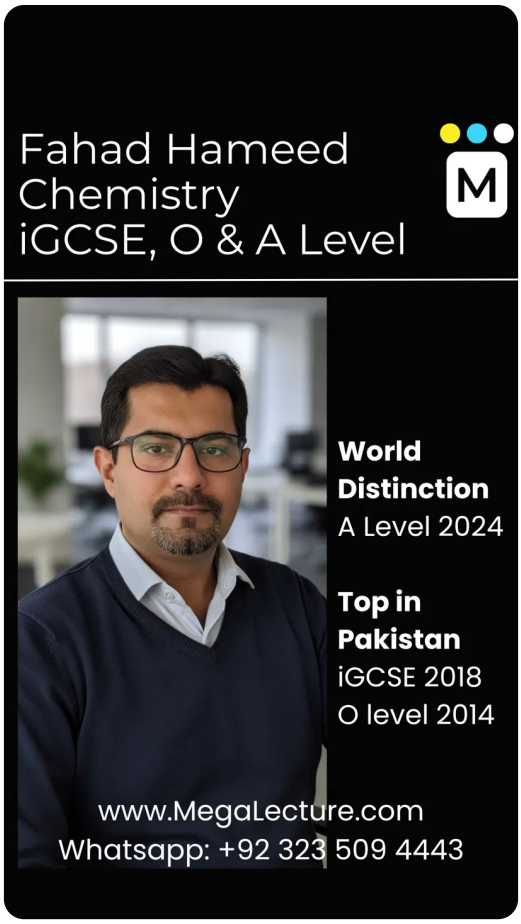
MEGA LECTURE · A LEVEL CHEMISTRY

Chapter 7: Periodicity

OCR A Level Chemistry A (H432) — Structured Practice Worksheet



SPECIFICATION	TOTAL MARKS	SUGGESTED TIME
3.1.1 Periodicity: classification, atomic radius, melting point & ionisation energy trends	84	2 hours

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Instructions to candidates

- Answer **all** questions in the spaces provided.
- Refer to Period 3 (Na to Ar) unless another period is specified.
- Marks are shown in brackets [ ] at the end of each part.
- You may use the periodic table on the OCR Data Sheet.

Question 1 — Classifying the periodic table

3.1.1

a. State the meaning of the term *periodicity*. **[2]**

b. Explain what is meant by describing the modern periodic table as arranged in order of *atomic (proton) number*. **[2]**

c. Classify sodium, silicon and sulfur as metal, metalloid or non-metal, and justify your classification of silicon in terms of its physical properties. **[3]**

d. State the block (s, p or d) to which each of the following elements belongs: potassium, chlorine, iron, calcium. **[2]**

Question 1 total: 9 marks

Question 2 — Atomic radius

3.1.1

a. Describe and explain the trend in atomic radius across Period 3, from sodium to argon. **[3]**

b. Describe and explain the trend in atomic radius down Group 1, from lithium to caesium. **[3]**

c. Explain why the ionic radius of Na^+ is smaller than the atomic radius of Na, but the ionic radius of Cl^- is larger than the atomic radius of Cl. **[3]**

d. Explain why Mg^{2+} has a smaller ionic radius than Na^+, even though both ions have the same electron configuration. **[2]**

Question 2 total: 11 marks

Question 3 — Melting points across Period 3

3.1.1

Approximate melting points (°C): Na = 98, Mg = 650, Al = 660, Si = 1410, P_4 = 44, S_8 = 115, Cl_2 = −101, Ar = −189.

a. Explain why the melting point rises steadily from Na to Al. **[3]**

b. Explain why silicon has by far the highest melting point of any Period 3 element. **[4]**

c.

Explain the sharp drop in melting point between silicon and phosphorus. **[3]**

d. Explain why sulfur (S_8) has a higher melting point than phosphorus (P_4), even though both are simple molecular substances held together by van der Waals forces. **[3]**

e. Explain why argon has the lowest melting point of all the Period 3 elements. **[2]**

Question 3 total: 15 marks

Question 4 — Structure and bonding summary 3.1.1

a. Complete the table for the elements of Period 3. **[8]**

Element	Structure type	Bonding
Na, Mg, Al		
Si		
P_4, S_8, Cl_2		
Ar		

Question 4 total: 8 marks

Question 5 — First ionisation energy trends 3.1.1

a. Define *first ionisation energy* and give the equation representing the first ionisation of magnesium. **[2]**

b. Explain the general increase in first ionisation energy across Period 3. **[3]**

c. Explain why the first ionisation energy of magnesium is higher than that of aluminium. **[3]**

d. Explain why the first ionisation energy of phosphorus is higher than that of sulfur. **[3]**

e. Explain the general decrease in first ionisation energy down Group 7, from fluorine to iodine. **[3]**

Question 5 total: 14 marks

Question 6 — Graphical interpretation 3.1.1

a. Sketch a graph of first ionisation energy (y-axis) against atomic number for the elements of Period 3 (Na to Ar), labelling each element and showing the dips at Al and S. **[4]**

Sketch the Period 3 first ionisation energy graph

b. A student plots first ionisation energy against atomic number for the first 20 elements (H to Ca). Explain how this graph provides evidence for the existence of electron shells and sub-shells. **[3]**

Question 6 total: 7 marks

Question 7 — Oxides of Period 3 3.1.1

a. Classify the oxides Na_2O, Al_2O_3 and SO_3 as basic, amphoteric or acidic. **[3]**

b. Write an equation for the reaction of sodium oxide with water, and state the approximate pH of the resulting solution. **[2]**

c. Write an equation for the reaction of sulfur trioxide with water, and state the approximate pH of the resulting solution. **[2]**

d. Aluminium oxide is amphoteric. Write equations to show its reaction with (i) hydrochloric acid and (ii) sodium hydroxide solution. **[4]**

e. Explain, in terms of structure and bonding, why the trend from basic to acidic oxides across Period 3 mirrors the trend from metallic to non-metallic character. **[3]**

Question 7 total: 14 marks

Question 8 — Extended response

Synoptic

Explain fully why the first ionisation energy generally increases across Period 3 from sodium to argon, but shows a drop at aluminium and another drop at sulfur. Your answer should refer to nuclear charge, shielding, and sub-shell structure. **[6]**

This question is marked using a level of response.

Question 8 total: 6 marks

PAPER TOTAL: 84 MARKS

MARK SCHEME — Chapter 7: Periodicity

Award marks independently unless stated.

Q1 (a) [2]

- The repeating trend/pattern in physical and chemical properties of elements... (1)
- ...seen across each period as atomic number increases. (1)

Q1 (b) [2]

- Elements are ordered by the number of protons in the nucleus (not by relative atomic mass). (1)
- This order correctly places elements with similar properties into the same group. (1)

Q1 (c) [3]

- Sodium: metal; sulfur: non-metal. (1)
- Silicon: metalloid. (1)
- Justification: silicon has some properties of both, e.g. it is a semiconductor / has a giant covalent structure with a high melting point unlike typical non-metals. (1)

Q1 (d) [2]

- Potassium: s-block; calcium: s-block. (1)
- Chlorine: p-block; iron: d-block. (1)

Q2 (a) [3]

- Atomic radius decreases across the period. (1)
- Nuclear charge increases while shielding remains approximately constant (electrons added to the same outer shell). (1)
- Greater nuclear attraction pulls the outer electrons closer to the nucleus. (1)

Q2 (b) [3]

- Atomic radius increases down the group. (1)
- An extra electron shell is added at each element down the group. (1)
- Increased shielding/distance outweighs the increased nuclear charge, so the atom is larger. (1)

Q2 (c) [3]

- Na^+ has one fewer electron shell than Na (loses its outer shell entirely), so it is much smaller. (1)
- Cl^- has one more electron than Cl in the same outer shell. (1)
- Increased electron–electron repulsion in Cl^- with no increase in nuclear charge causes the ion to be larger than the atom. (1)

Q2 (d) [2]

- Mg^{2+} has a greater nuclear charge (more protons) than Na^+. (1)
- With the same number of (shielding) electrons, the greater nuclear attraction pulls the electron shells in more, giving a smaller ionic radius. (1)

Q3 (a) [3]

- Na, Mg and Al are all giant metallic structures. (1)
- Down this sequence, the ionic charge increases (+1 → +3) and the number of delocalised electrons per atom increases. (1)
- Stronger metallic bonding (electrostatic attraction between ions and delocalised electrons) requires more energy to melt. (1)

Q3 (b) [4]

- Silicon has a giant covalent (macromolecular) structure. (1)
- Every Si atom is bonded to four others by strong covalent bonds extending throughout the lattice. (1)
- Melting requires breaking many strong covalent bonds. (1)
- This needs far more energy than overcoming metallic bonding or (later) weak intermolecular forces. (1)

Q3 (c) [3]

- Phosphorus (P_4) is a simple molecular substance. (1)
- Only weak van der Waals forces exist between P_4 molecules (the strong covalent bonds within each molecule are not broken on melting). (1)
- Much less energy is needed to overcome these weak forces than the covalent lattice of silicon, so melting point drops sharply. (1)

Q3 (d) [3]

- S_8 is a larger molecule than P_4, with more electrons. (1)
- Stronger van der Waals forces exist between S_8 molecules than between P_4 molecules. (1)
- More energy is needed to overcome these stronger forces, giving sulfur a higher melting point. (1)

Q3 (e) [2]

- Argon exists as single (monatomic) atoms with very few electrons. (1)
- Extremely weak van der Waals forces exist between atoms, needing very little energy to overcome. (1)

Q4 (a) [8] — 1 mark each cell (structure + bonding for each row)

- Na, Mg, Al: giant metallic structure — metallic bonding.
- Si: giant covalent (macromolecular) structure — covalent bonding.
- P_4, S_8, Cl_2: simple molecular structure — covalent bonding within molecules, van der Waals between molecules.
- Ar: simple atomic (monatomic) structure — van der Waals forces between atoms.

Q5 (a) [2]

- The energy required to remove one electron from each atom in one mole of gaseous atoms, forming one mole of gaseous 1+ ions. (1)
- $Mg(g) \rightarrow Mg^+(g) + e^-$. (1)

Q5 (b) [3]

- Nuclear charge increases across the period. (1)
- Shielding stays approximately the same (electrons added to the same outer shell). (1)
- Stronger nuclear attraction on the outer electron means more energy is needed to remove it. (1)

Q5 (c) [3]

- Mg's outer electron is in the 3s sub-shell; Al's outer electron is in the 3p sub-shell. (1)
- The 3p sub-shell is at a higher energy (further from the nucleus / more shielded by the 3s electrons). (1)
- The 3p electron in Al is therefore easier to remove, despite Al's greater nuclear charge. (1)

Q5 (d) [3]

- In sulfur, the fourth 3p electron must pair up with another electron in the same orbital. (1)
- Repulsion between the paired electrons in the same orbital makes this electron easier to remove. (1)
- Phosphorus has three unpaired 3p electrons in separate orbitals (extra stability from the half-filled sub-shell), so more energy is needed to remove one. (1)

Q5 (e) [3]

- Atomic radius increases down the group (extra electron shells). (1)
- Increased shielding down the group. (1)
- Both effects outweigh the increased nuclear charge, so the outer electron is easier to remove — ionisation energy decreases. (1)

Q6 (a) [4]

- General upward zig-zag/increasing trend from Na to Ar shown. (1)
- Correct dip shown at Al (lower than Mg). (1)
- Correct dip shown at S (lower than P). (1)
- All eight elements correctly labelled on the x-axis in order. (1)

Q6 (b) [3]

- Large jumps in ionisation energy occur when a new (inner) shell starts to be removed — evidence for shells. (1)
- Smaller dips within a period (e.g. at Al-type and S-type positions, repeating in each period) show electrons are removed from different sub-shells (s and p) of differing energy. (1)
- The pattern of these dips repeating in each period supports the existence of sub-shells within shells. (1)

Q7 (a) [3]

- Na_2O: basic. (1)
- Al_2O_3: amphoteric. (1)
- SO_3: acidic. (1)

Q7 (b) [2]

- $Na_2O + H_2O \rightarrow 2NaOH$. (1)
- Strongly alkaline, pH 13–14. (1)

Q7 (c) [2]

- $SO_3 + H_2O \rightarrow H_2SO_4$. (1)
- Strongly acidic, pH 0–1. (1)

Q7 (d) [4]

- (i) $Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + 3H_2O$. (2)
- (ii) $Al_2O_3 + 2NaOH + 3H_2O \rightarrow 2NaAl(OH)_4$ (accept $Al_2O_3 + 2NaOH \rightarrow 2NaAlO_2 + H_2O$). (2)

Q7 (e) [3]

- Metallic elements (Na, Mg, Al) form ionic oxides containing O^{2-}, which reacts as a base by accepting protons — basic/amphoteric oxides. (1)
- Non-metallic elements (P, S) form covalent, simple molecular oxides which react with water to form acidic solutions (release H^+). (1)
- As metallic character decreases across the period, oxide bonding shifts from ionic to covalent, and behaviour shifts from basic to acidic. (1)

Q8 [6] — Level of response

- **Level 3 (5–6):** Explains the overall increasing trend (nuclear charge/shielding) and both anomalies (Al and S) correctly, with clear sub-shell reasoning throughout.
- **Level 2 (3–4):** Explains the general trend and at least one anomaly correctly; the other anomaly is partially explained or omitted.
- **Level 1 (1–2):** General trend stated with limited or no correct explanation of the anomalies.

Indicative content: *across the period, nuclear charge increases while shielding remains roughly constant, so first ionisation energy generally increases. At aluminium, the outer electron occupies the higher-energy 3p sub-shell rather than 3s, making it easier to remove than magnesium's 3s electron, causing a drop. At sulfur, the fourth 3p electron must pair in an already-occupied orbital; inter-electron repulsion in that orbital makes it easier to remove than phosphorus's third (unpaired, half-filled sub-shell) 3p electron, causing a second drop.*

END OF MARK SCHEME · 84 marks