InkChemistry

ANSWER BOOK

Half-equations and building redox equations

Redox · Unit C07

AQA 3.1.7, 3.2.3.2 · OCR A 2.1.5, 3.1.3, 5.2.3

20 questions · 68 marks

NAVY EDITION

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SECTION A · Short, 1 to 2 marks

A1 HEB-Q13

B1 copper is oxidised, from 0 in Cu to +2 in Cu^{2+}. **B1** the nitrate ion is reduced, nitrogen falling from +5 in NO_3^- to +2 in NO. [2]

SECTION B · Standard, 3 to 5 marks

B1 HEB-Q3

B1 $2I^-(aq) \rightarrow I_2(aq) + 2e^-$. **B1** $H_2O_2(aq) + 2H^+(aq) + 2e^- \rightarrow 2H_2O(l)$. **B1** both halves carry two electrons, so they are added as they stand and the electrons cancel. **B1** $H_2O_2(aq) + 2H^+(aq) + 2I^-(aq) \rightarrow I_2(aq) + 2H_2O(l)$; ignore state symbols. [4]

B2 HEB-Q7

B1 $Cl_2(g) + 2NaOH(aq) \rightarrow NaCl(aq) + NaClO(aq) + H_2O(l)$. **B1** chlorine falls from 0 in Cl_2 to -1 in NaCl, which is reduction. **B1** chlorine rises from 0 in Cl_2 to +1 in NaClO, which is oxidation. **B1** the same element in the same species, Cl_2, is both oxidised and reduced, which is disproportionation. [4]

B3 HEB-Q10

B1 balance the atoms of every element other than oxygen and hydrogen. **B1** balance oxygen by adding H_2O molecules to the side short of oxygen. **B1** balance hydrogen by adding H^+ ions to the side short of hydrogen. **B1** balance the charge by adding electrons to the more positive side. [4]

B4 HEB-Q14

B1 disproportionation is a redox reaction in which the same element in one species is simultaneously oxidised and reduced. **B1** in both reactions chlorine goes from 0 in Cl_2 to -1, which is reduction, and to +1, which is oxidation. **B1** with water the products are HCl and HClO; with sodium hydroxide they are NaCl and NaClO. **B1** the reaction with water is reversible and only a small fraction of chlorine reacts, whereas hydroxide removes the acids as they form so the reaction goes to completion. [4]

B5 HEB-Q21

B1 $2IO_3^- \rightarrow I_2$ needs $6H_2O$ on the right for the oxygen and then $12H^+$ on the left for the hydrogen. **B1** the charge is +10 on the left and 0 on the right, so $2IO_3^-(aq) + 12H^+(aq) + 10e^- \rightarrow I_2(aq) + 6H_2O(l)$; iodine falls from +5 to 0 in each of two atoms. **B1** the iodide half-equation, $2I^- \rightarrow I_2 + 2e^-$, is multiplied by five so that ten electrons cancel. **B1** $IO_3^-(aq) + 5I^-(aq) + 6H^+(aq) \rightarrow 3I_2(aq) + 3H_2O(l)$, after dividing through by two; accept the doubled equation. [4]

B6 HEB-Q22

M1 $Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$, balanced for oxygen with water, for hydrogen with H^+ and for charge with electrons. **M1** $Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$, one electron lost by each iron(II) ion. **M1** the iron half-equation is multiplied by six so that the electrons gained and lost are equal, and the two are added. **A1** $Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6Fe^{2+}(aq) \rightarrow 2Cr^{3+}(aq) + 7H_2O(l) + 6Fe^{3+}(aq)$, so the ratio is 1 : 6; the check from oxidation states is two chromiums falling by three each, six electrons. [4]

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B7 HEB-Q2 **B1** $7H_2O(l)$ on the right balances the oxygen, and then $14H^+(aq)$ on the left balances the hydrogen. **B1** $6e^-$ on the left balance the charge: $Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$. **B1** each chromium falls from +6 to +3, and two chromium atoms change, so six electrons are needed. [3]

B8 HEB-Q4 **M1** moles of $Cr_2O_7^{2-} = 0.0500 \times 25.0/1000 = 1.25 \times 10^{-3}$ mol. **M1** moles of $I_2 = 3 \times 1.25 \times 10^{-3} = 3.75 \times 10^{-3}$ mol, from the 1 : 3 ratio. **A1** mass $= 3.75 \times 10^{-3} \times 253.8 = 0.952$ g, to three significant figures. [3]

B9 HEB-Q5 **M1** each MnO_4^- gains five electrons, so electrons transferred $= 5 \times 9.60 \times 10^{-4} = 4.80 \times 10^{-3}$ mol. **M1** electrons lost per X ion $= 4.80 \times 10^{-3} \div 2.40 \times 10^{-3} = 2$. **A1** the oxidation state of X rises from +2 to +4, an integer with no unit. [3]

B10 HEB-Q6 **B1** every electron released in the oxidation is taken up in the reduction; electrons are not created or left over. **B1** matching the numbers lets the electrons cancel, so none appears in the overall equation. **B1** the multipliers used fix the mole ratio of oxidising agent to reducing agent, such as 1 MnO_4^- to 5 Fe^{2+}. [3]

B11 HEB-Q8 **B1** chlorine reacts with water to form chloric(I) acid, HClO, which kills bacteria. **B1** this prevents water-borne diseases such as cholera and typhoid, and chlorine left in the water protects it in the pipes. **B1** it is used at a low concentration, at which the benefit outweighs the risk of toxicity and of forming chlorinated hydrocarbons. [3]

B12 HEB-Q11 **B1** vanadium balances; one H_2O on the right balances the oxygen. **B1** two H^+ on the left balance the hydrogen. **B1** one electron on the left balances the charge, matching vanadium falling from +5 to +4: $VO_2^+(aq) + 2H^+(aq) + e^- \rightarrow VO^{2+}(aq) + H_2O(l)$. [3]

B13 HEB-Q12 **B1** oxidation: $2Br^- \rightarrow Br_2 + 2e^-$. **B1** reduction: $H_2SO_4 + 2H^+ + 2e^- \rightarrow SO_2 + 2H_2O$. **B1** overall, with two electrons cancelling: $2Br^- + H_2SO_4 + 2H^+ \rightarrow Br_2 + SO_2 + 2H_2O$. [3]

B14 HEB-Q15 **B1** the atoms balance: one Mn, four O and eight H on each side. **B1** the charge does not balance: -1 + 8 - 3 = +4 on the left against +2 on the right. **B1** manganese falls from +7 to +2, a gain of five electrons, so the equation needs $5e^-$, not $3e^-$. [3]

B15 HEB-Q16 **B1** the blue colour of the solution fades towards colourless and a brown solid, copper, forms as the zinc dissolves. **B1** $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$ and $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$. **B1** $Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$, with sulfate ions left out as spectator ions. [3]

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B16 HEB-Q18 **B1** chlorine starts at 0 in Cl_2, falls to -1 in NaCl and rises to +5 in $NaClO_3$, so this is disproportionation. **B1** each chlorine atom oxidised to +5 releases five electrons, while each chlorine atom reduced to -1 gains one. **B1** electrons lost must equal electrons gained, so five chlorine atoms are reduced for every one oxidised, a 5 : 1 ratio of chloride to chlorate(V). [3]

B17 HEB-Q19 **B1** balanced as in acid first: $SO_3^{2-} + H_2O \rightarrow SO_4^{2-} + 2H^+ + 2e^-$, sulfur rising from +4 to +6. **B1** two OH^- are added to each side, and the $2H^+$ and $2OH^-$ on the right form $2H_2O$, one of which cancels the H_2O on the left. **B1** $SO_3^{2-}(aq) + 2OH^-(aq) \rightarrow SO_4^{2-}(aq) + H_2O(l) + 2e^-$, with a charge of -4 on each side. [3]

B18 HEB-Q20 **B1** sulfur falls by eight, from +6 to -2, and each iodine rises by one, from -1 to 0, so eight I^- react with each H_2SO_4, giving four I_2. **B1** four H_2O on the right balance the oxygen, and eight H^+ on the left balance the hydrogen. **B1** $H_2SO_4 + 8H^+ + 8I^- \rightarrow H_2S + 4I_2 + 4H_2O$, with a total charge of 0 on each side. [3]

SECTION C · Long, 6 marks or more

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

B1 the dichromate(VI) half-equation is $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$, with each chromium falling from +6 to +3. **B1** the ethanol half-equation is $CH_3CH_2OH \rightarrow CH_3CHO + 2H^+ + 2e^-$, balanced for hydrogen with H^+ and for charge with electrons. **B1** the mean oxidation state of carbon rises from -2 in ethanol to -1 in ethanal, two carbons giving two electrons in all, so ethanol is oxidised. **B1** the ethanol half-equation is multiplied by three so that both halves carry six electrons, which then cancel when the two are added. **B1** after cancelling $6H^+$ from each side the overall equation is $Cr_2O_7^{2-} + 8H^+ + 3CH_3CH_2OH \rightarrow 2Cr^{3+} + 3CH_3CHO + 7H_2O$, with a charge of +6 on each side. **B1** the solution turns from orange, the colour of $Cr_2O_7^{2-}$, to green, the colour of Cr^{3+}, as the dichromate(VI) is reduced; reject 'yellow to green'.

Levels

Level 3 (5–6 marks) both half-equations are correct with the oxidation state changes, the electrons are balanced by multiplying the ethanol half-equation by three, the overall equation is given with the H^+ cancelled and the charge balanced, and the colour change from orange to green is stated.

Level 2 (3–4 marks) both half-equations are correct and the overall equation is attempted; the electrons are left unbalanced, H^+ is not cancelled, or the oxidation states or colour change are absent.

Level 1 (1–2 marks) one half-equation is right or the colour change is stated, often the wrong way round as green to orange, with no overall equation.

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