InkChemistry

ANSWER BOOK

Group 2: trends down the group and reactions with water

Group 2 and Group 7 · Unit C13

AQA 3.2.2 · OCR A 3.1.2 (a), 3.1.2 (b), 3.1.2 (d)

20 questions · 65 marks

NAVY EDITION

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SECTION A · Short, 1 to 2 marks

A1 GTD-Q13

B1 beryllium has the smallest atoms in the group, so its outer electrons are closest to the nucleus and least shielded. **B1** it has the highest ionisation energies, so it loses electrons least readily; a surface oxide layer also protects the metal. [2]

A2 GTD-Q23

B1 about pH 12 to 13, between the values for calcium oxide and barium oxide. **B1** the oxide forms strontium hydroxide, which is more soluble than calcium hydroxide and less soluble than barium hydroxide, so it gives an intermediate hydroxide ion concentration. [2]

SECTION B · Standard, 3 to 5 marks

B1 GTD-Q4

B1 the metals have metallic bonding: a lattice of 2+ ions attracted to delocalised electrons. **B1** down the group the ions are larger with the same 2+ charge, so the delocalised electrons are further from the centre of each ion. **B1** the attraction is weaker, so less energy is needed to break up the lattice; reject any reference to intermolecular forces or molecules. **B1** magnesium does not fit: at 650 °C it melts below calcium, 842 °C, although its ions are smaller; ignore any attempted explanation. [4]

B2 GTD-Q11

B1 magnesium is oxidised, from 0 in Mg to +2 in $MgCl_2$. **B1** titanium is reduced, from +4 in $TiCl_4$ to 0 in Ti, so magnesium is the reducing agent. **B1** at about 1000 °C titanium and magnesium would react with the oxygen and nitrogen in air. **B1** argon is unreactive and excludes air, so the titanium is not contaminated with oxide or nitride, which make it brittle; 'argon is inert' alone is not enough. [4]

B3 GTD-Q14

B1 magnesium reacts very slowly, giving only a few bubbles, whereas barium reacts vigorously with rapid fizzing. **B1** both give hydrogen and the metal hydroxide, with the metal oxidised from 0 to +2. **B1** magnesium hydroxide is sparingly soluble and stays as a white solid, whereas barium hydroxide dissolves. **B1** so the barium solution is much more alkaline, with a higher pH, than the water around the magnesium. [4]

B4 GTD-Q15

B1 the claim is not supported: titanium is one of the most abundant elements in the Earth's crust, and rutile is plentiful. **B1** the cost comes from the extraction, which is a batch process held at high temperatures for long periods. **B1** it needs chlorine, argon and magnesium, and the magnesium is itself extracted by electrolysis, which uses a great deal of electricity. **B1** carbon cannot be used as the reducing agent because it forms brittle titanium carbide, so the cheaper route used for iron is not available. [4]

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B5 GTD-Q3 — [3]

B1 the outer electron is in a shell further from the nucleus, so atomic radius increases; allow 'more energy levels'. **B1** there are more filled inner shells, so the outer electron is more shielded from the nucleus. **B1** the attraction between the nucleus and the outer electron is weaker, outweighing the increase in nuclear charge, so less energy is needed to remove it.

B6 GTD-Q6 — [3]

B1 the magnesium burns with a bright white light. **B1** a white solid (powder) of magnesium oxide is left, and the hydrogen can be lit at the end of the tube. **B1** $Mg(s) + H_2O(g) \rightarrow MgO(s) + H_2(g)$; reject $Mg(OH)_2$ as the product with steam.

B7 GTD-Q7 — [3]

B1 the products are $Ba(OH)_2$ and H_2, in a 1 : 1 ratio. **B1** the state symbols are $Ba(OH)_2(aq)$ and $H_2(g)$; allow $Ba^{2+}(aq) + 2OH^-(aq)$ for the hydroxide. **B1** barium goes from 0 to +2, so it is oxidised and acts as the reducing agent.

B8 GTD-Q8 — [3]

B1 when the metal reacts each atom loses its two outer electrons, so it is oxidised. **B1** down the group the outer electrons are further from the nucleus and more shielded, so they are less strongly attracted. **B1** the sum of the first and second ionisation energies falls, so the electrons are lost more easily and the metal reacts faster.

B9 GTD-Q9 — [3]

M1 $Mr(TiCl_4) = 47.9 + 4 \times 35.5 = 189.9$, so amount of $TiCl_4 = 5.00 \times 10^5$ g ÷ 189.9 = 2633 mol. **M1** $TiCl_4 + 2Mg \rightarrow Ti + 2MgCl_2$, so amount of Mg = 2 × 2633 = 5266 mol. **A1** mass of Mg = 5266 × 24.3 = 1.28×10^5 g = 128 kg, to three significant figures; error carried forward from M2.

B10 GTD-Q10 — [3]

M1 amount of Ca = 0.400 g ÷ 40.1 g mol^{-1} = 9.975×10^{-3} mol. **M1** $Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + H_2(g)$ is 1 : 1, so 9.975×10^{-3} mol of H_2 forms. **A1** volume = $9.975 \times 10^{-3} \times 24.0 = 0.239$ dm^3 = 239 cm^3, to three significant figures.

B11 GTD-Q12 — [3]

B1 sodium loses its outer electron very easily, so it is a strong reducing agent, like magnesium. **B1** $TiCl_4(g) + 4Na(l) \rightarrow Ti(s) + 4NaCl(l)$. **B1** four moles of sodium are needed for each mole of titanium, against two of magnesium, because each sodium atom gives one electron and each magnesium atom two.

B12 GTD-Q16 — [3]

B1 both metals form their hydroxide and hydrogen. **B1** calcium hydroxide is only sparingly soluble, so some of it comes out of solution as a white solid. **B1** barium hydroxide is much more soluble, because hydroxide solubility increases down the group, so it stays dissolved.

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B13 GTD-Q19 **B1** calcium sulfate is only sparingly soluble, so it forms as a solid layer on the surface of the calcium. **B1** the layer keeps the acid away from the metal, so the reaction slows and stops. **B1** magnesium sulfate is soluble, so it dissolves and the magnesium surface stays exposed to the acid. [3]

B14 GTD-Q20 **M1** amount of Sr = 0.250 g ÷ 87.6 g mol^{-1} = 2.854 × 10^{-3} mol. **M1** Sr(s) + 2HCl(aq) → $SrCl_2$(aq) + H_2(g) is 1 : 1 for strontium and hydrogen, so 2.854 × 10^{-3} mol of H_2 forms. **A1** volume = 2.854 × 10^{-3} × 24.0 = 6.85 × 10^{-2} dm^3 = 68.5 cm^3, to three significant figures. [3]

B15 GTD-Q21 **B1** calcium oxide reacts with the water in an exothermic reaction, forming powdery calcium hydroxide. **B1** CaO(s) + H_2O(l) → $Ca(OH)_2$(s). **B1** about pH 12, because calcium hydroxide is sparingly soluble and releases some hydroxide ions; allow 11 to 12.5. [3]

B16 GTD-Q22 **B1** the magnesium glows or burns with a white light and a white solid forms on the walls of the jar. **B1** Mg(s) + Cl_2(g) → $MgCl_2$(s). **B1** magnesium goes from 0 to +2 and is oxidised; chlorine goes from 0 to -1 and is reduced. [3]

B17 GTD-Q24 **M1** amount of $CaCO_3$ = 0.750 g ÷ 100.1 g mol^{-1} = 7.493 × 10^{-3} mol. **M1** $CaCO_3$(s) + 2HCl(aq) → $CaCl_2$(aq) + CO_2(g) + H_2O(l) is 1 : 1 for carbonate and carbon dioxide. **A1** volume = 7.493 × 10^{-3} × 24.0 = 0.180 dm^3 = 180 cm^3, to three significant figures. [3]

SECTION C · Long, 6 marks or more

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C1 GTD-Q18 **Indicative content** [6]

B1 atomic radius increases down the group because each element has one more occupied shell of electrons than the element above it. **B1** first ionisation energy decreases down the group although the nuclear charge increases, so less energy is needed to remove an outer electron. **B1** the outer electrons are further from the nucleus and more shielded by inner shells, so they are less strongly attracted, which outweighs the greater nuclear charge. **B1** reactivity with water increases down the group, from a very slow reaction for magnesium with cold water to a vigorous one for barium. **B1** because the sum of the first two ionisation energies falls, the two outer electrons are lost more easily and the metal is oxidised to M^{2+} more readily. **B1** a correct balanced equation with state symbols, for example $Ba(s) + 2H_2O(l) \rightarrow Ba(OH)_2(aq) + H_2(g)$, or the steam reaction of magnesium.

Levels

Level 3 (5–6 marks) all three trends are stated and each is explained: radius through the added shell, ionisation energy through distance and shielding outweighing nuclear charge, and reactivity through the easier loss of both outer electrons, with a correct balanced equation with state symbols.

Level 2 (3–4 marks) the three trends are stated and two are explained, or all three are explained and the equation is unbalanced or absent.

Level 1 (1–2 marks) one or two trends are stated, typically with the greater nuclear charge given as the reason the outer electrons are lost more easily; no correct equation.

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