InkChemistry

ANSWER BOOK

The Period 3 elements: reactions with oxygen and water

Periodicity and Period 3 · Unit C12

AQA 3.2.4

19 questions · 65 marks

NAVY EDITION

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SECTION B · Standard, 3 to 5 marks

B1 PER-Q1 [5]

B1 the sodium floats, melts into a ball and moves around on the surface. **B1** there is fizzing, or effervescence; ignore 'hydrogen is given off', which is not an observation. **B1** the sodium gets smaller and disappears. **B1** the indicator turns purple, and the solution has a pH of 13 to 14; reject 'alkaline' with no value. **B1** $2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$, with every state symbol correct.

B2 PER-Q6 [4]

B1 sulfur melts and burns with a blue flame. **B1** a colourless gas with a choking smell forms, which is sulfur dioxide, SO_2. **B1** white phosphorus catches fire without being lit and burns with a white flame. **B1** dense white smoke forms, which is phosphorus(V) oxide, P_4O_{10}; allow P_2O_5.

B3 PER-Q12 [4]

B1 sodium is +1 in Na_2O and phosphorus is +5 in P_4O_{10}. **B1** sulfur is +4 in SO_2 and +6 in SO_3. **B1** phosphorus has five outer electrons and uses all five in P_4O_{10}, so +5 is its highest oxidation state. **B1** sulfur has six outer electrons but uses only four in SO_2, so it can be oxidised further, to +6 in SO_3.

B4 PER-Q18 [4]

B1 mineral wool soaked in water is placed at the closed end of a hard-glass boiling tube, with magnesium ribbon in the middle. **B1** the magnesium is heated strongly, with the flame moved to the wool at intervals to drive steam over it. **B1** the hydrogen is burned at a jet, or collected over water. **B1** if the gas is collected over water, the delivery tube is removed from the water before heating stops, to prevent suck-back cracking the hot tube.

B5 PER-Q3 [3]

B1 magnesium forms magnesium hydroxide and sodium forms sodium hydroxide. **B1** magnesium hydroxide is only sparingly soluble, so only a small concentration of hydroxide ions reaches the solution. **B1** sodium hydroxide is very soluble, so the concentration of hydroxide ions is much higher and the pH is higher.

B6 PER-Q4 [3]

B1 with steam the reactants are at a much higher temperature, so a greater proportion of collisions have energy greater than the activation energy. **B1** with cold water the product is magnesium hydroxide, $Mg(OH)_2$, whereas with steam it is magnesium oxide, MgO. **B1** magnesium hydroxide is not stable at the temperature of the steam reaction and decomposes to magnesium oxide and water.

B7 PER-Q5 [3]

B1 the magnesium glows or burns with a bright white light. **B1** a white solid is left in the tube and a gas is given off that burns at the jet. **B1** $Mg(s) + H_2O(g) \rightarrow MgO(s) + H_2(g)$; reject $H_2O(l)$.

B8 PER-Q7 [3]

B1 $4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$. **B1** $Si(s) + O_2(g) \rightarrow SiO_2(s)$. **B1** $P_4(s) + 5O_2(g) \rightarrow P_4O_{10}(s)$; allow $4P(s) + 5O_2(g) \rightarrow P_4O_{10}(s)$ and multiples.

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B9 PER-Q9 — [3]

M1 amount of Na = 0.345 ÷ 23.0 = 0.0150 mol. **M1** amount of H_2 = 0.0150 ÷ 2 = 0.00750 mol, from the 2 : 1 ratio in the equation. **A1** volume of H_2 = 0.00750 × 24.0 = 0.180 dm^3, to three significant figures; allow 180 cm^3.

B10 PER-Q10 — [3]

M1 amount of P = 1.24 ÷ 31.0 = 0.0400 mol, so amount of P_4O_{10} = 0.0400 ÷ 4 = 0.0100 mol. **M1** Mr of P_4O_{10} = 4(31.0) + 10(16.0) = 284.0. **A1** mass of P_4O_{10} = 0.0100 × 284.0 = 2.84 g, to three significant figures.

B11 PER-Q11 — [3]

M1 mass of oxygen combined = 1.020 − 0.540 = 0.480 g. **M1** amount of Al = 0.540 ÷ 27.0 = 0.0200 mol and amount of O = 0.480 ÷ 16.0 = 0.0300 mol. **A1** the ratio Al : O is 2 : 3, so the empirical formula is Al_2O_3; error carried forward from an incorrect mass of oxygen.

B12 PER-Q14 — [3]

B1 the sheet is covered by a thin layer of aluminium oxide, which keeps oxygen away from the metal beneath. **B1** the powder has a much larger surface area, so far more aluminium is in contact with oxygen and it heats up quickly enough to ignite. **B1** $4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$.

B13 PER-Q15 — [3]

B1 sodium reacts with both water and oxygen, so it is kept under oil, which excludes both. **B1** white phosphorus catches fire in air at about 30 °C, so it must be kept away from oxygen. **B1** phosphorus does not react with water, so water excludes air and keeps it cool without reacting with it.

B14 PER-Q16 — [3]

B1 sodium reacts vigorously, whereas magnesium reacts very slowly, giving only a few bubbles over several days. **B1** both produce hydrogen; sodium gives sodium hydroxide in solution, magnesium gives sparingly soluble magnesium hydroxide. **B1** the sodium solution has a pH of 13 to 14, the magnesium solution a pH of about 10.

B15 PER-Q17 — [3]

B1 white phosphorus is P_4, four atoms at the corners of a tetrahedron, so each P–P–P bond angle is 60°. **B1** the bonds are strained and weak, so little energy is needed to start breaking them and the activation energy for burning is low. **B1** in red phosphorus the tetrahedra are opened out and joined into chains, so the bonds are not strained and a flame is needed to ignite it.

B16 PER-Q19 — [3]

B1 chlorine is −1 in each chloride, so the oxidation state of the Period 3 element rises from +1 in NaCl to +5 in PCl_5. **B1** the oxidation state rises by one at each step, matching the number of outer electrons, from one in sodium to five in phosphorus. **B1** each element uses all of its outer electrons in bonding to chlorine, so each chloride shows the element's highest oxidation state.

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B17 PER-Q20 **M1** amount of P_4 = 0.496 ÷ (4 × 31.0) = 0.00400 mol. **M1** amount of Cl_2 = 10 × 0.00400 = 0.0400 mol. **A1** volume of Cl_2 = 0.0400 × 24.0 = 0.960 dm³, to three significant figures. [3]

B18 PER-Q21 **B1** aluminium chloride sublimes at about 178 °C, so it leaves the hot metal as a vapour and turns back to solid where the tube is cooler. **B1** aluminium chloride reacts with water, so wet chlorine would hydrolyse the product, giving hydrogen chloride. **B1** the vapour contains Al_2Cl_6 dimers, held by dative bonds from chlorine lone pairs to aluminium. [3]

SECTION C · Long, 6 marks or more

C1 PER-Q22 **Indicative content** [6]

B1 sodium and magnesium burn when heated, sodium with a yellow flame and magnesium with a bright white flame, each giving a white solid oxide. **B1** aluminium sheet does not burn because its oxide layer keeps oxygen off the metal, but aluminium powder burns with a bright white flame to give white Al_2O_3. **B1** silicon reacts only on strong heating, and slowly, because its giant covalent lattice must be broken into, giving white solid SiO_2. **B1** white phosphorus catches fire in air at about 30 °C because the 60° bond angles in P_4 leave its bonds strained, and it gives white smoke of P_4O_{10}. **B1** sulfur burns with a blue flame to give sulfur dioxide, a colourless gas with a choking smell, and gives no SO_3 without a catalyst. **B1** the oxidation state in Na_2O, MgO, Al_2O_3, SiO_2 and P_4O_{10} rises from +1 to +5, equal to the number of outer electrons, because all of them are used in bonding.

Levels

Level 3 (5–6 marks) all six elements are covered with their observations and products, the differences in how readily they start are explained, aluminium through its oxide layer, silicon through its lattice and phosphorus through bond strain, and the oxidation states of the oxides are linked to the number of outer electrons.

Level 2 (3–4 marks) four or five elements are described with correct observations and products and the oxidation-state pattern stated; one reason for reactivity, or the link to outer electrons, is not given.

Level 1 (1–2 marks) two or three reactions are described; burning sulfur is often said to give SO_3, and the formulae are not tied to the outer electrons.

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