InkChemistry

ANSWER BOOK

The Period 3 oxides: structure, bonding and acid–base character

Periodicity and Period 3 · Unit C12

AQA 3.2.4

18 questions · 66 marks

NAVY EDITION

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SECTION B · Standard, 3 to 5 marks

B1 POS-Q1

B1 $Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$, giving pH 13 to 14; allow pH 12 to 14. **B1** $P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$, giving pH 0 to 1; allow pH 0 to 2. **B1** $SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$, giving pH 2 to 3. **B1** sodium oxide is a basic oxide; phosphorus(V) oxide and sulfur dioxide are acidic oxides. [4]

B2 POS-Q4

B1 silicon dioxide is giant covalent, each Si bonded to four O and each O to two Si throughout the structure. **B1** melting silicon dioxide breaks many strong covalent bonds, which needs a lot of energy. **B1** phosphorus(V) oxide is simple molecular, made of P_4O_{10} molecules. **B1** it changes state by overcoming only the weak van der Waals forces between molecules; reject breaking covalent bonds in P_4O_{10}. [4]

B3 POS-Q6

B1 sodium oxide is ionic and contains oxide ions, O^{2-}. **B1** the oxide ion accepts a proton from water: $O^{2-} + H_2O \rightarrow 2OH^-$, so hydroxide ions make the solution alkaline. **B1** sulfur trioxide is covalent and reacts with water to form sulfuric(VI) acid: $SO_3 + H_2O \rightarrow H_2SO_4$. **B1** the O–H bonds in the acid break, releasing H^+ ions, so the solution is acidic. [4]

B4 POS-Q7

B1 neither oxide reacts with water or dissolves in it, so no H^+ or OH^- ions are released. **B1** the aluminium oxide lattice is too strong for water to break up, and silicon dioxide is a giant covalent network with no ions to release. **B1** aluminium oxide reacts with acid, $Al_2O_3(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2O(l)$, and also with alkali, so it is amphoteric. **B1** silicon dioxide reacts with hot, concentrated sodium hydroxide, $SiO_2(s) + 2NaOH(aq) \rightarrow Na_2SiO_3(aq) + H_2O(l)$, so it is acidic. [4]

B5 POS-Q11

M1 amount of P_4O_{10} = 1.42 ÷ 284.0 = 0.00500 mol. **M1** amount of H_3PO_4 = 4 × 0.00500 = 0.0200 mol. **M1** amount of NaOH = 3 × 0.0200 = 0.0600 mol; error carried forward from M2. **A1** volume = 0.0600 ÷ 0.200 = 0.300 dm^3, or 300 cm^3, to three significant figures. [4]

B6 POS-Q14

B1 the electronegativity difference, 2.0, is the same as aluminium's with oxygen, so BeO is ionic with covalent character. **B1** so beryllium oxide is amphoteric, like aluminium oxide. **B1** $BeO(s) + 2HCl(aq) \rightarrow BeCl_2(aq) + H_2O(l)$. **B1** $BeO(s) + 2NaOH(aq) + H_2O(l) \rightarrow Na_2Be(OH)_4(aq)$; allow $BeO(s) + 2NaOH(aq) \rightarrow Na_2BeO_2(aq) + H_2O(l)$. [4]

B7 POS-Q15

B1 it holds for sodium oxide and magnesium oxide, which are ionic, basic and form alkaline solutions. **B1** it holds for the non-metal oxides P_4O_{10}, SO_2 and SO_3, which are covalent and form acidic solutions. **B1** it fails for aluminium oxide, a metal oxide that is amphoteric, reacting with both acids and bases. **B1** silicon, a metalloid or non-metal, has an oxide that is acidic although insoluble in water, so the statement is a useful outline that needs aluminium oxide as an exception. [4]

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B8 POS-Q19 [4]

B1 sodium chloride is ionic; it dissolves and the ions are hydrated, but neither Na^+ nor Cl^- reacts with water, so the solution is neutral. **B1** silicon tetrachloride is covalent, and water attacks the partially positive silicon atom, breaking the Si–Cl bonds: it is hydrolysed. **B1** $SiCl_4(l) + 2H_2O(l) \rightarrow SiO_2(s) + 4HCl(aq)$. **B1** the hydrogen chloride formed dissolves to give hydrochloric acid, a strong acid, so the pH is low.

B9 POS-Q20 [4]

M1 Mr of PCl_5 = 31.0 + 5(35.5) = 208.5, so amount of PCl_5 = 1.043 ÷ 208.5 = 0.00500 mol. **M1** amount of HCl = 5 × 0.00500 = 0.0250 mol. **M1** $[H^+] = [HCl]$ = 0.0250 ÷ 0.500 = 0.0500 mol dm^{-3}, since HCl is fully dissociated. **A1** pH = -log(0.0500) = 1.30, to two decimal places; error carried forward from an incorrect $[H^+]$.

B10 POS-Q8 [3]

B1 amphoteric describes a substance that can react both as a base, with acids, and as an acid, with bases. **B1** $Al_2O_3(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2O(l)$. **B1** $Al_2O_3(s) + 2NaOH(aq) + 3H_2O(l) \rightarrow 2NaAl(OH)_4(aq)$; allow $Al_2O_3(s) + 2NaOH(aq) \rightarrow 2NaAlO_2(aq) + H_2O(l)$.

B11 POS-Q10 [3]

B1 phosphoric(V) acid has a central phosphorus atom bonded to four oxygen atoms. **B1** one oxygen is joined by a P=O double bond and three are in P–O–H groups, so all three hydrogens are on oxygen atoms. **B1** the phosphate(V) ion, PO_4^{3-}, is phosphorus bonded to four oxygens, formed when all three H^+ ions are lost, with a 3- charge.

B12 POS-Q12 [3]

M1 amount of HCl = 2.00 × 25.0 ÷ 1000 = 0.0500 mol. **M1** $MgO + 2HCl \rightarrow MgCl_2 + H_2O$, so amount of MgO = 0.0500 ÷ 2 = 0.0250 mol. **A1** mass of MgO = 0.0250 × 40.3 = 1.01 g, to three significant figures.

B13 POS-Q13 [3]

B1 sulfur dioxide is an acidic oxide, because it is a covalent non-metal oxide. **B1** calcium oxide is a basic, ionic oxide, so the two react as an acid and a base to form a salt. **B1** $CaO(s) + SO_2(g) \rightarrow CaSO_3(s)$.

B14 POS-Q16 [3]

B1 neither reacts with or dissolves in water, so neither changes the pH. **B1** aluminium oxide reacts with acids, forming an aluminium salt and water, whereas silicon dioxide does not. **B1** both react with sodium hydroxide, aluminium oxide to give $NaAl(OH)_4$ and silicon dioxide, when the alkali is hot and concentrated, to give Na_2SiO_3.

B15 POS-Q18 [3]

B1 $P_4O_{10}(s) + 12NaOH(aq) \rightarrow 4Na_3PO_4(aq) + 6H_2O(l)$. **B1** $SO_2(g) + 2NaOH(aq) \rightarrow Na_2SO_3(aq) + H_2O(l)$. **B1** $SO_3(l) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + H_2O(l)$; allow $SO_3(g)$.

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B16 POS-Q21 **B1** with a little water, aluminium chloride is hydrolysed and hydrogen chloride gas escapes as steamy fumes: $AlCl_3 + 3H_2O \rightarrow Al(OH)_3 + 3HCl$. **B1** in a large volume of water the aluminium chloride dissolves to give $[Al(H_2O)_6]^{3+}$ ions, and any HCl dissolves rather than escaping. **B1** the small, highly charged Al^{3+} ion polarises the O–H bonds of its water ligands, which release some H^+, so the solution is acidic, about pH 3. [3]

B17 POS-Q22 **M1** $n(SO_2) = 1.20 \div 24.0 = 0.0500$ mol. **M1** $SO_2(g) + 2NaOH(aq) \rightarrow Na_2SO_3(aq) + H_2O(l)$, so $n(NaOH) = 2 \times 0.0500 = 0.100$ mol. **A1** $V = n \div c = 0.100 \div 1.00 = 0.100$ dm³ = 100 cm³, with the working shown in full because the answer is given. [3]

SECTION C · Long, 6 marks or more

C1 POS-Q17 **Indicative content** [6]

B1 Na_2O and MgO are ionic, Al_2O_3 is ionic with covalent character, SiO_2 is giant covalent, and P_4O_{10}, SO_2 and SO_3 are simple molecular covalent. **B1** the change follows the fall in electronegativity difference between the element and oxygen across the period. **B1** the ionic oxides contain O^{2-}, which accepts protons from water to form OH^-: Na_2O gives NaOH at pH 13 to 14, MgO gives sparingly soluble $Mg(OH)_2$ at pH 9 to 10. **B1** Al_2O_3 and SiO_2 do not react with water, the lattice and the covalent network being too strong, so the pH stays at 7. **B1** the molecular oxides react with water to form oxoacids: P_4O_{10} gives H_3PO_4 and SO_3 gives H_2SO_4, both at pH 0 to 1. **B1** SO_2 gives H_2SO_3, a weak acid at pH 2 to 3; in each oxoacid the O–H bonds break to release H^+.

Levels

Level 3 (5–6 marks) the change in bonding across the full set of oxides is stated and explained through electronegativity difference, and every reaction with water is matched to the bonding, the ionic oxides giving hydroxide, the two that do not react, and the molecular oxides giving oxoacids, with approximate pH values.

Level 2 (3–4 marks) the change from ionic to covalent is described and most reactions with water are right; the reason for the change in terms of electronegativity, the two oxides that do not react, or the pH values are not there.

Level 1 (1–2 marks) the oxides are said to go from basic to acidic; silicon dioxide is typically said to dissolve to give an acid, and bonding is not linked to pH.

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