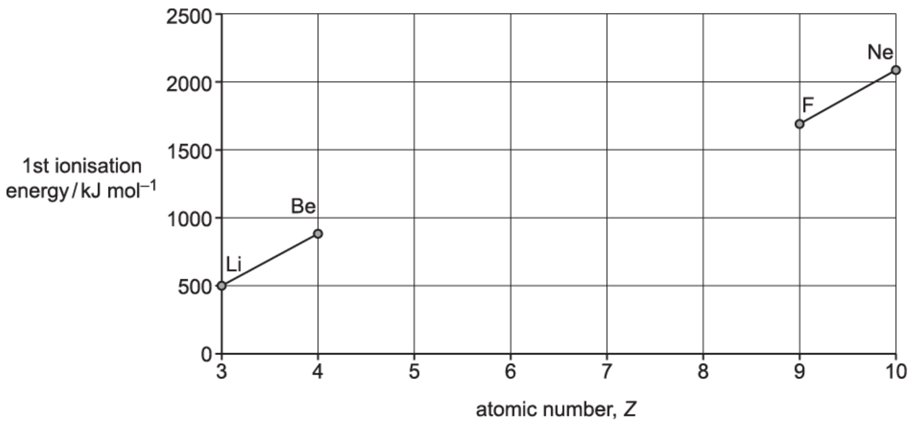


Fig. 16.1

[2]

ii. First ionisation energies decrease down groups in the Periodic Table.

Explain this trend and the effect on the reactivity of groups containing metals.

[3]

24. How many electrons are removed from 2.02×10^{-2} g of Ne(g) atoms to form Ne^+(g) ions?

A 3.36×10^{-26}
B 1.66×10^{-27}
C 6.02×10^{20}
D 1.22×10^{22}

Your answer ☐ **[1]**

25. Which element has the highest melting point?

A silicon
B phosphorus
C sulfur
D chlorine

Your answer [1]

26. B and **C** are ionic compounds of two different Group 1 elements.
The molar masses of **B** and **C** are both approximately 140 g mol^{-1}.

A student dissolves **B** and **C** in water in separate test tubes and analyses the solutions.

The observations are shown below.

Test	**Observation**	
	B(aq)	**C(aq)**
Addition of HNO_3(aq) followed by $BaCl_2$(aq)	bubbles no change	no change white precipitate

Use this information and the observations to identify the formulae of **B** and **C**.

Explain your reasoning.

[5]

27. The reactivity of the Group 2 elements Mg–Ba increases down the group.

Explain why.

[3]

28. The table below compares the properties of sodium sulfide, sodium and sulfur.

Complete the table.

		Sodium sulfide	**Sodium**	**Sulfur**
Melting point / °C		1180	98	113
Type of structure (**giant** or **simple**)				
Electrical conductivity (**good** or **poor**)	solid			
	liquid			

[3]

29. Which statement best explains why nitrogen has a larger first ionisation energy than oxygen?

A N atoms have less repulsion between p-orbital electrons than O atoms.
B N atoms have a smaller nuclear charge than O atoms.
C N atoms lose an electron from the 2s subshell, while O atoms lose an electron from the 2p subshell.
D N atoms have an odd number of electrons, while O atoms have an even number.

Your answer **[1]**

30(a). This question refers to the elements in the first three periods (H → Ar) of the Periodic Table.

Select an element from the first three periods that fits each of the following descriptions.

i. The element that forms a 1− ion with the same electron configuration as helium.

[1]

ii. The element with the highest first ionisation energy.

[1]

iii. The element in Period 3 which has the successive ionisation energies shown below.

Ionisation number	1st	2nd	3rd	4th
Ionisation energy/kJ mol^{-1}	738	1451	7733	10541

[1]

iv. The element which forms a compound with fluorine that has octahedral molecules.

[1]

v. An element which reacts with water to form an acidic solution.

[1]

vi. The element **X**, which forms a compound with hydrogen, XH_3, with a molar mass of 34.0 g mol^{-1}.

[1]

vii. An element which forms a compound with hydrogen in which the element has an oxidation number of −4.

[1]

viii. The element which has a density of 1.33×10^{-3} g cm^{-3} at room temperature and pressure.

[1]

(b). Table 1.1 shows some properties of Period 3 chlorides.

Group		**1**	**2**	**14 (4)**	**15 (5)**	**16 (6)**
Chloride	$NaCl$	$MgCl_2$	$SiCl_4$	PCl_3	SCl_2	
Electrical conductivity	**Solid**	poor	poor	poor	poor	poor
	Liquid	good	good	poor	poor	poor
Melting point		high	high	low	low	low

Table 1.1

Explain the properties shown in **Table 1.1** in terms of bonding and structure.

[5]

31. What determines the order of elements in the Periodic Table?

A first ionisation energy
B number of electrons in the outer shell
C number of protons in the nucleus
D relative atomic mass

Your answer

[1]

32. The first five successive ionisation energies of an element **Y** are shown below.

1st	2nd	3rd	4th	5th
496	4563	6913	9544	13352

What is the formula of a chloride of **Y**?

A YC*l*
B YC*l*$_2$
C YC*l*$_3$
D YC*l*$_4$

Your answer ☐ **[1]**

33. Which element has induced dipole–dipole interactions (London forces) in its solid lattice?

A boron
B magnesium
C silicon
D sulfur

Your answer ☐ **[1]**

34. Why are silicon, carbon, oxygen and chlorine all classified as p-block elements?

[1]

35. SiO_2 and CO_2 are oxides of Group 14 (Group 4) elements.

Solid SiO_2 melts at 2156 °C. Solid CO_2 melts at −56 °C.

Suggest the type of lattice structure in solid SiO_2 and in solid CO_2 and explain the difference in melting points in terms of the types of force within each lattice structure.

Structure in SiO_2(s)

Structure in CO_2(s)

Explanation

[4]

36. Which set of elements in the solid state contain a simple molecular lattice, a giant covalent lattice and a giant metallic lattice?

A S, Si, *Al*
B P, Si, C
C S, P, Si
D Mg, P, S

Your answer **[1]**

37. Which statement about the periodic table is **not** correct?

A The elements are arranged in groups with similar chemical properties.
B The elements are arranged in periods with repeating trends in properties
C The elements are arranged in order of increasing atomic number.
D The elements in the halogen group increase in reactivity down the group.

Your answer **[1]**

38. Sir Humphry Davy discovered several elements including sodium, potassium, magnesium, calcium and strontium.

Explain which block in the Periodic Table sodium and magnesium belong to.

[1]

39. The table below shows two physical properties of the element strontium.

Melting point	high
Electrical conductivity	very good

Explain these physical properties of strontium, in terms of bonding and structure.
Include a labelled diagram in your answer.

Diagram

Explanation

[5]

40(a). This question is about some elements in Period 4 of the periodic table.

The table shows the melting point and electrical conductivity of two elements in Period 4.

Element	Melting Point / °C	Electrical conductivity
Calcium	842	Good
Bromine	–7	Poor

Use your knowledge of structure and bonding to explain the properties in the table.

[5]

(b). Calcium reacts with bromine to form calcium bromide, $CaBr_2$.

i. Draw a '*dot-and-cross*' diagram to show the bonding in $CaBr_2$.

Show **outer** electrons only.

[2]

ii. The reaction of barium with bromine is more vigorous than the reaction of calcium with bromine.

Explain why.

[3]

41. This question is about magnesium, bromine and magnesium bromide.

Table 16.1 shows some physical properties of magnesium, bromine and magnesium bromide.

Substance	**Melting point / °C**	**Electrical conductivity**	
		Solid	**Liquid**
Magnesium	711	Good	Good
Bromine	−7	Poor	Poor
Magnesium bromide	650	Poor	Good

Table 16.1

Explain the physical properties shown in **Table 16.1** using your knowledge of structure and bonding.

[6]

42. Which sequence has elements in order of increasing first ionisation energy?

A Na < Mg < A*l*
B Mg < A*l* < Si
C A*l* < Si < P
D Si < P < S

Your answer [ ] **[1]**

43(a). Nickel and gallium are in period 4 of the periodic table.

i. Which block in the periodic table does nickel belong to?

______________________________ **[1]**

ii. Complete the electron configuration of gallium.

$1s^2$ ______________________________ **[1]**

(b). Element **A** is in period 3 of the periodic table (Na-Ar).

The first six ionisation energies (I.E.) of element **A** are shown below.

1st I.E. / kJ mol^{-1}	2nd I.E. / kJ mol^{-1}	3rd I.E. / kJ mol^{-1}	4th I.E. / kJ mol^{-1}	5th I.E. / kJ mol^{-1}	6th I.E. / kJ mol^{-1}
789	1577	3232	4356	16091	19785

Identify element **A**.

Explain your answer.

Element **A** = ______________________________

____

Explanation ______________________________

____

[2]

44. Which row shows elements in order of increasing first ionisation energy?

A Ca < Si < P < N
B N < P < Si < Ca
C Ca < N < P < Si
D C < Si < P < Ca

Your answer ☐ **[1]**

45(a). This question is about magnesium and magnesium halides.

Magnesium has metallic bonding and is a good conductor of electricity.

Describe, with the aid of a labelled diagram, the metallic bonding in magnesium and explain why magnesium conducts electricity.

Include the correct charges on the particles in your diagram.

[3]

(b). The 12 successive ionisation energies of magnesium are shown in **Table 16.1**.

Ionisation number	Ionisation energy / kJ mol^{-1}
1	738
2	1451
3	7733
4	10541
5	13629
6	17995
7	21704
8	25657
9	31644
10	35463
11	169996
12	189371

Table 16.1

i. Write an equation to represent the **fourth** ionisation energy of magnesium.

Include state symbols.

[1]

ii. Explain how the successive ionisation energies provide evidence that magnesium is in Group 2 of the periodic table.

[1]

iii. Electrons occupy orbitals.

In **Table 16.2** below, add a tick (✓) below the ionisation numbers that are responsible for removing an electron from a full orbital in a magnesium atom.

Ionisation number	1	2	3	4	5	6	7	8	9	10	11	12

Table 16.2 **[1]**

46. This question is about some Group 2 elements and their compounds.

Strontium and calcium both react with water.

i. Write an equation for the reaction of strontium with water.

[1]

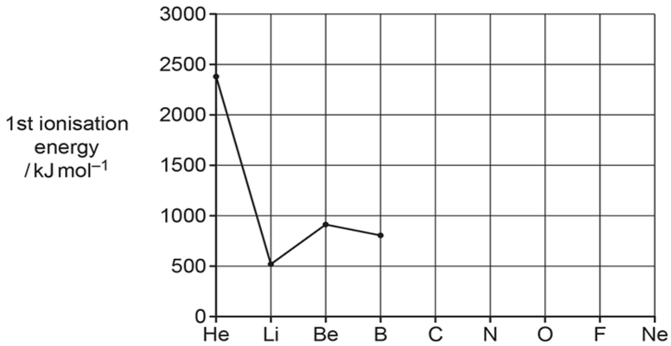
ii. Using oxidation numbers, explain why the reaction of strontium with water is a redox reaction.

[2]

iii. Explain why calcium reacts more slowly with water than strontium does.

[3]

47(a). The graph shows the first ionisation energies for elements from helium, He, to boron, B, in the periodic table.



Complete the graph for C, N, O, F and Ne.

[2]

(b). Estimate the energy required to form **one** $Li^+(g)$ ion from one Li(g) atom.

Give your answer in kJ, in standard form, and to **two** significant figures.

energy = ... kJ **[1]**

(c). Explain why the first ionisation energies of He and Be are both higher than the first ionisation energy of Li.

Explanation for He:

Explanation for Be:

[4]

(d). Explain why the first ionisation energy of Be is higher than the first ionisation energy of B.

[2]

48. Which substance has a giant covalent lattice structure in its solid state?

A potassium
B silicon
C sodium chloride
D water

Your answer **[1]**

49. Which element has the lowest melting point?

A S
B P
C C*l*
D Ar

Your answer **[1]**

50. The first four ionisation energies of a Period 3 element **X** are shown in the table.

Ionisation energy/kJ mol^{-1}			
1st	**2nd**	**3rd**	**4th**
738	1451	7733	10 541

Element **X** is reacted with chlorine.

What is the formula of the chloride formed?

A XCl
B XCl_2
C XCl_3
D XCl_4

Your answer **[1]**

51. Describe the structure and bonding and electrical conductivity of calcium in the solid state. You may wish to include a labelled diagram in your answer.

[4]

52. This question is about titanium (atomic number 22) and its compounds.

An ore of titanium contains impure TiO_2.

Titanium is manufactured from TiO_2 in a two-stage process.

Stage 1	$TiO_2 + 2C + 2Cl_2 \rightarrow TiCl_4 + 2CO$	**Reaction 1.1**
Stage 2	$TiCl_4 + 4Na \rightarrow Ti + 4NaCl$	**Reaction 1.2**

i. The common name for TiO_2 is titanium dioxide.

What is the systematic name of TiO_2?

[1]

ii. In **Reaction 1.2**, the percentage yield of titanium from $TiCl_4$ is 72.0%.

Calculate the minimum mass, in kg, of sodium that is needed to produce 1.00 kg of titanium.

Give your answer to **3** significant figures.

mass of sodium = ... kg **[4]**

iii. **Reaction 1.2** produces a mixture of titanium and sodium chloride.

Suggest how titanium could be separated from this mixture at room temperature.

Explain your answer.

[2]

53. The table below shows melting points and electrical conductivities of some elements in Period 3 and compounds they form.

Substance	**Magnesium sulfide, MgS**	**Aluminium, Al**	**Silicon, Si**	**Phosphorus trichloride, PCl_3**
Melting point / °C	2000	660	1414	–94
Electrical conductivity		Good	Poor	
Type of lattice structure	Giant	....	....	....

i. Complete the table above to show the type of lattice structure of each substance.

[4]

ii. Explain the following:

- MgS has a higher melting point than PCl_3.
- Al has a greater electrical conductivity than Si.

Melting points

Conductivities

[4]

54. Successive ionisation energies, in kJ mol^{-1}, of an element in Period 3 of the periodic table are shown below.

1st	2nd	3rd	4th	5th	6th	7th	8th	9th
578	1817	2745	11578	14831	18378	23296	27460	31862

What is the formula of the oxide of the Period 3 element?

A Na_2O
B MgO
C Al_2O_3
D SiO_2

Your answer **[1]**

55. Which element has the largest third ionisation energy?

A Li
B F
C Ne
D Na

Your answer [ ] **[1]**

56. This question is about energy changes.

The first and second ionisation energies of magnesium, Mg, and strontium, Sr, in Group 2 are given in the table below.

Element	**First ionisation energy / kJ mol^{-1}**	**Second ionisation energy / kJ mol^{-1}**
Mg	+738	+1451
Sr	+550	+1064

- Explain why the first ionisation energy of Mg is greater than the **first** ionisation energy of Sr.
- Explain why the second ionisation energy of Sr is greater than the **first** ionisation energy of Sr.

[4]

57(a). This question is about the first 36 elements in the periodic table:

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr

From these 36 elements **only**, write the symbol for the element(s) that fit each description.

The element in Period 2 with the successive ionisation energies shown below.

Ionisation number	1st	2nd	3rd	4th	5th	6th	7th	8th
Ionisation energy / kJ mol^{-1}	1000	2251	3361	4564	7012	8496	27 107	31 671

.... **[1]**

(b). An element that is a solid at RTP with a simple molecular lattice structure.

.... **[1]**

(c). The element in Period 3 that exists in the solid state as a network of atoms bonded by strong covalent bonds.

.... **[1]**

58(a). This question is about periodicity and the reaction of some Group 2 metals.

Periodicity is the repeating trend in properties of elements across different periods in the periodic table.

i. Complete the table below with the electron configurations and blocks.

	Group 2	**Group 17 (7)**
Period 2	Be $1s^2$	F $1s^2$ ....
Period 3	Mg $1s^2$	Cl $1s^2$ ....
Block	....	....

[3]

ii. Use your answers to **(i)** to explain why electron configuration is an example of a periodic trend.

[2]

iii. Mg forms 2+ ions but C*l* usually forms 1− ions in their reactions. Explain why.

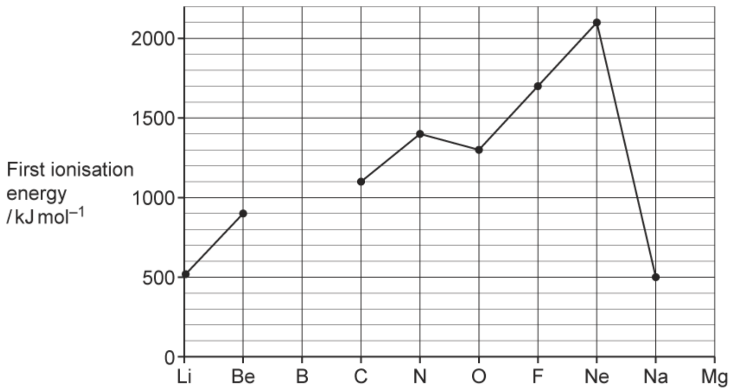
[2]

iv. Magnesium reacts with oxygen in the air.

Write the equation for this reaction.

[1]

(b). The graph shows the first ionisation energies for the elements Li to Be and for C to Na.



i. Complete the graph by adding points for the missing values of B and Mg.

[2]

ii. Write an equation, including state symbols, to represent the **second** ionisation energy of B.

[2]

59. Chlorine has the electron configuration [Ne]$3s^2 3p^5$.

Which statement(s) about chlorine is/are correct when it reacts in redox reactions?

1 It can gain one electron to form 1− ions.
2 It can lose its $3s^2$ electrons to form 2+ ions.
3 It can lose its $3p^5$ electrons to form 5+ ions.

A 1, 2 and 3
B Only 1 and 2
C Only 2 and 3
D Only 1

Your answer [ ] **[1]**

60. The table shows the melting points of some of the elements in Period 3 of the periodic table.

Element	**Al**	**Si**	**P_4**	**S_8**
Melting point / °C	660	1410	44	119

Explain the melting points in terms of bonding and structure.

[6]

61. Which statement about the periodic table is **not** correct?

A Elements in the same group have similar **chemical** properties.
B The elements are ordered by increasing atomic mass.
C The elements are ordered by increasing atomic number.
D There is a repeating trend of **physical** and **chemical** properties across the periods.

Your answer ☐ **[1]**

END OF QUESTION PAPER

Mark scheme

Question			Answer/Indicative content	Marks	Guidance
1			C	1	
			Total	**1**	
2			B	1	
			Total	**1**	
3			A	1	
			Total	**1**	
4			D	1	
			Total	**1**	
5			C	1	
			Total	**1**	
6			B	1	
			Total	**1**	
7		i	$Na^{6+}(g) \rightarrow Na^{7+}(g) + e^-$ *State symbols must be included*	1	**ALLOW** $Na^{6+}(g) - e^- \rightarrow Na^{7+}(g)$ **ALLOW** e for electron (i.e. charge omitted) **IGNORE** state with e^-
		ii	radius decreases **AND** attraction between (the remaining) electrons and nucleus increases	1	**ALLOW** same number of protons attract fewer electrons **ALLOW** electron removed from increasing + ion **IGNORE**: atomic / ionic before radius electron shielding / repulsion decreases effective nuclear charge increases
		iii	large difference / increase / rise shows a different / new shell large difference / increase / rise between 1st and 2nd IEs **AND** 9th and 10th IEs	2	**ALLOW** energy level for shell **DO NOT ALLOW** sub-shell or orbital for 1st mark **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 **AND**	2	**ALLOW** Mg and Al has (outer) electron in different sub-shells

			Al has (outer) electron in (3)p sub-shell (3)p sub-shell has higher energy than (3)s sub-shell		
			Total	**6**	
8	a		$Cl(g) \rightarrow Cl^{+}(g) + e^{-}$ Correct species, balanced **AND** correct state symbols	1	**allow** $Cl(g) - e^{-} \rightarrow Cl^{+}(g)$ **ignore** state symbols after electron
	b		**Group**: 2 (1) **Justification**: Large increase between 2nd and 3rd ionisation energy values. (1)	2	**allow** alkaline earth **No ecf** for justification (dependent on correct group)
			Total	**3**	
9			*Please refer to the marking instruction point 10 for guidance on how to mark this question.* **Level 3 (5–6 marks)** 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 *There is a detailed explanation of the different melting points which is clear and logically structured.* **Level 2 (3–4 marks)** Attempts to explain all three main points but the explanations may be incomplete or may contain only some correct statements or comparisons **OR** Correctly explains two of the three main points with most elements included. *There is an explanation of the different melting points which is mostly clear and logically structured.* **Level 1 (1–2 marks)** Explains the trend in melting point across Period 3 but identifies only some of the structure, forces and particles	6	**Indicative scientific points may include:** **1. Structure and bonding / forces in Period 3** **Si:** • **Structure**: giant covalent • **Forces**: Covalent bonding • **Particles:** atoms **P–S–Cl:** • **Structure**: simple molecular • **Forces**: induced dipole-dipole interactions (London forces) **OR** van der Waals' forces • **Particles:** molecules **2. Comparison of strength in Period 3** • Covalent bonds in Si are much stronger than London forces in P–ArCl • P–ArCl: London forces greatest with larger molecules (more electrons), i.e.$S_8 > P_4$ • (The stronger the force, the higher the melting point) **3. Period 4** • Ge, Se and Br have **similar** trend

			AND attempts to compare strengths but does not compare correct forces. *The explanation is basic and communicated in an unstructured way. The response lacks fine detail.* **0 marks:** No response or no response worthy of credit.		• As has much **higher melting point** (than P) suggesting giant (covalent) structure • (Ge has lower melting point suggesting weaker covalent bonds)
			Total	**6**	
10			$HgBr_2$ conducts when molten but not when solid (1) … because **ions** are mobile in molten $HgBr_2$ (1) … but are fixed in a lattice in solid $HgBr_2$ (1) Mercury conducts in both the solid and molten states … (1) … because delocalised electrons move (in both solid and liquid state) (1)	5	Explanations **must** be included for 2nd and 3rd marks. **ignore** references to aqueous $HgBr_2$ **ignore** 'delocalised ions' **OR** 'free ions' for 'mobile ions' **do not allow** any mention of electrons moving **do not allow** any mention of + ions moving
			Total	**5**	
11			Potassium (atoms) have one more proton (than argon)	1	
			Total	**1**	
12			period = 5 **AND** block = p ✓	1	**Examiner's Comments** Although virtually every candidate got off to a steady start with this opening question, it was perhaps not quite as secure an opening question as in previous years. Of the two parts, it was the identification of the Block that caused problems with some candidates giving the Group number.
			Total	**1**	
13	a		Giant covalent (lattice) ✓	1	**ALLOW** 'Giant lattice with covalent bonds' **ALLOW** 'Giant covalent bonds'

					IGNORE 'Giant molecular' or 'macromolecular' **DO NOT ALLOW** 'Covalent bonds between molecules' **Examiner's Comments** 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 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* M1: Sodium conducts in the solid and molten states ✓ *Reason for conductivity of Na mark* M2: Sodium has delocalised electrons (in both solid and liquid state) ✓ *Conductivity of Na_2O mark* M3: Na_2O conducts when molten and not when solid ✓ *Reason for conductivity of Na_2O marks* M4: Molten Na_2O has **ions** which are mobile ✓ M5: Solid Na_2O has **ions** which are fixed (in position) **OR ions** are held (in position) **OR ions** are not mobile **AND** in an (ionic) lattice **OR** structure ✓	5	Quality of written communication 'delocalis(z)ed spelled correctly once and used in context for second marking point **ALLOW** 'carries charge' for conducts for M1 and M3 **IGNORE** 'charge carriers' for electrons **OR** ions for M2, M4 and M5 **DO NOT ALLOW** M2 if incorrect bonding is seen for Na **DO NOT ALLOW** ions move for solid Na for M2 **IGNORE** ions move for molten Na for M2 **ALLOW** solid Na_2O is a poor conductor for M3 **IGNORE** references to aqueous Na_2O for M3 **IGNORE** references to aqueous Na_2O for M4 **IGNORE** 'delocalised ions' **OR** 'free ions' for 'mobile ions' for M4 **DO NOT ALLOW** M4 **AND** M5 if incorrect bonding is seen in Na_2O **DO NOT ALLOW** any mention of electrons moving for M4 **DO NOT ALLOW** suggestion that it is only positive or only negative ions move for M4 **IGNORE** 'there are no delocalised electrons' for M5 **ALLOW** first and second statements of M5

					to be unlinked in separate sentences **ALLOW** 'ions fixed in position by ionic bonds' for M5 **Examiner's Comments** 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 give the required explanation of why they lacked mobility. 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**	
14			M1 *Trend **AND** nuclear charge mark* (from Li to F) atomic radius decreases **AND** nuclear charge increases or number of protons increases ✓ M2 *same shell / shielding mark* (outer) electrons are in same shell **OR** (outer) electrons experience similar or same shielding ✓ **OR** same number of shells	3	**ALLOW ORA** throughout if it is clear that the Period is being crossed right to left **ALLOW** 'proton number increases' **IGNORE** 'atomic number increases' **IGNORE** 'nucleus gets bigger' **IGNORE** 'effective nuclear charge increases' **DO NOT ALLOW** 'charge increases' without reference to nuclear' **IGNORE** there is shielding **DO NOT ALLOW** sub-shells **OR** orbitals **DO NOT ALLOW** 'electrons are at a similar distance' This will also contradict M1 **ALLOW** 'there is no change in shielding' **IGNORE** 'shielding has no effect' **DO NOT ALLOW** 'there is no shielding'

			M3 *nuclear attraction mark* Greater **nuclear** attraction on (outer) **electrons** or **shells** **OR** (Outer) **electrons** or **shells** are attracted more strongly to the **nucleus** ✓		Quality of written communication 'nucleus' **OR** 'nuclear' spelled correctly once and used in context for third marking point **ALLOW** pull for attraction **IGNORE** for M3, 'electrons are pulled closer to nucleus' as this is a re-statement of the trend mark. **DO NOT ALLOW** 'greater nuclear charge' for 'greater nuclear attraction' for M3 **Examiner's Comments** 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 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**	
15		i	$Al^{2+}(g) \rightarrow Al^{3+}(g) + e^{-}$ ✓	1	State symbols required (ignore states on electrons) **ALLOW** $Al^{2+}(g) - e^{-} \rightarrow Al^{3+}(g)$ **ALLOW** e for e^{-} **Examiner's Comments** 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+}.

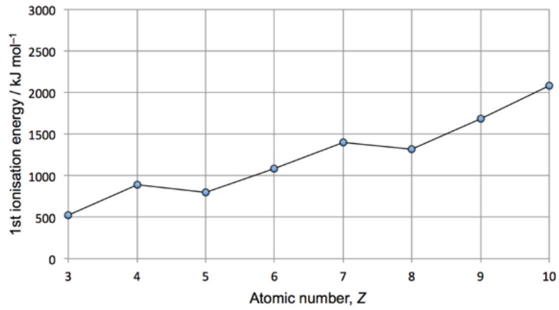
		ii	All (thirteen) ionisation energies show an increase ✓ The two largest increases are between the third and fourth **AND** the eleventh and twelfth ionisation energies ✓	2	**IGNORE** line if drawn **IGNORE** 0 if included **ALLOW** one mark for three lines (no crosses) showing an increase between: first and third; fourth and eleventh; twelfth and thirteenth **AND** Largest increases between each line **ALLOW** crosses outside grid **Examiner's Comments** 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. 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**	
16			The attraction (between nuclei and outermost electrons) increases (across the period) **AND** The nuclear charge increases **OR** The number of protons increase ✓ (Outer) electrons are in the same shell **OR** (Outer) electrons experience similar shielding **OR** Same number of shells **OR** Atomic radius decreases ✓	2	**ALLOW** There is no change in shielding But **DO NOT ALLOW** 'there is no shielding' **DO NOT ALLOW** electrons are at the same distance **Examiner's Comments** This question was well answered.

			Total	**2**	
1 7		i	$Sr^{+}(g) \rightarrow Sr^{2+}(g) + e^{-}$ ✓	1	**ALLOW** $Sr^{+}(g) - e^{-} \rightarrow Sr^{2+}(g)$ **ALLOW** e for electron (i.e. charge omitted) **IGNORE** states on the electron **Examiner's Comments** 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	*Atomic radius* larger atomic radius OR more shells ✓ *Effect of nuclear charge / shielding* Increased nuclear charge outweighed by increased distance / shielding **OR** more / increased shielding ✓ *Nuclear attraction* less nuclear attraction **OR** less attraction on electrons ✓	3	**FULL ANNOTATIONS MUST BE USED** .... **ALLOW ORA**: comparison needed for each mark. **ALLOW** 'more / higher energy levels' **ALLOW** 'electrons further from nucleus' **ALLOW** 'extra / new shell' **IGNORE** more orbitals OR more sub-shells **OR** different shell **ALLOW** more electron repulsion from inner shells **IGNORE** responses with no comparison **IGNORE** nuclear charge / effective nuclear charge **ALLOW** 'less nuclear pull' **OR** 'electrons held less tightly' **Examiner's Comments** 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**	
18	a		Phosphorus has more electrons ✓	1	**ALLOW ORA** but comparison should be used for the all marks **DO NOT ALLOW** Phosphorus has more electrons in the outer shell or larger electron cloud. **IGNORE** Phosphorus molecules are bigger or have greater M_r. **Examiner's Comments** 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 mainly due to not discussing the influence the number of electrons has on the strength of the force.
			Stronger London forces **OR** Stronger induced dipole(-dipole) interactions ✓	1	**ALLOW** 'more' for 'stronger' **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** metallic (bonds) ✓	1	**ALLOW** the (electrostatic) attraction between cations / positive ions and delocalised electrons for both Mg marks ✓✓
			cations/positive ions/Mg^{2+} **AND** **delocalised** electrons ✓	1	**DO NOT ALLOW** molecules for second mark **IGNORE** 'sea of electrons'
			Silicon 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 **Examiner's Comments** 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**	
19	a		Periodicity ✓	1	**Examiner's Comments** The term 'periodicity' was known to all but a very small minority of candidates.
	b		Sodium **OR** Na ✓ Silicon OR Si ✓ Neon **OR** Ne ✓	3	**Examiner's Comments** 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* Magnesium has more outer **OR** bonding electrons ✓ *M2 Ionic charge mark* Magnesium **ions** have a greater (positive) charge (density) ✓	3	**ALLOW** reverse argument throughout **ALLOW** 'more delocalised electrons' for 'more outer electrons' **DO NOT ALLOW** 'Magnesium molecules' for M1 **ALLOW** Mg^{2+} ion **OR** Mg ion for 'magnesium ion' **ALLOW** Mg^{2+} **and** Na_{+} for M2 (may be seen in a diagram) **IGNORE** magnesium has a greater charge but **ALLOW** magnesium has a greater ionic

			M3 Attraction mark Magnesium has a greater attraction between ions and delocalised electrons ✓		charge **IGNORE** nuclear charge **DO NOT ALLOW** ‘atoms’ or ‘molecules’ having a greater charge for M2 **ALLOW** ‘stronger metallic bonds’ **only** when a clear description of metallic bonding is given. Eg ‘The attraction of positive (metal) ions to delocalised electrons’ QWC ‘delocalised/delocalized’ spelled correctly at least once in context of M3 (may be seen in M1 but used in M3) ‘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 **Examiner's Comments** 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**	
20			D	1	**Examiner's Comments** B and C were common incorrect answers
			Total	**1**	
21			C	1	**Examiner's Comments** Many candidates did not take into account the trend across periods, with A being a common incorrect answer.
			Total	**1**	

22			B	1	**<u>Examiner's Comments</u>** Generally scored well.
			Total	**1**	
23		i	 Increase from 5–7 (B→N) **AND** 5 below 4 but above 3 ✓ 8(O) below 7 and 9 **AND** above 6 ✓	2	**ALLOW** if points correct but straight lines not drawn
		ii	Trend described down group *Atomic radius* larger atomic radius **OR** more shells ✓ *Effect of nuclear charge/shielding* Increased nuclear charge is outweighed by increased distance/shielding **OR** **more/increased** shielding ✓ *Reactivity **AND** Nuclear attraction* Reactivity increases **AND** less nuclear attraction	3	***FULL ANNOTATIONS MUST BE USED*** .... **ALLOW ORA** but comparison should be used for each mark. **ALLOW** 'more/higher energy levels' **ALLOW** 'electrons further from nucleus' **ALLOW** 'different shell' **OR** 'new shell' **IGNORE** more orbitals **OR** more sub-shells **ALLOW more** electron repulsion from inner shells **IGNORE** responses with no comparison e.g. 'is shielding' Mark requires statement that reactivity increases **AND** reason **IGNORE** nuclear charge/effective nuclear charge

			OR less attraction on electrons ✓		**ALLOW** 'less nuclear pull' **OR** 'electrons held less tightly'
			Total	**5**	
2 4			**C**	1	
			Total	**1**	
2 5			A	**1**	**Examiner's Comments** Most candidates correctly identified Si as giant covalent. A common error was answer option D.
			Total	**1**	
2 6			**Observations linked to anion identifications** Bubbles/effervescence/fizzing/gas **AND** carbonate ✓ (white **OR** precipitate) **AND** sulfate ✓ **Use of molar mass in reasoning** Molar mass used **ONCE** with carbonate **OR** sulfate ✓ **Identification** **B:** K_2CO_3 ✓ **C:** Na_2SO_4 ✓	**5**	**FULL ANNOTATIONS WITH TICKS, CROSSES, CON, etc MUST BE USED** For bubbles, ALLOW carbon dioxide/CO_2 **BUT** **DO NOT ALLOW** hydrogen/H_2 For carbonate, **ALLOW** CO_3 For sulfate, **ALLOW** SO_4 e.g. Carbonate: 140 − (12 + 48); 140 − 60 Sulfate: 140 − (32.1 + 64); 140 − 96.1 K_2CO_3 = 138.1 Na_2SO_4 = 142.1 **ALLOW ONE** of the two identification marks for: • Correct names: **B** potassium carbonate **AND C** sodium sulfate • Incorrect formulae i.e. **B** KCO_3 **AND C** $NaSO_4$ *Communicates the same as names* **Examiner's Comments** 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. Weak candidates seemed to have little idea on how to approach such a question and they often achieved no credit. 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. 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 $CaSO_4$. Strangely, some candidates thought they were identifying Group 1 metals and not salts.
			Total	**5**	
27			*Increasing size:* Atomic radius increases **OR** more shells **OR** more (electron) shielding ✓ *Attraction* Nuclear **attraction** decreases **OR**	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 **ALLOW more** electron repulsion between shells **IGNORE** just 'shielding' *(more / greater needed)* **IGNORE** 'nuclear shielding' **IGNORE** 'pull' for attraction **IGNORE** 'electrons less tightly held'

<table>
<tr><td></td><td></td><td></td><td>(outer) electron(s) experience less attraction ✓

Ionisation energy
Ionisation energy decreases
OR
less energy needed to remove electron(s) ✓</td><td></td><td>IGNORE ‘nuclear charge’ for ‘nuclear attraction’

IGNORE ‘easier to remove electron’
Energy is required

ALLOW less energy to oxidise

Examiner’s Comments
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.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>3</td><td></td></tr>
<tr><td>28</td><td></td><td></td><td>
<table>
<tr><td></td><td>Na_2S</td><td>Na</td><td>S</td></tr>
<tr><td>Melting point / °C</td><td>1180</td><td>98</td><td>113</td></tr>
<tr><td>Type of structure</td><td>giant</td><td>giant</td><td>simple</td></tr>
<tr><td>Conductivity of solid</td><td>poor</td><td>good</td><td>poor</td></tr>
<tr><td>Conductivity of liquid</td><td>good</td><td>good</td><td>poor</td></tr>
<tr><td></td><td>✓</td><td>✓</td><td>✓</td></tr>
</table>

One mark for each correct column</td><td>3</td><td>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.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>3</td><td></td></tr>
<tr><td>29</td><td></td><td></td><td>A</td><td>1 (AO 1.2)</td><td><u>Examiner’s Comments</u>

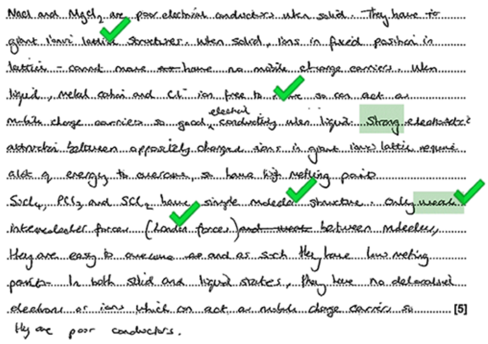
The majority of candidates knew the key factor affecting the relative ionisation energies of nitrogen and oxygen.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>1</td><td></td></tr>
<tr><td>30</td><td>a</td><td>i</td><td>Hydrogen/H ✓</td><td>1</td><td>ALLOW H_2

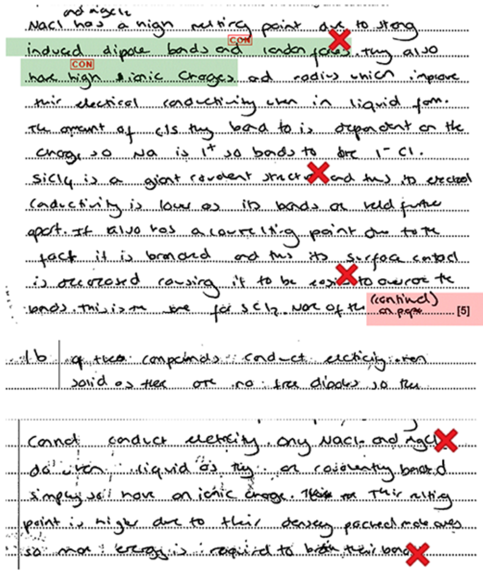
<u>Examiner’s Comments</u></td></tr>
</table>

					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. Candidates are recommended to look closely at the requirements of the question set.
		ii	Helium/He ✓	1	**<u>Examiner's Comments</u>** 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'. 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	**<u>Examiner's Comments</u>** Most candidates did correctly select magnesium, but many other elements were seen, especially aluminium, silicon, beryllium and calcium. 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 **<u>Examiner's Comments</u>** 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 **Examiner's Comments** 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 (which does form a solution with water, but on that is alkaline rather than acidic).
		vi	Phosphorus/P ✓	1	**ALLOW** P_4 **Examiner's Comments** Almost all candidates correctly responded with phosphorus and this was the easiest part of 1(a).
		vii	Carbon/C ✓	1	**ALLOW** silicon/Si **Examiner's Comments** 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 **Examiner's Comments** 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

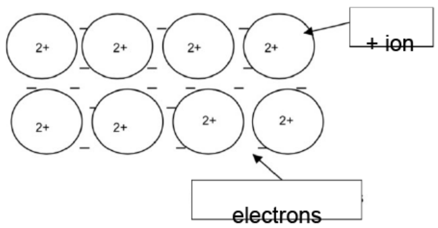
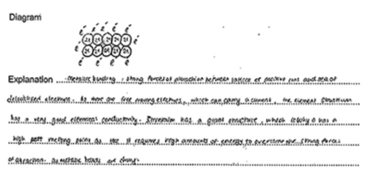
					that the element was gaseous and could not be sulfur.
	b		**NaC*l* OR MgC*l*₂** **2 marks** Giant **ionic OR ionic** lattice ✓ **Ions** are **mobile** in **liquid** state ✓ --- **SiC*l*₄ OR PC*l*₃ OR SC*l*₂** **2 marks** (Simple) molecular **OR** simple covalent (lattice) ✓ Induced dipole(−dipole) forces/interactions **OR** London forces ✓ --- **Comparison of bond strengths** **1 marks** • Ionic bonds are stronger than London forces **OR** • Ionic bonds need more energy to break than London forces ✓	5	**IGNORE** aqueous/dissolved ions are mobile **IGNORE** 'free ions' **AND** 'ions are free to carry current' --- — **ALLOW** 'are molecules' **IGNORE** • permanent dipole(−dipole) forces • IDID and LDF • van der Waals --- – **ALLOW** attraction between ions for ionic bonds **ALLOW** intermolecular forces for London forces **ALLOW** overcome for break **ALLOW** indirect comparison, i.e. • Ionic bonds are strong **AND** London forces are weak **OR** • Ionic bonds need a large amount of energy to break **AND** London forces need little energy to break **<u>Examiner's Comments</u>** This part required candidates to determine the structure and bonding of unfamiliar

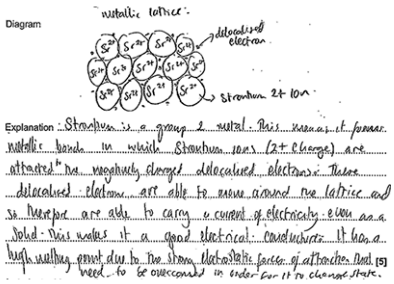
					compounds from their melting points and electrical conductivities. This part discriminated very well. Candidates with a good knowledge and understanding of structure and bonding, often produced concise, clear responses which were credited with a high mark, as shown in the Exemplar 1. Poor understanding 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. 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**  NaCl and MgCl2 are poor electrical conductors when solid. They have to giant ionic lattice structures. When solid, ions in fixed position in lattice - cannot move ~~so~~ have no mobile charge carriers. When liquid, metal cation and Cl⁻ ion free to move so can act as mobile charge carriers so good electrical conductivity when liquid. Strong electrostatic attraction between oppositely charged ions in giant ionic lattice requires alot of energy to overcome, so have high melting point. SiCl4, PCl3 and SCl2 have simple molecular structure. Only weak intermolecular forces (London forces) ~~and weak~~ between molecules, they are easy to overcome ~~as~~ and as such they have low melting points. In both solid and liquid states, they have no delocalised electrons or ions which can act as mobile charge carriers so [5] they are poor conductors. **Exemplar 2**

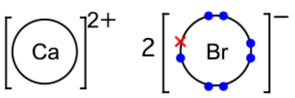
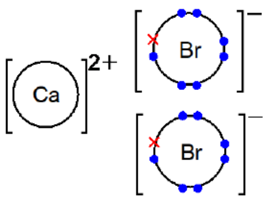
					
			Total	**13**	
3 1			**C**	**1**	**Examiner's Comments** Most candidates correctly selected C (number of protons) but a sizeable number selected D (relative atomic mass) or B (number of electrons) instead.
			Total	**1**	
3 2			**A**	**1**	**Examiner's Comments** Success depended on identifying the group of Y and working out the formula of the chloride. Most candidates recognised the large increase between 1st and 2nd ionisation energies, leading to the conclusion that Y is in Group 1 and the correct formula is YCl (A).
			Total	**1**	
3 3			**D**	**1**	**Examiner's Comments** As is often the case, candidates find structure and bonding difficult. Many candidates selected silicon (C) instead of the correct response of sulfur (D).
			Total	**1**	
3 4			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**

					ALLOW electron configuration ends in p **OR** the last electron is in a p orbital **ALLOW** valence electron(s) in p orbital/sub-shell **Examiner's Comments** 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**	
35			**Type of lattice 2 marks** • **SiO_2**: Giant (covalent lattice) ✓ • **CO_2**: Simple molecular/covalent (lattice) ✓ -------------------------------------- **Explanation 2 marks** **1. Forces in CO_2** • Induced dipole–dipole interactions / London forces ✓ **2. Comparison of forces with strength / melting point** • (Covalent) bonds in SiO_2 are stronger **THAN intermolecular** forces in CO_2 **OR** • More energy to break (covalent) bonds in SiO_2 **THAN intermolecular** forces in CO_2 ✓ **ORA**	4 AO1.1×2 AO1.1×1 AO2.1×1	**Throughout, IGNORE** 'ionic' for SiO_2 **FOR SiO_2, IGNORE** macromolecular **DO NOT ALLOW** giant **metallic** Mark explanation independently on type of lattice i.e. no **ECF** from incorrect lattice For CO_2 **IGNORE** • covalent bonds • van der Waals' forces • idid • LDF **DO NOT ALLOW** hydrogen bonds **OR** permanent dipole interactions For SiO_2, comparison needs just 'bonds' **OR** 'forces' For intermolecular, **ALLOW** 'between molecules' For comparison, **ALLOW** strong in SiO_2 **AND** weak in CO_2

					DO NOT ALLOW responses containing intermolecular forces in SiO_2 **IGNORE** 'More bonds' **<u>Examiner's Comments</u>** A good understanding of structure and bonding continues to be difficult for candidates, demonstrated by many explanations seen for the different melting points. Most candidates obtained two relatively easy marks for identifying the giant and simple molecular/covalent structures of SiO_2 and CO_2 respectively. 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**	
36			A	1 (AO 1.1)	
			Total	**1**	
37			**D**	1 (AO1.1)	
			Total	**1**	
38			s-block **AND** highest energy **or** outer **electron** is in a s orbital **or** s sub–shell ✓	1 (AO 1.1)	**ALLOW** 'outer' or 'valence' for 'highest energy' **IGNORE** electron configurations **DO NOT ALLOW** s shell / energy level **<u>Examiner's Comments</u>** Many candidates knew the block magnesium belonged but only very few could explain this was because

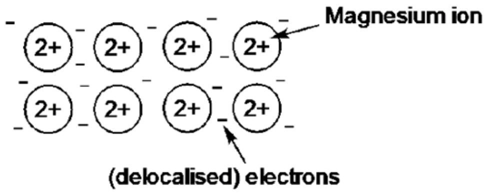
					magnesium's highest energy electron was in a s sub-shell or s orbital.
			Total	**1**	
3 9			**Bonding and structure**  **Metallic bonding diagram** Regular arrangement of **labelled** + ions ✓ scattering of **labelled** electrons **between** other species ✓ **Properties linked to explanation** metallic bond or attraction between the electrons and the positive ions/cations ✓ bonds are strong/require a lot of energy to break **AND** high melting point ✓ Delocalised electrons move **AND** good conductivity ✓	5 (AO1.1×3) (AO2.1×2)	**Diagram must have at least two rows and a minimum of two ions per row (allow Sr^+ or Sr^{2+})** **ALLOW** for labels: + ions, positive ions, cations **ALLOW** e^- **OR** e as label for electron **DO NOT ALLOW** intermolecular forces **ALLOW** mobile electrons **<u>Examiner's Comments</u>** 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. **Exemplar 1** 

					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. **Exemplar 2**  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**	
40	a		Ca: metallic bonding **OR** giant metallic lattice ✓ Br2: simple molecular **OR** simple covalent ✓ Induced dipole(–dipole) forces/interactions **OR** London forces ✓ **Conductivity linked to mobile electrons** In Ca electrons are mobile **OR** electrons are delocalised **OR** electrons can move **AND** in Br_2 charge carriers/electrons are not mobile ✓ **Melting point linked to bond strengths** Metallic bonds are strong **AND** London forces are weak **OR** Metallic bonds need a large amount of energy to break **AND** London forces need little energy to break ✓	5 (AO1.1×2) (AO2.1×1) (AO3.2×2)	**ALLOW** Metallic structure **DO NOT ALLOW** reference to molecules or intermolecular forces for calcium **ALLOW** 'are molecules' **IGNORE** • permanent dipole(–dipole) forces • IDID and LDF • van der Waals **DO NOT ALLOW** 'free electrons' for mobile electrons **ALLOW** comparison, e.g. • Metallic bonds are stronger than London forces **OR** • Metallic bonds need more energy to break than London forces ✓

					ALLOW intermolecular forces instead of London forces for this mark **<u>Examiner's Comments</u>** 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. 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. **AfL** 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 intermolecular forces their specific names should be used.
	b	i	 Ca shown with either 8 or 0 electrons **AND** Br shown with 8 electrons with 7 crosses and 1 dot (or vice versa) ✓ Correct charges on both ions ✓	2 (AO1.2×1) (AO2.5×1)	**ALLOW** separate Br– ions, i.e.  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. **IGNORE** inner shells Circles or brackets not required

					Examiner's Comments 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** Ba has a **greater** atomic radius than Ca **OR** Ba has **more** shells **OR** Ba has **more** shielding ✓ **Attraction** Nuclear attraction is less in Ba **OR** (outer) electrons in Ba are less attracted (to nucleus) **OR** Increased distance / shielding in Ba outweighs increased nuclear charge ✓ **Ionisation energy** Ionisation energy of Ba is less **OR** (outer) electrons in Ba are less attracted (to nucleus) **OR** easier to remove (outer) electrons in Ba ✓	3 (AO1.1×1) (AO2.3×2)	Comparison required throughout **ORA** throughout For **more** shells, **ALLOW** higher energy level **IGNORE** more orbitals **OR** more sub-shells **IGNORE** 'different shell' or 'new shell' **ALLOW** Ba has less nuclear pull' **OR** 'Ba electrons are less tightly held' **IGNORE** less effective nuclear charge' **IGNORE** 'nuclear charge' for 'nuclear attraction' **ALLOW** easier to oxidise Ba **Examiner's Comments** 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**	
41			*Refer to marking instructions on page 5 of mark scheme for guidance on marking this question.* **Level 3 (5–6 marks)** Explains all three melting point values and conductivities in terms of structure, bonding, particles and relative strengths of the forces.	6 (AO 1.1×3) (AO 2.1×3)	**Indicative scientific points may include:** **Structure and bonding** **Magnesium** • Structure: giant lattice • Metallic bonding • **Delocalised** electrons

			There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated. **Level 2 (3–4 marks)** 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. **OR** Correctly explains two of the melting point values and conductivities in terms of the structure, bonding, particles. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Identifies only some of the structures, forces and particles **AND** Attempts to explain the melting point values **OR** conductivities in terms of the structure, bonding, particles *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*		**Bromine** • Structure: simple molecular • induced dipole dipole forces (London forces) • (Between) molecules **DO NOT ALLOW** (between) atoms **Magnesium bromide** • Structure: giant lattice • Ionic bonding • (Between) oppositely charged ions **Comparison of bond strengths** • Metallic and ionic bonds are stronger than London forces **OR** Metallic and Ionic bonds need more energy to break than London forces **Conductivity** • Magnesium: conducts due to delocalised electrons can move/mobile. **IGNORE** 'Carry' charge for movement • Magnesium bromide: In solid IONS cannot move; in solution IONS can move. **DO NOT ALLOW** electrons. • Bromine: Does not conduct as no mobile charge carriers.
			Total	**6**	
42			C	1 AO1.2	
			Total	**1**	
43	a	i	d-block ✓	1 (AO1.1)	
		ii	$1s^22s^22p^63s^23p^63d^{10}4s^24p^1$ ✓ *Look carefully at $1s^22s^22p^63s^23p^6$– there may be a mistake*	1 (AO1.2)	**ALLOW** 4s **AND/OR** $4p^1$ before 3d, e.g. $1s^22s^22p^63s^23p^64s^23d^{10}4p^1$ **ALLOW** $1s^2$ after answer prompt (*ie* $1s^2$

					twice)**ALLOW** upper case D, etc and subscripts, e.g. ……$4S_23D_8$ **DO NOT ALLOW** [Ar] as shorthand for $1s^22s^22p^63s^23p^6$
	b		Element **A** is silicon/Si ✓ **AND** A large increase between the 4[rd] and 5[th] IE 5[th] electron is removed from shell closer to the nucleus **OR** there are 4 electrons in the outer shell ✓	2 (AO3.1) (AO3.2)	**ALLOW** an indication of a different shell (from removal of 5[th] electron)
			Total	**4**	
44			A	1 (AO1.1)	
			Total	**1**	
45	a		 Diagram with regular arrangement of **labelled** ‘**Mg^{2+}** ions’ **OR** ‘**2+** ions’ **AND** attempt to show electrons ✓ **Labelled** electrons between other species **AND** statement anywhere of **delocalised** electrons (can be in text or in diagram) Electrons move ✓	3	Regular arrangement must have at least two rows of correctly charged ions and a minimum of two ions per row **ALLOW** as label: +2 ions **OR** + 2 cations **OR** +2/2+ seen within circle **ALLOW** e^- or ‘e’ as a **label** for electron **IGNORE** “–“ for electron label **ALLOW** mobile/flow for move **IGNORE** ‘carry charge’
	b	i	$Mg^{3+}(g) \rightarrow Mg^{4+}(g) + e^-$ ✓	1 (AO1.2)	State symbols required (ignore states on electrons) **ALLOW** $Mg^{3+}(g) - e^- \rightarrow Mg^{4+}(g)$ **ALLOW** Mg^{+3} (g) **ALLOW** e for e^-
		ii	Big jump/larger difference between 2 and 3 ✓	1 (AO1.2)	**IGNORE** big jump between 10 and 11 **DO NOT ALLOW** other combinations.
		iii	1st **AND** 3rd **AND** 4th **AND** 5th **AND** 9th **AND** 11th ✓ i.e. 1 2 3 4 5 6 7 8 9 10 11 12	1 (AO2.1)	

			[✓][ ][✓][✓][✓][ ][ ][ ][✓][ ][✓][ ]		
			Total	**6**	
4 6		i	Sr + $2H_2O \rightarrow Sr(OH)_2 + H_2$ All formulae and balancing correct ✓	1 (AO2.6)	**IGNORE STATE SYMBOLS** **ALLOW** multiples **IGNORE** state symbols (even if wrong) **<u>Examiner's Comments</u>** Around half of all candidates did not score this mark. The most common error was giving SrO as the product rather than the hydroxide. Other errors included incorrect balancing (missing 2 on H_2O, SrOH as the formula of the hydroxide and no hydrogen formed (often giving H_2O instead)). **Assessment for learning** Regular practice writing formulae and balancing chemical equations will help to consolidate these concepts, avoiding basic errors such as giving formula of group 2 hydroxide as SrOH.
		ii	**Oxidation** Sr from **0** to **+2** ✓ **Reduction** H from **+1** to **0** ✓	2 (AO 2.1 × 2)	**ALLOW** 2+ for +2 and 1+ for +1 '+' is required in +2 and +1 oxidation numbers **ALLOW** H_2 for hydrogen **ALLOW** 1 mark for elements **AND** all oxidation numbers correct but oxidation and reduction wrong way round **OR** not given. **IGNORE** numbers around equation in **(i)** *(treat as rough working)*

					Examiner's Comments Most candidates managed to score at least 1 mark for this question. The most common reason for losing a mark, despite demonstrating a good understanding of redox, was stating that H changed from +2 to 0 (need to give oxidation number per atom). Other errors seen included only giving change for Sr, descriptions in terms of electrons rather than oxidation numbers, Sr change from 0 to +1 (linked to SrOH), oxygen being reduced rather than H and mixing up oxidation/reduction or not specifying.
		iii	*Atomic radius* Ca has smaller atomic radius **OR** fewer shells ✓ *Effect of nuclear charge/shielding* Ca has **less/decreased** shielding ✓ *Nuclear attraction* Ca has greater nuclear attraction (for electrons) **OR** Ca has a higher ionisation energy **OR** more energy is required to lose the outer electrons✓	3 (AO 1.2) (AO 1.2) (AO 1.2)	**FULL ANNOTATIONS MUST BE USED** -- **ORA in terms of Sr** **Comparison** needed for each mark. **ALLOW** 'fewer energy levels' **ALLOW** 'electrons closer to nucleus' **IGNORE** fewer orbitals **OR** fewer sub-shells **OR** different shell **ALLOW more** electron repulsion from inner shells **IGNORE** nuclear charge/effective nuclear charge **ALLOW** 'less nuclear pull' **OR** 'electrons held less tightly' **Examiner's Comments** Most candidates gained some marks here although a significant proportion were unable to score all 3 marks covering atomic radius, shielding, nuclear attraction/IE. The mark most often missed was for shielding. Some candidates did not answer the

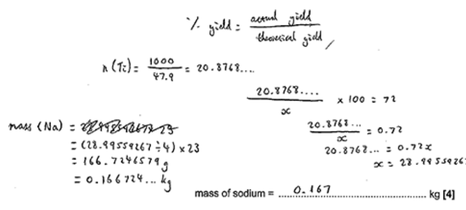
					question asked and gave the trend down the group so could not be given marks unless they made it clear Sr is below Ca in the group. Care must be taken to answer question asked not similar questions they have seen before. The best responses were those with direct comparative statements, e.g. "Ca has a smaller atomic radius than Sr". It is worth noting that harder/easier to lose electrons didn't gain marks, but was seen fairly frequently, as response needs to be in terms of energy required or linked to nuclear attraction.
			Total	**6**	
47	a		 All points show a **general** increase from B (i.e ignore O) **AND** Ne lower than He ✓ O lower than N **AND** O is higher than C **AND** F higher than O✓	2 (AO1.1) (AO1.2)	**<u>Examiner's Comments</u>** Few candidates scored full marks here, with some candidates not increasing the 1st IE across the period, and many getting the dip for the wrong element (not O) and finishing too high with Ne. Less successful candidates had clearly confused it with MP trend across the period.
	b		8.3×10^{-22} (kJ) ✓ From $\frac{500}{6.02 \times 10^{23}}$ Answer **MUST** be to 2 SF **AND** in standard form.	1 (AO2.2)	**ALLOW** use of IEs close to 500 giving a range: *8.3* × 10^{-22} *(from 500)* *to 9.1* × 10^{-22} *(from 550)* **<u>Examiner's Comments</u>** This question proved demanding for candidates, with many simply quoting a molar value taken from the graph and converting into standard form. Of those who recognised the need to use the Avogadro constant, a few tried to multiply it by the molar ionisation enthalpy. For those who worked out the correct answer, several lost marks due to the requirement of 2 significant figures.

	c		**Explanation for He** *Distance/shielding* (Outer) electrons are in a lower energy/closer shell/smaller atomic radius/fewer shells ✓ **Explanation for Be** *Nuclear charge* number of protons/proton number increases **OR** greater **nuclear** charge ✓ *Distance/shielding* (Outer) electrons are in the same shell **OR** sub-shell **OR** (Outer) electrons experience the same/similar shielding **OR** Atomic radius decreases ✓ **For either Be or He** *Attraction* **Greater** nuclear attraction (on outer electrons) **OR** (outer) electrons attracted more strongly to the nucleus ✓	4(AO1.1 AO1.1 AO1.2 AO1.2)	FULL ANNOTATIONS WITH TICKS, CROSSES, CON, etc MUST BE USED **ORA** throughout Comparison needed for each mark **ALLOW** change of **shell** (i.e **2**s and **1**s) **IGNORE** 'different sub-shell' **IGNORE** atomic number increases **IGNORE** nucleus gets bigger **IGNORE** 'effective nuclear charge increases' **ALLOW** same orbital **IGNORE** 'there is shielding' **ALLOW** 'greater repulsion from inner shells' **IGNORE** just 'greater attraction' **OR** greater force **IGNORE** 'pull' for 'attraction' **IGNORE** 'held' for attracted, *e.g. IGNORE 'held more strongly* **Examiner's Comments** Some very wordy responses to this straightforward question were seen, with many candidates going onto the extra pages. Candidates are reminded that keeping responses concise and to the point can make their answer clearer and potentially avoid contradicting themselves in the process. There were a good number of excellent answers seen, although many candidates were distracted by arguments about the stability of full shells or subshells rather than explaining why nuclear attraction would be greater. Some students mixed up the explanation for Be/Li with the

					difference in ionisation energies between groups 5 and 6 (electron pair repulsion).
	d		***Sub-shells*** Be electron is in (2)s **AND** B electron is in (2)p ✓ ***Energy levels*** B / (2)p is higher **energy** (level) **OR** Be / (2)s is lower **energy** (level) ✓	2(AO1.2×2)	**IGNORE** number before s and p **DO NOT ALLOW** "shell" **IGNORE** block **DO NOT ALLOW** unpaired electron removed more easily (**ORA**) **IGNORE** 'less energy to remove' **IGNORE** comments about distance from nucleus **IGNORE** 2s shielding **Examiner's Comments** Many candidates did not achieve full marks as they did not discriminate between the three different comparisons that were being tested in Question 18 (c) and 18 (d). Few candidates did identify the electron being in the s or p but then explained the ionisation energy in terms of full subshells, electron pair repulsion and described the 2s sub-shell as closer to the nucleus rather than as lower energy.
			Total	**9**	
48			**B**	1(AO1.1)	**Examiner's Comments** Most candidates selected B (silicon) as the correct response. A and C featured more than D as theincorrect choice but there seemed to be no pattern.
			Total	**1**	
49			**D**	1(AO1.2)	**ALLOW** Ar **Examiner's Comments** Candidates found this question difficult. Although argon looked to be the obvious choice, many candidates selected phosphorus (B) or chlorine (C). Candidate annotations alongside the question included atomic number and electron configurations suggesting that many find it

					difficult to link trends in melting point to the correct chemical concepts.
			Total	**1**	
5 0			**B**	1(AO2.1)	**Examiner's Comments** Although two steps were required to solve this problem, most candidates answered this question correctly. Candidate annotations showed that many identified element X as being in Group 2 and even as magnesium. The correct formula of XCl_2 (B) then usually followed.
			Total	**1**	
5 1			**Structure** Giant ✓ **Bonding** Metallic (bonding) ✓ **Particles** **2+ /Ca^{2+}**ions and delocalised electrons ✓ **Conductivity** (Delocalised) electrons **move**/flow ✓ ***Idea of movement required*** ***Delocalised can be seen anywhere***	4 (AO1.1 ×4)	**ALLOW** marks from labelled diagram **'Giant metallic'** gains **BOTH** structure and bonding marks **ALLOW** attraction between cations and electrons Attraction between nucleus and electrons is **CON** **Watch for 'metallic' being CONNed within overall response** **ALLOW** charge flows **ONLY** when linked to electrons **IGNORE** electrons carry charge **IGNORE** electrons are free **BUT ALLOW mobile electrons** carry charge **Examiner's Comments** Many candidates answered this question well, with most identifying the model of metallic bonding as fixed positive ions and mobile delocalised electrons. The question did ask for bonding and structure and the **giant** feature of the structure was often omitted. Unfortunately, some candidates contradicted a correct metallic bonding statement by including descriptors of intermolecular forces, covalent bonding or attraction between electrons and the

					nucleus rather than with positive ions. Less successful responses demonstrated less understanding: some didn't realise that Ca is a metal and conductivity explanations were often given as ions moving in the molten and not in the solid state, clear confusion with ionic bonding. Full marks were only given for showing the correct charges on the Ca^{2+} cations (+ was insufficient) and for explaining conductivity in terms of electron movement, rather than the common 'the electrons carry charge' and 'the electrons are free'.Overall, this relatively simple question discriminated very well and demonstrated how well the candidates understood metal bonding and structure.
			Total	**4**	
5 2		i	Titanium (IV) oxide ✓	1 (AO2.5)	**DO NOT ALLOW** titanium dioxide **<u>Examiner's Comments</u>** Very few candidates gave the correct answer for this question. The most common errors included: titanium oxide, titanium(IV) **di**oxide, titanium oxide(IV), titanium(II) oxide. A few also attempted to give names like those for organic compounds: 1,1-titanium dioxide or the reverse 1,1-dioxytitanium. **How Science Works** It is important in Chemistry to have clear communication by use of systematic and unambiguous nomenclature. This includes the use of Roman numerals to indicate the magnitude of the oxidation number when an element, such as Ti, may have different oxidation numbers in different compounds. See specification statement 2.1.5(c) and HSW8.
		ii	**FIRST CHECK ANSWER ON ANSWER LINE** **If answer = 2.67 kg award 4 marks** --- $n(\text{Ti}) = \frac{1000}{47.9}$ **OR** 20.8768… (mol) ✓	4 (AO2.2 × 4)	**ALLOW ECF** throughout **TAKE CARE: values shown may be truncated calculator values.** Steps can be calculated in any order which will change the intermediate answers**.**

			n(Na) for 72% yield = 20.88 × 4 **OR** 83.5073… (mol) ✓ n(Na) for 100% yield = 83.51 × $\frac{100}{72}$ **OR** 115.98237… (mol) ✓ mass Na = 115.98 x 23.0 = 2667.659… (g) = 2.67 (kg) ✓ **3 SF AND kg required**		Marks are for the processing of the data. **ALLOW 3SF** up to calculated value throughout **IGNORE** rounding errors past **3SF** **Common Errors for 3 marks:** 1.92 (missing yield) 1.38 (yield wrong way round) 0.673 (use of Mr 189.9 for $TiCl_4$ instead 47.9 for Ti) **<u>Examiner's Comments</u>** Candidates found this calculation quite challenging, with less than a quarter achieving full marks. The most common errors are highlighted on the mark scheme. Many that struggled were often given credit for the x4 ratio mark but only if it was possible to see this in the working. Many gave multiple, often contradictory attempts at the calculation. It was not always clear how the final answer had been obtained. Clear working enables us to follow the logic and give ECF where appropriate. Many divided 1000 g by the molar mass for $TiCl_4$ and then found 72% of this. It was important here to read the question carefully to ensure complete understanding. Exemplar 1  This candidate achieved 3 out of the 4 possible marks. The steps in their calculation are logical and it is easy to follow their working and therefore spot the error in their calculation. They have divided by 4 rather than multiplying. It also shows

					the calculation can be performed in a different order to that on the mark scheme. All intermediate values are used in calculations as calculator values without rounding to ensure an accurate answer.
		iii	Add water **AND** filter ✓ Ti does not dissolve **OR** NaCl does dissolve ✓	2 (AO 3.3 × 2)	**ALLOW** dissolve **in water** **ALLOW** Ti is insoluble **OR** NaCl is soluble/aqueous **ALLOW** Ti is the residue **OR** NaCl is the filtrate **Examiner's Comments** Most candidates did not gain any credit here. However, the range of responses seen highlighted some misconceptions in their understanding of how different mixtures can be separated. Many assumed that sodium chloride was in solution/aqueous, not recognising that water was not present in this reaction. Responses such as "sodium chloride will evaporate" or "remove the water" were seen. Some gave a description of the purification method for an organic liquid - the use of a separating funnel and/or distillation were common. Some suggested the use of a magnet to remove Ti despite it being a non-magnetic metal. **Misconception** Understanding how to separate mixtures is covered in both KS3 and KS4 but it is important that these concepts can be applied during further study. Asking this type of problem solving question would make a good starter activity. Some useful activities for separating mixtures can be found in the GCSE Chemistry B (Twenty First Century Science) Chemical analysis transition guide

<table>
<tr><th></th><th></th><th></th><th>Total</th><th>7</th><th></th></tr>
<tr><td>53</td><td></td><td>i</td><td>
<table>
<tr><td>Substance</td><td>Magnesium sulfide</td><td>Aluminium</td><td>Silicon</td><td>Phosphorus trichloride</td></tr>
<tr><td>Melting point / °C</td><td>2000</td><td>660</td><td>1414</td><td>–94</td></tr>
<tr><td>Electrical conductivity</td><td></td><td>Good</td><td>Poor</td><td></td></tr>
<tr><td>Type of lattice structure</td><td>Giant Ionic</td><td>Giant Metallic</td><td>Giant Covalent</td><td>Simple Molecular</td></tr>
</table>
✓ ✓ ✓ ✓</td><td>4
(AO 1.1 × 2)
(AO 2.1 × 2)</td><td>ALLOW Simple covalent instead of simple molecular

<u>Examiner's Comments</u>

About half the candidates gained all 4 marks. Candidates often find it tricky to recognise the type of structure even when given some details about physical properties. Often giant was omitted especially for Al as metallic bonding. Some used 'small' in place of 'simple'. Common errors included MgS as metallic and Si as simple covalent with PCl_3 as giant covalent. Many added unnecessary detail such as filling in the greyed-out boxes for conductivity or adding lattice to each box.</td></tr>
<tr><td></td><td></td><td>ii</td><td>Melting points

MgS: ionic bonds (between oppositely charged ions) ✓

PCl3: intermolecular forces ✓

More energy needed (to separate ions in MgS)
OR
<u>Strong</u> ionic bonds AND <u>weak</u> intermolecular forces✓

Conductivity

Al: mobile/delocalised electrons
AND
Si: no mobile/delocalised electrons OR no charge carriers OR no mobile ions</td><td>4
(AO 1.1)
(AO 2.1)
(AO 3.1 × 2)</td><td>ALLOW London forces or permanent dipole dipole interactions

ORA answer must be comparative

ALLOW ECF from incorrect type of bonding i.e. stronger attraction/more energy

IGNORE 'free electrons' for mobile/delocalised electrons

<u>Examiner's Comments</u>

Candidate explanations often lacked clarity even if the correct structure had been identified in (i). Most gained at least 1 mark, usually for recognising that for MgS to have a higher melting point that it must contain stronger bonds than in PCl_3. Responses highlighted a range of misconceptions including the presence of intermolecular forces in ionic/metallic substances, oppositely charged atoms in ionic compounds, and thinking London forces are between atoms. Most were able to gain the conductivity mark, but some compared to PCl_3 rather than Si as asked</td></tr>
</table>

					in the question. Some described 'mobile ions' in Al or that Si has 'no electrons'. The use of 'free electrons' was seen in many responses, and we would encourage the use of 'delocalised electrons' for a more accurate description of metallic bonding. **OCR support** OCR have produced a KS4-KS5 transition guide for bonding and structure to support teaching of these tricky concepts. A bonding delivery guide is also available. **Assessment for learning** Checking understanding of different types of bonding and structure plus links to their physical properties is very important. OCR have produced a range of multiple choice question quizzes that can be used to help check understanding - these are available as digital versions as well, enabling you to view responses. Guidance is given on how to use the digital versions on the OCR website. A useful multiple-choice quiz to use here is on electrons, bonding and structure..
			Total	**8**	
54			**C**	1 (AO 2.1)	**Examiner's Comments** Most candidate chose the correct response of C. From the annotations on the scripts, most candidates identified the largest jump between the 3rd and 4th ionisation energies. Option D proved to be the main distractor. Having identified the correct large jump, a significant number of candidates chose the group at the end of the jump (Group 4) rather than the group at

					the start of the jump (Group 3). This suggests a misconception.
			Total	**1**	
5 5			**A**	1 (AO 1.2)	ALLOW Li **Examiner's Comments** The correct answer was A. This question proved to be challenging, with the common incorrect answer being C.
			Total	**1**	
5 6			**Ist IE of Mg and Sr** (Mg) removes electron from shell closer to the nucleus / smaller **atomic** radius ✓✓ Greater nuclear **attraction** (between atom and outer electron) ✓ **2nd/1st IE of Sr** 2nd electron removed from cation/positively charged **ion** **OR** proton:electron ratio (in (1)+ ion) is great**er** (than in atom) ✓ Greater nuclear **attraction** / **attraction** between ion (and outer electron)✓	4 (AO 1.1) (AO 1.2) (AO 1.1) (AO 1.2)	**ORA** throughout **ALLOW** going down the group for comparison of Mg/Sr Assume 'it' means Mg **ALLOW** (Mg) fewer shells **ALLOW** less shielding **ALLOW** removal of electron from 3s rather than 5s **ALLOW** Greater attraction between nucleus (and outer electron) **ALLOW** Sr^+ **ion** smaller (than Sr atom) **ALLOW same** number of protons/nuclear charge **attracting** one fewer electron **IGNORE** repulsion between electrons in the s orbital **IGNORE** shielding **Examiner's Comments** Most candidates were able to explain why the first ionisation energy of Mg is greater than that of Sr due to the Mg's smaller atomic radius/less shielding and therefore increased nuclear attraction. Candidates should be reminded that there is no

					requirement to restate the question in their answers. Terminology is important and some candidates lost marks as they referred to nuclear radius instead of atomic radius. However, most candidates did not recognise that the second ionisation energy of Sr involves removing an electron from a +1 ion and instead discussed the repulsion between electrons in the s orbital. Atomic radius instead of ionic radius was often seen when discussing the Sr^+ ion. Some candidates were still referring to Mg in this part of their answer and they should be advised to reread the question between each part to remain focused on the requirement.
			Total	**4**	
57	a		O ✓	1 (AO 2.1)	**ALLOW** S **BOD** **<u>Examiner's Comments</u>** Most successful candidates looked for the large difference between successive ionisation, usually shown by annotations below the table. The commonest incorrect response was F, the element after the large difference. Other incorrect responses were random.
	b		P **OR** S ✓	1 (AO 1.1)	**ALLOW** S_8, P_4 **ALLOW** As, Se **<u>Examiner's Comments</u>** Candidates found this question harder than Questions 1 (a) and (b) with S and P being the most common correct elements seen. As and Se were also allowed. Si was a common incorrect response.
	c		Si ✓	1 (AO 1.1)	**<u>Examiner's Comments</u>** Most candidates correctly chose Si. As with earlier questions, there seemed to be little pattern with incorrect elements.
			Total	**3**	

58	a	i	Be: $1s^22s^2$ F: $1s^22s^22p^5$ ✓ Mg: $1s^22s^22p^63s^2$ C*l*: $1s^22s^22p^63s^23p^5$ ✓ Block: s p ✓	3	**1 mark** per correct row **ALLOW** upper case letter S and P, and subscripts, e.g. $2S_22P_5$ **IGNORE** superscripts/numbers given on block (e.g. s^2 and p^5) if the letter is clear **<u>Examiner's Comments</u>** A very well answered question with most candidates very confident in giving the correct electron configurations and blocks. Errors were rare but included: $2p^5$ or $3p^6$ ending for Cl; using mass number for number of electrons; and assigning group 17 as d block and giving orbital box diagrams rather than block.
		ii	Across period 2, the (2)s subshell fills first, followed by the (2)p ✓ **same pattern or trend** of filling (the subshells) repeated in other periods ✓	2	**ALLOW** Elements in the same group have same number of electrons in their outer shells or subshell e.g. s^2 in group 2/ s^2p^5 in group 17(7) **ALLOW** Elements in the same period have the same number of energy levels/shells **ALLOW** for both marks for indication that the pattern repeats across each period e.g Across each period, elements repeat the pattern of electrons filling the s-subshell then p-subshell ✓ ✓ **<u>Examiner's Comments</u>** Many found this question challenging despite doing well in Question 2(a)(i). The question states 'use your answers from (a)(i)' but not many candidates wrote about the electron configurations they had given. Many gave very simplistic responses in terms of the number of electrons increasing but made no reference to how those electrons are arranged (e.g. 'number of electrons increases across a period as the electron configuration gets higher' or 'atomic number increases'). Some candidates struggled with terminology, often referring to 'block' or 'orbital' instead of subshell (e.g. 'outer electrons are in same block', 'going across

					a period the number of orbitals increases', 'elements in same group have their highest energy electron in same block' or 'orbital'). Candidates need clarity on the terminology used for electron configurations and periodic table i.e. blocks, shells, sub-shells and orbitals. It was rare for candidates to score both marks as this was a question that they were unfamiliar with. However, some did gain a mark for linking the number of outer shell electrons to the group number or stating that elements in the same period have the same number of shells. It was not enough to refer to the highest energy electron being in the s-subshell or p-subshell as this is the link to the block, but all groups in same block will be the same. Some described the trend in other physical or chemical properties. Some examples included: 'Elements have same chemical and physical properties due to similar electronic configuration'; 'as you go across period, number of electrons increase and their boiling and melting points increase'; and 'electrons are more easily lost in a paired orbital, due to greater repulsion and so have lower ionisation energies'. **OCR support** We have produced a transition guide on the topic of atomic structure. It covers content from KS4 and how this is developed at KS5 with a wide range of suggested resources to support teaching. At KS4, candidates are expected to be able to explain how the position of an element in the Periodic Table is related to the arrangement of electrons in its atoms, with development at KS5 to arrangement in to s, p and d orbitals.

					https:/ocr.org.uk/Images/170375-atomic-structure-ks4-ks5.pdf
		iii	Mg loses (2) electrons **AND** Cl gains an electron ✓ To gain a full/complete shell **OR** Noble gas configuration **OR** Stable/full octet✓	2	**ALLOW** Mg is oxidised **AND** Cl is reduced **Examiner's Comments** Generally, this question was well answered with a clear understanding of how and why ions are formed. However, approximately a quarter of students only gained 1 mark as they either didn't explain electrons being lost by Mg and gained by Cl or gave no justification. A common slip was stating Cl has one electron in its outer shell. Some described bonding between Mg and Cl, which wasn't what the question asked, but this didn't prevent them from scoring both marks.
		iv	$2Mg + O_2 \rightarrow 2MgO$ ✓	1	**ALLOW** multiples e.g. $Mg + \frac{1}{2}O_2 \rightarrow MgO$ **IGNORE** state symbols even if wrong **Examiner's Comments** Many candidates correctly gave the balanced equation here. However, some didn't balance but had the correct formula. A few gave Mg_2 as a reactant or MgO_2 as a product. Some had O_2 on both sides of the equation.
	b	i	B is below Be but above Li (about 800 kJ mol^{-1}) ✓ Mg is above Na but below Be (about 700 kJ mol^{-1}) ✓	2	**DO NOT ALLOW** if on the line of 900 kJ mol^{-1}. It must be clear that IE for Mg is less than Be as below it in group 2 **Examiner's Comments** Approximately a quarter of candidates scored both marks here. Many candidates omitted to plot a point for Mg or positioned the point for Mg at 900 or above so higher than Be.
		ii	$B^{+}(g) \rightarrow B^{2+}(g) + e^{-}$	2	**ALLOW** $B^{+}(g) - e^{-} \rightarrow B^{2+}(g)$ for 2 marks

			Equation correct ✓ *Correct state symbols* ✓		The second mark is dependent upon the first mark except for the following close attempts: **ALLOW** one mark for the following for state symbols $B(g) \rightarrow B^{2+}(g) + 2e^-$ $B^+(g) + e^- \rightarrow B^{2+}(g) + 2e^-$ $B(g) \rightarrow B^+(g) + e^-$ **ALLOW** e for electron (i.e. charge omitted) **IGNORE** states on the electron **<u>Examiner's Comments</u>** More than half of candidates scored both marks here. Errors seen included missing or incorrect state symbols, especially (s), but also (aq) was seen. Some had electrons on the left hand side of the equation, i.e. '$B^+ + e^- \rightarrow Be^{2}+$'. Some included negatively charged ions and occasionally the wrong element was used, e.g. Mg or Be.
			Total	**12**	
5 9			**D**	1	**<u>Examiner's Comments</u>** The correct answer was D. Most candidates were able to select this response, but the common error was the selection of A. It is important that candidates can distinguish the difference between oxidation states and charge on the ions. Oxidation state is the measure of the number of electrons that an atom uses to bond with atoms of another element.
			Total	**1**	
6 0			**Level 3 (5–6 marks)** Describe the types of structure and bonding of all four elements **AND** explains most of the differences in melting points in terms of the relative strengths of the forces between the particles. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and*	6	**Indicative scientific points may include:** **ALLOW** minor omissions as we are looking for a holistic approach to LoR marking. **Al (Giant metallic)** • Giant metallic structure/lattice • Strong metallic bonding

			substantiated. **Level 2 (3–4 marks)** Attempt to describe the types of bonding of three elements **AND** explains most of the differences in melting points in terms of the relative strengths of the forces between the particles. **OR** Describe in detail and bonding of two of the three types of structure **AND** explains most of the differences in melting points in terms of the relative strengths of the forces between the particles. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Attempt to describe the bonding of two elements **AND** explains most of the differences in melting points in terms of the relative strengths of the forces between the particles. **OR** Describes in detail the bonding of one of the three types of structure **AND** explains the melting point in terms of the strength of the forces between the particles. *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear*. **0 mark** *No response or no response worthy of credit*.		• Electrostatic attraction between (positive) metal ions/cations and delocalised electrons • A lot of energy needed to break bonds **Si (Giant covalent)** • Each Si atom forms 4 bonds / bonds with 4 other Si atoms • Giant covalent structure/lattice • Strong covalent bonds between atoms • Between shared pair of electrons and adjacent nuclei. • Most energy needed to break bonds **P, S (Simple covalent)** • <u>Simple</u> covalent / molecular structure/lattice • Strong covalent bonds between atoms • Weak induced dipole-dipole interactions between molecules* • Least energy to overcome the forces • Melting point of S_8 > P_4 • More electrons • Stronger induced dipole-dipole interactions • **DO NOT ALLOW** breaks BONDS • **IGNORE** van der Waals' (VDW) ***ALLOW** London (dispersion) forces for induced dipole–dipole interactions. Aspects of the communication statement might typically not have been met when irrelevant information (e.g. ionisation energies, ionic radius etc) have been included. **<u>Examiner's Comments</u>**

					Structure and bonding continue to be a difficult concept for many candidates. High-attaining candidates were able to identify why the element had a certain magnitude of melting point. They clearly linked the structure type with the type of bonding. They then described, in detail, the nature of the bond. The strength of force required to break/overcome the bond/London Force was linked to the melting point. It was very common for 'giant' to be omitted in the name of the lattice, especially in Al. Candidates find it particularly challenging to associate the correct terminology with the correct structure, often describing intermolecular forces in giant covalent explanations or use of molecules in giant metallic explanations. London forces were mentioned widely but sometimes not described as being forces between molecules and not linked to the increased number of electrons. A holistic, rather than a point based, approach is used in marking these responses. This allowed Level 2 to be given when the candidate did not use all of the correct terminology throughout the three structure types. Several candidates described the varying melting point going across the period as being due to atoms having more electrons in the outer shell and a greater nuclear charge. **OCR support** Our bonding delivery guide provides details of common misconceptions students hold relating to this topic, and also includes resources and guidance that can help overcome them: Teach Cambridge (ocr.org.uk)
			Total	**6**	

6 1			**B**	1	**<u>Examiner's Comments</u>** This question did discriminate, but the correct option of B was missed by many candidates. D was the main distractor, despite the question assessing basic chemical facts. This multiple-choice question required candidates to choose the option that is not correct, and some candidates may not have read the question closely enough. It is recommended that candidates underline the word **not** in such MCQs to highlight what is required.
			Total	**1**	