9.1 PERIODICITY OF PHYSICAL PROPERTIES OF ELEMENTS IN PERIOD 3

Learning outcomes

Candidates should be able to:

1. describe qualitatively (and indicate the periodicity in) the variations in atomic radius, ionic radius, melting point and electrical conductivity of the elements
2. explain the variation in melting point and electrical conductivity in terms of the structure and bonding of the elements

Introduction

1. X and Y are atoms of different elements in Period 3 of the Periodic Table. Neither X nor Y is argon.
   X is a non-metal.
   X has a greater atomic radius than Y.
   Which statement is correct?

   A X has more occupied electron shells than Y.
   B X has more protons in each atom than Y.
   C X has the same number of outer electrons in each atom as Y.
   D Y is a non-metal.

Periodicity: the repeating patterns in the physical and chemical properties of the elements across the periods of the periodic table.

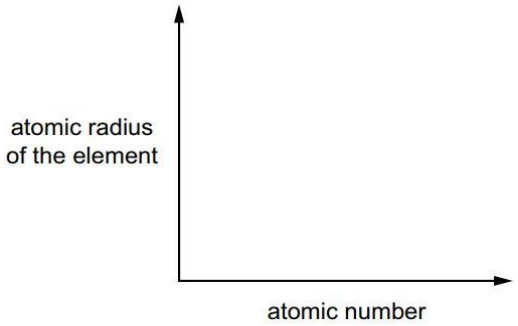
Periodic patterns of atomic radii

The atomic radius decreases across a period because the increasingly positive nuclear charge pulls the outer-shell electrons closer to the nucleus.

Period 3 element	Na	Mg	Al	Si	P	S	Cl	Ar
Atomic radius / nm	0.157	0.136	0.125	0.117	0.110	0.104	0.099	–

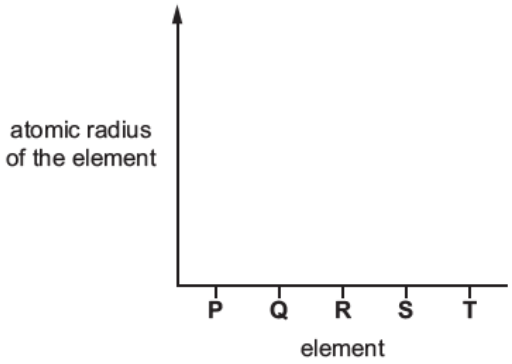
Student's activity: plotting the above data in a graph

1. (i) On the following sketch a graph to show the trend in the atomic radius of successive elements in Period 3.



(ii) Explain your answer to **(i)**. [3]

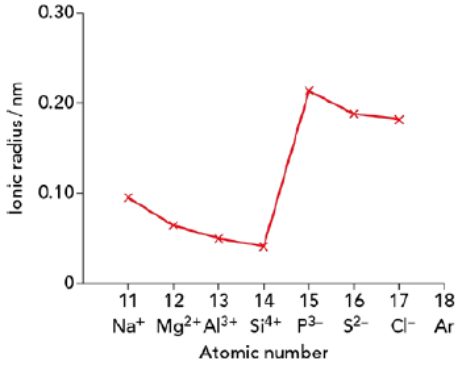
2. **P**–**T** are successive elements in Period 3 of the Periodic Table.
The letters are **not** the symbols of the elements.
On the axes, sketch a graph to show the trend in the atomic radius of the elements **P**–**T**.



Explain your answer. [3]

Periodic patterns of ionic radii

The ionic radius decreases across a period as the positive charge on the ion increases and the negative charge on the ion decreases. This is because the increasingly positive nuclear charge pulls the electrons in the outer shell closer to the nucleus. In the same period, the negative ions have larger ionic radii than the positive ions because they have one more electron shell, so the outer electrons are further from the nucleus and there is more shielding.



3. Explain the variation in anionic radius for the elements with atomic numbers 14 to 17. [2]

2. Which row describes the relative sizes of the ionic radii of Na^+, Mg^{2+} and S^{2-}?

	smallest →		largest
A	Na^+	Mg^{2+}	S^{2-}
B	Mg^{2+}	Na^+	S^{2-}
C	S^{2-}	Na^+	Mg^{2+}
D	S^{2-}	Mg^{2+}	Na^+

3. Which ion has the smallest radius?

A Al^{3+} **B** Ba^{2+} **C** Mg^{2+} **D** Na^+

4. Why is the ionic radius of a sulfide ion larger than the ionic radius of a potassium ion?

A Ionic radius always decreases with increasing atomic number.
B Positive ions always have smaller radii than negative ions.
C The potassium ion has more protons in its nucleus than the sulfide ion.
D The sulfide ion is doubly charged; the potassium ion is singly charged.

5. V and Z are both elements in Period 3 of the Periodic Table. Each element forms one stable ion that does not contain another element.
The atomic radius of each element and the ionic radius of the ion described above is shown.

ionic radius /nm	atomic radius /nm	element
0.095	0.186	V
0.181	0.099	Z

Which statement is correct?

A Ions of V and Z have the same number of full electron shells.
B Ions of Z are positively charged.
C Z has a greater electronegativity than V.
D V has more outer electrons than Z.

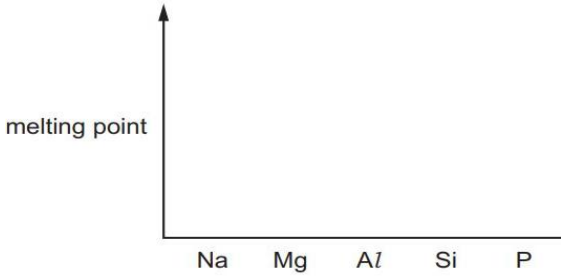
Periodic patterns of melting points and electrical conductivity

The change in melting point across a period reflects the type of structure and bonding. As we go across a period, the metals have increasingly strong metallic bonding and their melting points increase. In Period 2 and Period 3, the Group 14 elements have giant covalent structures so have very high melting points. In Groups 15 to 18, most of the elements have simple molecular structures so have relatively low melting points.

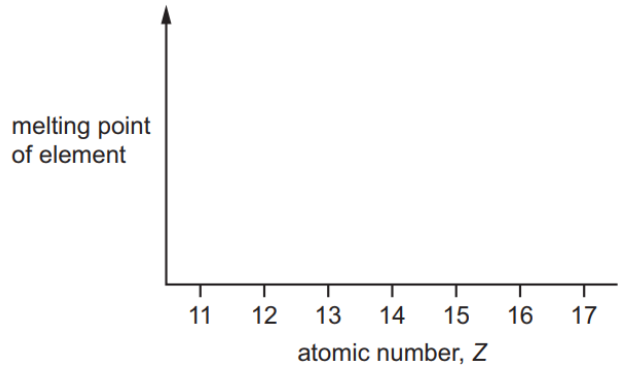
Period 3 element	sodium (Na)	magnesium (Mg)	aluminium (Al)	silicon (Si)	phosphorus (P)	sulfur (S)	chlorine (Cl)	argon (Ar)
Melting point / K	371	923	932	1683	317	392	172	84

4. The elements silicon, phosphorus and sulfur are in Period 3 of the Periodic Table.
The melting point of silicon is 1410°C. The melting point of sulfur is 113°C.
Explain this difference. [3]

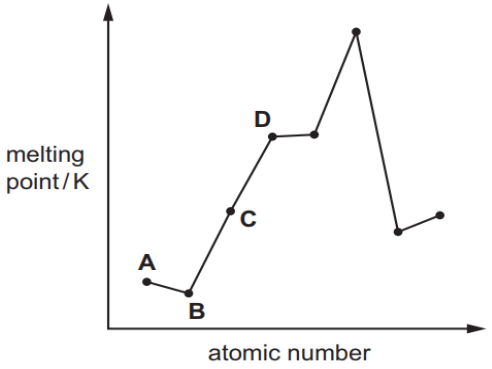
5. Period 3 elements and their compounds show trends in their physical properties.
On Fig. 2.1, sketch a graph to show the melting points of the first five elements in Period 3.



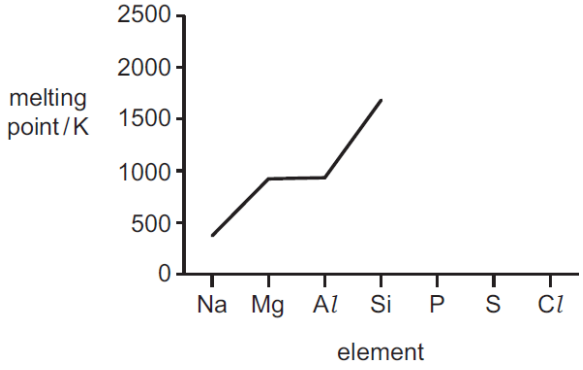
6. Use the axes to sketch a graph that shows the trend in melting points of the elements with atomic numbers 11 to 17.



7. The diagram shows the melting points of eight elements with consecutive atomic numbers.
Which element could be sodium?



8. Fig. 1.1 shows the variation in melting point of some Period 3 elements in their standard states at room temperature and pressure.



(i) Explain why Si has a high melting point. [1]

(ii) Complete Fig. 1.1 to show the variation in the melting points of the elements P, S and Cl. [2]

9. Some of the common chlorides of Period 3 elements are shown in the list.
NaCl $MgCl_2$ $AlCl_3$ $SiCl_4$ PCl_5
From this list, identify the chloride formed from the *element* with the highest melting point. [1]

6. The melting points of the Period 3 elements sodium to aluminium are shown in the table.

element	Na	Mg	Al
melting point / K	371	923	932

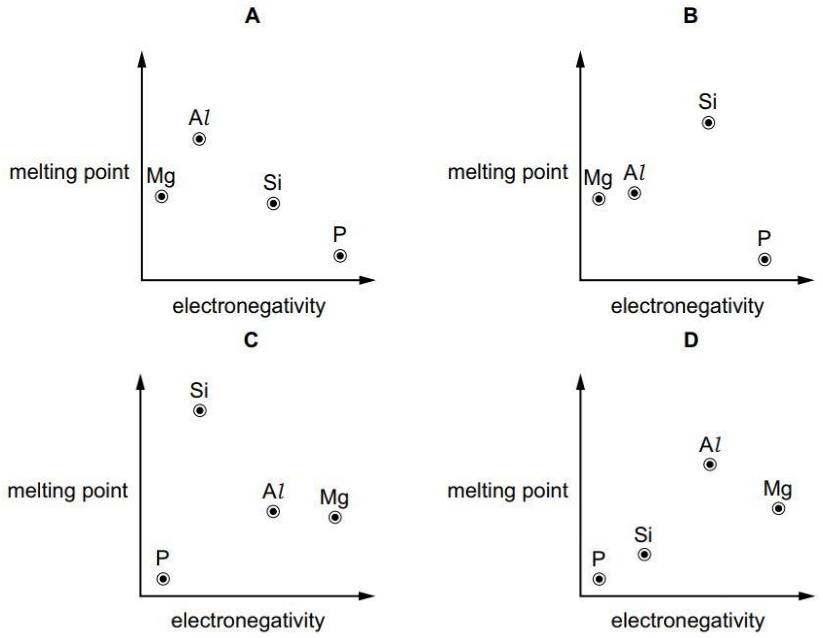
Which factor explains the increase in melting points from sodium to aluminium?

A the change in first ionisation energy from sodium to aluminium
B the increase in electronegativity from sodium to aluminium
C the increase in the Ar of the elements from sodium to aluminium
D the increase in the number of outer electrons in each atom from sodium to aluminium

7. Which row gives the best description of the variations in the melting points and the first ionisation energies of the elements in Period 3 from sodium to argon?

	melting points	first ionisation energies
A	increase up to a peak at aluminium then decrease	generally decrease
B	increase up to a peak at aluminium then decrease	generally increase
C	increase up to a peak at silicon then decrease	generally decrease
D	increase up to a peak at silicon then decrease	generally increase

8. Which graph correctly shows the relative melting points of the elements Mg, Al, Si and P plotted against their relative electronegativities?



Period 3 element	sodium (Na)	magnesium (Mg)	aluminium (Al)	silicon (Si)	phosphorus (P)	sulfur (S)	chlorine (Cl)	argon (Ar)
Electrical conductivity / S m^{-1}	0.218	0.224	0.382	2×10^{-10}	10^{-17}	10^{-23}	–	–

Period 3 element	sodium (Na)	magnesium (Mg)	aluminium (Al)	silicon (Si)	phosphorus (P)	sulfur (S)	chlorine (Cl)	argon (Ar)
Bonding	metallic	metallic	metallic	covalent	covalent	covalent	covalent	–
Structure	giant metallic	giant metallic	giant metallic	giant molecular	simple molecular	simple molecular	simple molecular	simple molecular

Property	Na	Mg	Al	Si	P	S	Cl	Ar
Formula of common ion	Na^+	Mg^{2+}	Al^{3+}	(Si^{4+})	P^{3-}	S^{2-}	Cl^-	
Atomic radius/nm	0.186	0.160	0.143	0.117	0.110	0.104	0.099	(0.188)
Ionic radius/nm	0.095	0.065	0.050	–	0.212	0.184	0.181	
Melting point/°C	98	649	660	1410	44	113	–101	–189
Electrical conductivity/S cm^{-1}	2.1×10^5	2.3×10^5	3.8×10^5	2.5×10^{-6}	1.0×10^{-11}	5.0×10^{-18}	0	0
First ionisation energy/kJ mol^{-1}	494	736	577	786	1060	1000	1260	1520
Electronegativity	0.9	1.2	1.5	1.8	2.1	2.5	3.0	–
Common oxidation state(s)	+1	+2	+3	+4	–3, +3, +5	–2, +4, +6	–1, +1, +5, +7	–

Students activity: Plotting the melting points and electrical conductivity against number of proton from above table.

9. Which statements describe a trend in Period 3 between every pair of adjacent elements from sodium to chlorine?

A The atomic radius decreases.
B The first ionisation energy decreases.
C The melting point decreases.
D The electrical conductivity increases.

10. L, M and N are three different elements from Period 3 of the Periodic Table.
L is the element whose atoms have three unpaired electrons in its 3p sub-shell.
M is the element with the highest electrical conductivity in the period.
N is the element with the highest melting point in the period.
Which statement about element L is correct?

A L has a higher atomic number than M and a lower atomic number than N.
B L has a lower atomic number than M and a higher atomic number than N.
C L has a lower atomic number than both M and N.
D L has a higher atomic number than both M and N.

11. Which row is correct?

	statement	Reason
A	The first ionisation energy of phosphorus is greater than that of magnesium.	An electron is lost from a 3p orbital in both cases
B	The melting point of phosphorus is greater than that of magnesium.	phosphorus has more valence electrons than magnesium
C	The atomic radius of phosphorus is smaller than that of magnesium.	phosphorus has a greater nuclear charge than magnesium
D	The electrical conductivity of phosphorus is smaller than that of magnesium.	bonding changes from ionic in magnesium to covalent in phosphorus

12. Which row about silicon, Si, and magnesium, Mg, and their ions is correct?

	comparison of silicon and magnesium	explanation
A	Si has a greater atomic radius than Mg.	Si has electrons in 3p orbitals. Mg has electrons in the 3s orbital only.
B	Si has a lower electrical conductivity than Mg.	Si has 4 delocalised electrons per atom. Mg only has 2 delocalised electrons per atom.
C	Si has a lower melting point than Mg.	Si has covalent bonding. Mg has metallic bonding.
D	The radius of Si^{4+} is smaller than the radius of Mg^{2+}	Si has a greater nuclear charge than Mg.

13. Which statement is correct?

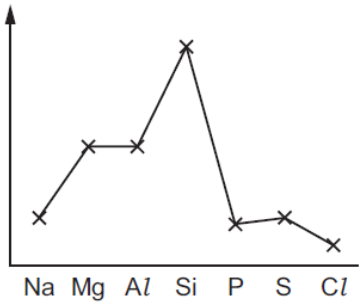
A The atomic radius of silicon is larger than that of aluminium.
B The boiling point of chlorine is higher than that of silicon.
C The first ionisation energy of sulfur is greater than that of phosphorus.
D The electrical conductivity of magnesium is greater than that of sodium.

14. Q, R and S are consecutive elements in Period 3 of the Periodic Table. Element R has the highest first ionisation energy and the lowest melting point of these three elements.
What are the identities of Q, R and S?

	Q	R	S
A	Na	Mg	Al
B	Mg	Al	Si
C	Al	Si	P
D	Si	P	S

15. The graphs show trends in four physical properties of elements in Period 3, excluding argon.
Which graph has electronegativity on the y-axis?

A



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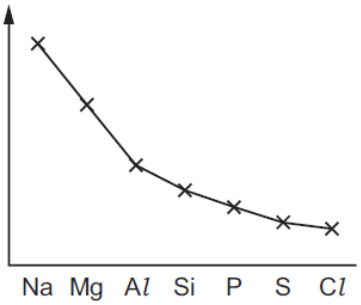

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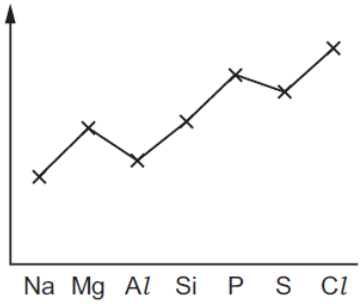

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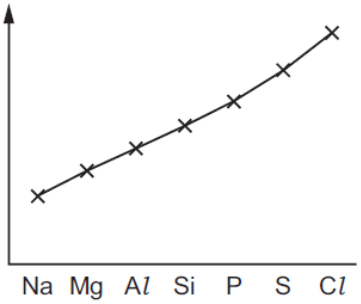

*****This is not a complete note. It is just to guide you. It is recommended to study prescribed textbooks along with this material. *****