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ANSWER BOOK

Periodicity: trends across Period 3 and the blocks of the table

Periodicity and Period 3 · Unit C12

AQA 3.2.1.1, 3.2.1.2 · OCR A 3.1.1

17 questions · 52 marks

NAVY EDITION

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SECTION A · Short, 1 to 2 marks

A1 PTA-Q12

M1 amount of aluminium = 0.540 ÷ 27.0 = 0.0200 mol. **A1** energy = 0.0200 × 578 = 11.6 kJ, to three significant figures; error carried forward from the amount. [2]

A2 PTA-Q14

B1 atomic radius is measured as half the distance between the nuclei of two bonded atoms of the element. **B1** argon atoms do not form bonds, so any value is a van der Waals radius between non-bonded atoms, which is larger and not comparable. [2]

A3 PTA-Q20

B1 K^+ is smaller than Cl^-. **B1** the two ions are isoelectronic, but potassium has 19 protons against chlorine's 17, so the same 18 electrons are pulled closer to the nucleus in K^+. [2]

A4 PTA-Q1

B1 a repeating pattern of physical or chemical properties across the periods of the periodic table; allow 'a trend that repeats in each period'. [1]

SECTION B · Standard, 3 to 5 marks

B1 PTA-Q2

B1 calcium is in the s block, because its last electron, in filling order, enters the 4s subshell. **B1** bromine is in the p block, because its last electrons enter the 4p subshell; reject d block because 3d is full. **B1** silicon is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$; reject [Ne] shorthand where the full configuration is asked for. **B1** silicon is a p-block element, because its last two electrons enter the 3p subshell. [4]

B2 PTA-Q6

B1 aluminium's outer electron is removed from a 3p orbital, whereas magnesium's comes from 3s. **B1** the 3p electron is higher in energy and is partly shielded by the 3s electrons, so less energy is needed to remove it. **B1** in sulfur the electron removed is from a 3p orbital that holds two electrons, whereas each 3p electron in phosphorus is unpaired. **B1** repulsion between the paired electrons means less energy is needed to remove one of them; ignore any reference to a half-filled subshell being stable. [4]

B3 PTA-Q15

B1 in both periods the melting point rises to a maximum at group 4, carbon in Period 2 and silicon in Period 3. **B1** both maxima are giant covalent structures, in which melting breaks many strong covalent bonds. **B1** in both periods there is a sharp fall at group 5, nitrogen and phosphorus, which are simple molecular. **B1** in Period 2 the group 3 element, boron, is giant covalent, whereas in Period 3 aluminium is metallic. [4]

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B4 PTA-Q4 — **B1** the nuclear charge increases across the period, from 11 protons in sodium to 17 in chlorine. **B1** the outer electrons are all in the same shell, the third, and the shielding by the inner electrons is similar; reject 'shielding increases'. **B1** so the outer electrons are attracted more strongly to the nucleus and are held closer to it. [3]

B5 PTA-Q5 — **B1** the nuclear charge increases across the period, one proton at each step. **B1** the electron removed is in the same shell each time, with similar shielding, and the atomic radius is smaller. **B1** so the outer electron is more strongly attracted to the nucleus and more energy is needed to remove it. [3]

B6 PTA-Q7 — **B1** both metals have metallic bonding: a lattice of positive ions attracted to a sea of delocalised electrons. **B1** magnesium ions are Mg^{2+} and smaller than Na^{+}, and each magnesium atom gives two delocalised electrons rather than one. **B1** so the attraction between the ions and the delocalised electrons is stronger in magnesium and more energy is needed to overcome it. [3]

B7 PTA-Q8 — **B1** silicon has a giant covalent structure; accept macromolecular. **B1** each atom is covalently bonded to four others throughout the structure, so melting breaks many strong covalent bonds. **B1** this needs much more energy than overcoming the metallic bonding of Na, Mg and Al or the van der Waals forces between the molecules of P_4, S_8 and Cl_2. [3]

B8 PTA-Q13 — **B1** germanium has a giant covalent structure like silicon's, each atom covalently bonded to four others. **B1** germanium atoms are larger, so the Ge–Ge bonds are longer than Si–Si bonds. **B1** longer bonds are weaker, so less energy is needed to break them and the melting point is lower. [3]

B9 PTA-Q17 — **B1** sodium, magnesium and aluminium conduct, increasingly well, because the number of delocalised electrons per atom increases. **B1** silicon is a semiconductor, because its electrons are held in covalent bonds but a few are freed as the temperature rises. **B1** phosphorus, sulfur, chlorine and argon do not conduct, because they have no delocalised electrons or ions. [3]

B10 PTA-Q18 — **B1** the three ions are isoelectronic, each with ten electrons in the configuration $1s^2 2s^2 2p^6$. **B1** the nuclear charge increases from 11 to 12 to 13 protons while the number of electrons stays the same. **B1** so the electrons are attracted more strongly to the nucleus and held closer, and the ionic radius decreases. [3]

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B11 PTA-Q19 [3]

B1 the sulfide ion has two more electrons than the atom, 18 against 16, added to the third shell, so the number of shells is unchanged. **B1** the nuclear charge is the same, 16, so it attracts more electrons and each is held less strongly. **B1** the extra electrons increase the repulsion between the outer electrons, so they move further from the nucleus and the ion is larger.

B12 PTA-Q21 [3]

B1 both solids are held together only by induced dipole–dipole forces between their particles, single atoms in argon and Cl_2 molecules in chlorine, with no covalent bonds between the particles to break. **B1** each argon atom has 18 electrons, whereas each chlorine molecule has 34, so the temporary dipoles are smaller and the forces between argon atoms are weaker. **B1** less energy is needed to separate argon atoms, so argon melts at 84 K and chlorine at 172 K; reject any mention of breaking Cl–Cl bonds.

SECTION C · Long, 6 marks or more

C1 PTA-Q10 [6]

Indicative content

B1 the melting point rises from sodium to aluminium, rises steeply to a maximum at silicon, falls sharply at phosphorus, rises at sulfur and falls to a minimum at argon. **B1** sodium, magnesium and aluminium have metallic bonding, and the ion charge and the number of delocalised electrons per atom increase while the ions get smaller. **B1** so the metallic bonding gets stronger from sodium to aluminium and more energy is needed to overcome it. **B1** silicon is giant covalent, and melting breaks many strong covalent bonds, which needs the most energy of any element in the period. **B1** phosphorus, sulfur, chlorine and argon are simple molecular, P_4, S_8, Cl_2 and Ar, and melting overcomes only weak van der Waals forces between molecules. **B1** the van der Waals forces are stronger for larger molecules with more electrons, giving the order S_8 > P_4 > Cl_2 > Ar.

Levels

Level 3 (5–6 marks) the whole trend is described and every part of it is explained from structure and bonding: the strengthening metallic bonding from sodium to aluminium, the giant covalent silicon at the maximum, and the molecular elements ordered by the size of their molecules; covalent bonds are broken on melting only in silicon.

Level 2 (3–4 marks) the metallic, giant covalent and molecular regions are identified and two are explained; the order among the molecular elements, or why metallic bonding strengthens, is not covered.

Level 1 (1–2 marks) silicon is said to have the highest melting point, or the molecular elements low ones; phosphorus and sulfur are commonly said to melt by breaking covalent bonds.

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