PEARSON EDEXCEL A-LEVEL CHEMISTRY · 9CH0

CHEMISTRY



MARK SCHEME

TOPIC 3: REDOX I

SCORE	PERCENTAGE
/196	%

STEMUP

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(Total for question = 14 marks)

Mark Scheme

Q1.

Question Number	Correct Answer	Reject	Mark
	C		1

Q2.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)(i)	An answer that makes reference to the following points: **EITHER** • the solution of manganate(VII) ions (1) • as distilled water/other solutions remaining in burette will dilute the solution of manganate(VII) ions (1) **OR** • Distilled water, followed by the solution of manganate(VII) ions (1) • So the distilled water will not dilute the solution of manganate(VII) ions (1)		**2**

Question Number	Acceptable Answer	Additional Guidance	Mark
(a) (ii)	An answer that makes reference to the following points: • measure from the bottom of the meniscus (of the solution of manganate(VII) ions) (1) • with eyes / head at same level (as meniscus) **or** ensuring the burette is vertical **or** use of white background to emphasise meniscus **or** ensuring funnel is removed from top of burette **or** ensuring there is no air bubble in the tip of the burette (1)		**2**

Question Number	Acceptable Answer	Additional Guidance	Mark
(a) (iii)	An explanation that makes reference to the following point: • it will not change the amount / moles (of reactants) in the flask		**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
(c)	• $H_2C_2O_4 \rightarrow 2CO_2 + 2H^+ + 2e^-$ / $C_2O_4^{2-} \rightarrow 2CO_2 + 2e^-$ <u>and</u> $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$ (1) • $5H_2C_2O_4 + 2MnO_4^- + 6H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$ / $5C_2O_4^{2-} + 2MnO_4^- + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$ (2)	Ignore state symbols Allow for 1 mark: $5H_2C_2O_4 + 2MnO_4^- + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O + 10H^+$	**3**

Question Number	Acceptable Answer	Additional Guidance	Mark
	• mean = 22.7 / 22.70 (cm^3) (1)		**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
(d)	• calculates amount of MnO_4^- (1) • calculates amount of $H_2C_2O_4$ (in 25 cm^3) (1) • calculates amount of $H_2C_2O_4$ (in 250 cm^3) (1) • calculates relative molecular mass of acid (1) • calculates **x** (1)	Example of calculation Amount of MnO_4^- = 22.7/1000 x 0.0105 = 2.3835 x 10^{-4} mol TE on mean in (c) Amount of $H_2C_2O_4$ (in 25 cm^3) = 2.3835 x 10^{-4} x 2.5 = 5.95875 x 10^{-4} mol TE on mol ratio in equation in (b) Amount of $H_2C_2O_4$ (in 250 cm^3) = 5.95875 x 10^{-4} x 10 = 5.95875 x 10^{-3} mol Relative molecular mass of acid = 0.747 / 5.95875 x 10^{-3} = 125.4 So relative mass of water of crystallisation = 125.4 – 90 = 35.4 35.4/18 = 1.97 so **x** = 2 Do not award **x** = 1.97	**5**

Question Number	Acceptable Answer	Additional Guidance	Mark
(e)	An answer that makes reference to the following point: • more MnO_4^- would show greater amount of $H_2C_2O_4$ (1) • so molecular mass of **x**H_2O would seem to be less, so value for **x** would be less (1) **or** • more MnO_4^- means lower molecular mass (1) • therefore mass of water of crystallisation is less so **x** is less than 2 (1)		**2**

Q3.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• +5		**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b) (i)	• choice of suitable reducing agent	From Data Booklet of the standard electrode potentials, the right hand substance in numbers 16-24	**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b) (ii)	An answer that makes reference to the following point: • may be kinetically hindered **or** activation energy may be too high	Allow reaction may be too slow	**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b) (iii)	An explanation that makes reference to the following points: • (yellow to) green then blue (1) • when the blue colour initially forms, it mixes with the yellow unreacted VO_2^+ (to turn green) (1)	Ignore colours caused by contamination with reducing agent chosen	**2**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(iv)	An explanation that makes reference to the following point: • justification of choice (1) • correct equation for reaction (1)	$E^{\ominus}$ value is between +0.34 V and −0.26 V Allow by comparison of electrode potentials / calculation of E_{cell} / use of anti-clockwise rule $S_2O_3^{2-} + VO^{2+} + 2H^+ \rightarrow V^{3+} + H_2O + \frac{1}{2}S_4O_6^{2-}$ or multiples	**2**

Q4.

Question Number	Acceptable Answers	Reject	Mark
(a)(i)	$TiCl_4 + 4Na \rightarrow 4NaCl + Ti$ IGNORE State symbols, even if incorrect ALLOW Multiples Reversible arrows		**1**

Question Number	Acceptable Answers	Reject	Mark
(a)(ii)	Ti **reduced** as oxidation number decreases from **+4 to 0**/ changes from **+4 to 0** **(1)** Na **oxidized** as oxidation number increases from **0 to +1** /changes from **0 to +1** **(1)** ALLOW Correct oxidation numbers only for one mark **NOTE** Max (1) if no + sign included ALLOW **'4+'** and/or **'1+'** given instead of **+4** and **+1** **NOTE** If any of the oxidation numbers are wrong, award max (1) for the idea that during oxidation the oxidation number increases **AND** during reduction the oxidation number decreases IGNORE References to loss and /or gain of electrons		**2**

Question Number	Acceptable Answers	Reject	Mark
(b)	(Ti [Ar]) $3d^2\ 4s^2$ / $4s^2\ 3d^2$ **(1)** (Ti^{3+} [Ar]) $3d^1$ / $3d^1\ 4s^0$ (Ti^{4+} [Ar]) 'nil' / $3d^0\ 4s^0$ /$3d^0$ space left blank by candidate BOTH Ti^{3+} and Ti^{4+} correct for second mark **(1)** Mark CQ on Ti electron configuration for the second mark ALLOW Upper case (e.g. 'D' for 'd' in electronic configurations) Subscripts for numbers of electrons Full correct electronic configurations $1s^2$, $2s^2$.....		**2**

Question Number	Acceptable Answers	Reject	Mark
(c)(i)	**(d-block element)** **EITHER** Ti has (two) electrons in the 3d subshell / Ti has a partially filled d-subshell / Ti has a partially filled d-orbital / Ti has electrons in d-orbital(s) / Ti has electrons in d-subshell (During the build up of its atoms) last added / valence electron is in a d-subshell / d-orbital **OR** (During the build up of its atoms) last added / valence electron is in a d-subshell / d-orbital	**Outer / highest energy** electrons are in a d-orbital / **Outer / highest energy** electrons are in a d-subshell Electrons in the 'd-block'/ 'electrons in the d-shell'	**1**

Question Number	Acceptable Answers	Reject	Mark
(c)(ii)	(transition element) Forms one (or more stable) **ions** / forms **Ti^{3+}** (ions) which have incomplete d-orbital(s) / an incomplete d-subshell / a partially filled d-subshell / an unpaired d electron IGNORE References to variable oxidation states		**1**

Question Number	Acceptable Answers	Reject	Mark
(d)(i)	**First mark:** d-subshell splits /d-orbital**s** split (in energy by ligands) /d energy level(s) split(s) **(1)** **Second mark:** **absorbs light** (in visible region) **(1)** **Third mark:** Electron transitions from lower to higher energy / electron(s) jump from lower to higher energy OR Electron(s) promoted (within d) **(1)** Mark independently **NOTE** Maximum of (1) mark (i.e. the first mark only) if refers to electrons falling back down again	d-**orbital /** d-**shell** splits absorbs **purple** light	**3**

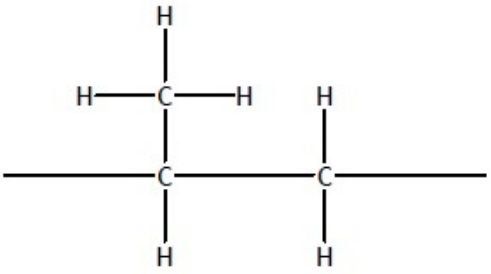
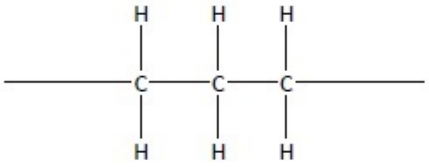
Question Number	Acceptable Answers	Reject	Mark
(d)(ii)	No d-electrons / empty d-subshell		**1**

Question Number	Acceptable Answers	Reject	Mark
(e)(i)	**TiO_2** **'Structure' mark** **EITHER** Giant (structure) **OR** Lattice (structure) IGNORE Whether stated as ionic or covalent for this mark **(1)** **TiO_2** **'Bonding' mark** EITHER **Strong** (electrostatic) attraction between ions ALLOW **Strong** ionic bonds / ionic bonds require a lot of energy to break **OR** **Strong** covalent bonds/covalent bonds require a lot of energy to break **(1)** **$TiCl_4$** **'Structure' mark** (Simple) molecules / (small) molecules **/**molecular **(1)** **$TiCl_4$** **'Bonding' mark** **Weak** London / dispersion / van der Waals' forces (between molecules) / London /dispersion / van der Waals' forces (between molecules) require little energy to break	TiO_2 (small) molecule**s** / simple molecular For TiO_2 mention of any type of intermolecular forces between molecules of TiO_2 $TiCl_4$ giant structure Covalent bonds broken (on melting) in $TiCl_4$ Ionic bonding in $TiCl_4$ Hydrogen bonding **(0)** for this mark	**4**

	NOTE If candidates assumes TiO_2 and $TiCl_4$ are both simple molecular, can score last mark for saying that the **named** intermolecular forces in TiO_2 are stronger that those in $TiCl_4$ IGNORE (Permanent) dipole-dipole forces **(1)** Mark the four scoring points independently		

Question Number	Acceptable Answers	Reject	Mark
(e)(ii)	Amphoteric ALLOW Recognisable spellings		**1**

Question Number	Acceptable Answers	Reject	Mark
(e)(iii)	$TiO_2 + 2H_2O + 2KOH \rightarrow K_2Ti(OH)_6$ OR $TiO_2 + 2H_2O + 2OH^- \rightarrow Ti(OH)_6^{2-}$ IGNORE state symbols even if incorrect		**1**

Question Number	Acceptable Answers	Reject	Mark
(e)(iv)	 **MUST** have continuation bonds at each end ALLOW CH_3 IGNORE n and any brackets	 **Two** (or more) repeat units shown	**1**

Question Number	Acceptable Answers	Reject	Mark
(f)(i)	$(H_2O_2 + 2H^+ +)$ **$2e^{(-)} \rightarrow 2H_2O$** **BOTH** $2e^{(-)}$ **and** **2**H_2O needed for the mark		**1**

Question Number	Acceptable Answers	Reject	Mark
(f)(ii)	(Moles H_2O_2 = $\frac{0.0200 \times 22.50}{1000}$ =) 4.5×10^{-4} mol H_2O_2 **(1)** (Moles Ti^{3+} reacting in 25.0 cm^3) = 9.0×10^{-4} mol Ti^{3+} (Moles Ti^{3+} in 250 cm^3) = 9.0×10^{-3} mol Ti^{3+} **(1)** (Original concentration of Ti^{3+} = $\frac{9.0 \times 10^{-3}}{0.00500}$ =) 1.8 (mol dm^{-3}) **(1)** 1.8 (mol dm^{-3}) with or without working scores **(3)** **NOTES:** If mole ratio H_2O_2 : Ti^{3+} is 1:1 final answer for concentration of Ti^{3+} is 0.9 (mol dm^{-3}) scores **(2)** overall If mole ratio H_2O_2 : Ti^{3+} is 2:1 final answer for concentration of Ti^{3+} is 0.45 (mol dm^{-3}) scores **(2)** overall If candidate forgets to multiply no. of moles of Ti^{3+} by 10 then answer is 0.18 (moldm-3) this scores **(2)** If volume of H_2O_2 used is 25.0 no first mark, but can score **(2)** if final answer CQ is 2(.0) (mol dm^{-3})		**3**

Question Number	Acceptable Answers	Reject	Mark
(f)(iii)	(It/titanium(III)/Ti^{3+}) **oxidized** (by oxygen in the air) ALLOW 'It is a **strong** reducing agent'	Hydrolysis	**1**

Q5.

Question Number	Answer	Additional Guidance	Mark
(i)	• balanced equation	Example of equation $3Cl_2 + 6OH^- \rightarrow 5Cl^- + ClO_3^- + 3H_2O$ Allow multiples Ignore state symbols even if incorrect	(1)

Question Number	Answer	Additional Guidance	Mark
(ii) Clip with (i)	An explanation that makes reference to the following points: • oxidation number for chlorine changes from 0 to -1 so it is **reduced** **(1)** • oxidation number for chlorine changes from 0 to +5 so it is **oxidised** **(1)**	Ignore general definitions of disproportionation Accept oxidation numbers and their changes shown with equation Allow 1 out of 2 marks for three correct oxidation numbers of the chlorine	(2)

Q6.

Question Number	Acceptable Answers	Reject	Mark
(a)(i)	**First two marks** Cl in Cl_2 is 0 Goes to +1 in HClO Goes to −1 in HCl **(2)** All three correct for two marks Any two correct for one mark Ignore correct oxidation numbers for other elements If three correct numbers given without saying what species they are in max 1 for these two marks **Third mark** Cl/Cl_2/the same element is both oxidized and reduced Allow same molecule/species/ type of atom is both oxidized and reduced if answer elsewhere has been in terms of chlorine OR Cl/Cl_2/the same element both increases and decreases in oxidation number OR Chlorine both loses and gains electrons **(1)**	Only 'Cl^+' for oxidation number +1 Only 'Cl^-' for oxidation number -1 (treat each separately) For each incorrect oxidation number change for O and H, lose one mark. 0 to +1 described as reduction and/or 0 to -1 described as oxidation (for third mark)	**3**

Question Number	Acceptable Answers	Reject	Mark
(a)(ii)	Equilibrium moves to the left / moves in reverse direction / moves to increase concentration of reactants **(1)** To use up (some of) added HCl/ to react with added HCl/ to stop formation of HCl/ restores equilibrium by producing more chlorine and water **(1)** Second mark depends on first Allow 'moves to decrease concentration of products/HCl' for both marks	Just "reverse reaction is **favoured**" Just "to counteract the change in the system" To minimise effect of HCl	**2**

Question Number	Acceptable Answers	Reject	Mark
(b)(i)	$ClO^- + 2H^+ + 2e^{(-)} \rightarrow Cl^- + H_2O$ ALLOW $ClO^- + 2H^+ \rightarrow Cl^- + H_2O - 2e^{(-)}$ **(1)** $2I^- \rightarrow I_2 + 2e^{(-)}$ ALLOW $2I^- - 2e^{(-)} \rightarrow I_2$ **(1)** Allow multiples Ignore state symbols even if incorrect	Equations without electrons	**2**

Question Number	Acceptable Answers	Reject	Mark
(b)(ii)	$ClO^- + 2H^+ + 2I^- \rightarrow Cl^- + H_2O + I_2$ Mark independently. No TE on 21(b)(i)	Equations including electrons	**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(iii)	Moles thiosulfate = (24.20 x 0.0500 / 1000) = 1.21×10^{-3} /1.2×10^{-3} /0.00121/ 0.0012 (mol) **(1)** Moles iodine = half moles of thiosulfate = 6.05×10^{-4} / 6.1×10^{-4} / 0.000605 / 0.00061 (mol) **(1)** Correct answer without working **(2)**	1.20×10^{-3} (mol) $1x\ 10^{-3}$/ 0.001 6.0×10^{-4} (mol) 6×10^{-4} (mol)	**2**

Question Number	Acceptable Answers	Reject	Mark
(b)(iv)	Moles ClO^- = 6.05×10^{-4} (mol) TE on (b)(ii) and (b)(iii): If ratio ClO^- :I_2 = 2:1 answer is 2 x answer to (b)(iii) If ratio ClO^- :I_2 = 1:2 answer is half of answer to (b)(iii)		**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(v)	Concentration = (6.05×10^{-4} x 1000/25) = 2.42×10^{-2} / 0.0242/ 0.024/ 2.4×10^{-2} (mol dm^{-3}) TE. Answer to (b)(iv) x 1000÷ 25	Answers to 1 significant figure	**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(vi)	(Minimum) amount of I^- to react with OCl^- =2 x answer to (b)(iv) = 2 x 6.05 x 10^{-4} = 1.21 x 10^{-3} (mol) **(1)** Allow TE for 2 x answer to (b)(iv) Ignore s.f. Moles of I^- (9.04 x 10^{-3}) is more than this number of moles of ClO^- / I^- is in excess / KI is in excess / so that all the ClO^- can react **(1)** **OR** 9.04 x 10^{-3} mol I^- can react with 4.52 x 10^{-3} mol OCl^- **(1)** Ignore s.f. TE from incorrect equation in (b)(ii) Moles OCl^- (6.05 x 10^{-4}) is less than this/ I^- is in excess / KI is in excess / so that all the ClO^- can react **(1)**	"KI is in excess" if no calculation has been done.	**2**

Question Number	Acceptable Answers	Reject	Mark
(b)(vii)	0.30 x 100 / 24.2 (=1.2396694) = 1.24/ 1.2 %		**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(viii)	Judgement (of colour change) at end point / adding starch too early in the titration / jet of burette not filled Errors must cause an increase in titre. Ignore Just "Human error" Just 'overshot endpoint' Transfer errors / spillage Errors due to misreading burette / pipette	Some potassium iodide did not dissolve Leaving funnel in burette Errors which affect both the students titre and an accurate titre using the same solutions e.g. impure solutions	**1**

Question Number	Acceptable Answers	Reject	Mark
(c)	(Cl radicals) break down ozone (layer)/ ozone depletion / ozone (layer) thinning Allow damage ozone (layer)/ react with ozone	Global warming Causes acid rain	**1**

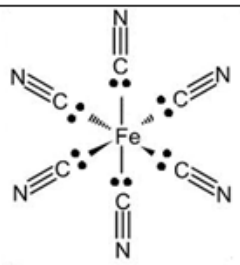
Q7.

Question Number	Answer	Additional Guidance	Mark
(i)	• four correct species **(1)** • balancing and the correct number of electrons **(1)**	An example of equation $[Cr(OH)_6]^{3-} + 2OH^- \rightarrow CrO_4^{2-} + 4H_2O + 3e^-$ Accept multiples	**(2)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• equation	An example of equation $2CrO_4^{2-} + 2H^+ \rightarrow Cr_2O_7^{2-} + H_2O$ Accept $\rightleftharpoons$ / multiples	**(1)**

Question Number	Answer	Additional Guidance	Mark
(iii)	• oxidation half equation **(1)** • reduction half equation **(1)** • overall equation **(1)**	$H_2O_2 \rightarrow 2H^+ + O_2 + 2e^-$ $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$ $Cr_2O_7^{2-} + 8H^+ + 3H_2O_2 \rightarrow 2Cr^{3+} + 7H_2O + 3O_2$ for M3 do not award if H^+/ e^- left on both sides Accept multiples Allow ⇌ Ignore state symbols even if incorrect Oxidation and reduction half equations scores (2) if not identified but in correct order Award (1) only for M1 and M2 if half equations are not in correct order No TE on incorrect half equations	**(3)**

Q8.

Question number	Answer	Additional guidance	Marks
(a)(i)	A		1
(a)(ii)	 • 3D shape correctly shown (1) • electron pairs shown OR all six bonds shown clearly to the carbons (1)	Charge and square brackets not required Allow dotted lines for the wedges going backwards Allow arrows to represent dative covalent bonds instead of electron pairs	2
(b)	• step 1 – ligand substitution/ligand exchange (1) • step 2 – redox (1)	Allow reduction **and** oxidation Allow oxidation	2
(c)	• identification: green precipitate is iron(II) hydroxide (1) Explanation: • precipitate turns brown because iron(II) hydroxide is oxidised by oxygen (and water) in the air (1) • to form iron(III) hydroxide (1)	$Fe(OH)_2$ / $Fe(H_2O)_4(OH)_2$ $Fe(OH)_3$ / $Fe(H_2O)_3(OH)_3$	3

Q9.

Question Number	Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • oxidation numbers of Br identified as (+)5 for BrO_3^-, −1 for Br^- and 0 for Br_2 **(1)** • this is not disproportionation because: two different species of bromine / reactants are oxidised and reduced / not one species oxidised and reduced **or** only one species containing bromine is produced / two different species containing bromine in two different oxidation states are not produced **(1)**	These may be shown in the equation Allow 5+ / V / 1− / −I Do not award any change in oxidation numbers of oxygen and or hydrogen Allow bromine is oxidised and reduced in the reverse reaction Allow this is reverse disproportionation / comproportionation	**(2)**

Question number	Answer	Mark
(ii)	**The only correct answer is D** (cannot tell from this information) ***A*** *is incorrect because there are 3 reactant species but the overall order of a reaction can only be determined by experiment* ***B*** *is incorrect because there is 1 bromate ion and 5 bromide ions but the overall order of a reaction can only be determined by experiment* ***C*** *is incorrect because there are 12 reactant particles but the overall order of a reaction can only be determined by experiment*	**(1)**

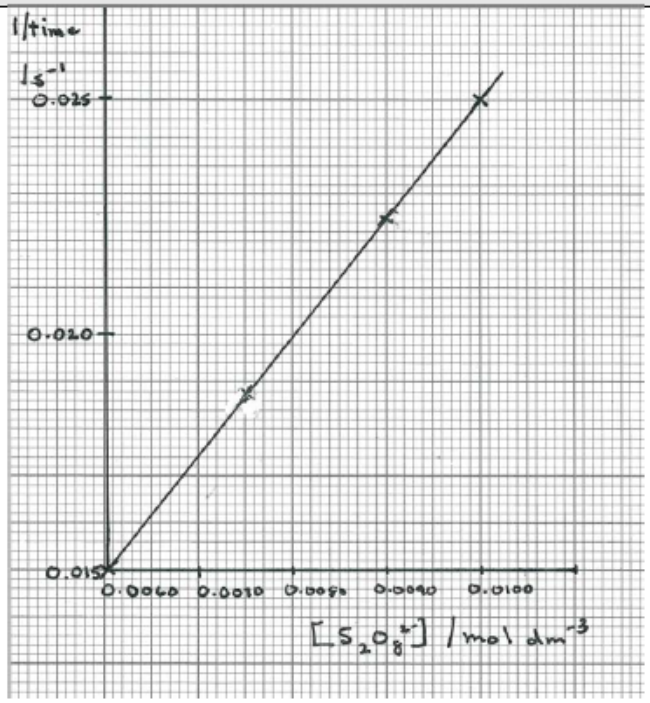
Q10.

Question Number	Correct Answer	Reject	Mark
(a)	$S_2O_8^{2-} + 2I^- \rightarrow 2SO_4^{2-} + I_2$ ALLOW multiples Ignore state symbols even if incorrect		**1**

Question Number	Correct Answer	Reject	Mark
(b)(i)	Blue/black /blue-black OR Colourless to blue-black/ blue/black	Purple	**1**

Question Number	Correct Answer	Reject	Mark
(b)(ii)	The mixture would change colour/ go blue/black /blue-black **immediately/straight away** ALLOW ...too quick(ly)/too early ...quicker ...no time delay		**1**

Question Number	Correct Answer	Reject	Mark
(b)(iii)	(As quickly as iodide reacts to form iodine it is) reduced/turned back to iodide by the thiosulfate ions ALLOW Persulfate reacts with thiosulfate first. OR Iodine reacts with thiosulfate.		**1**

Question Number	Correct Answer	Reject	Mark
(c)(i)	 **First mark** Correct graph of rate v concentration, with axes correct **and** values increasing on both axes labelled with quantity **and** units Note Units may be given in brackets with no slash. s/time meaning s divided by time is fine. **(1)**		**2**
	Second mark Sensible scales to use at least half the graph paper but allow graphs starting at the origin and points cover two by two big squares. Linear scales All points reasonably correct with straight line drawn **(1)** Second mark depends on correct graph of rate v concentration, but not other detail of first mark		

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Question Number	Correct Answer	Reject	Mark
(c)(ii)	First order This mark is independent of the graph drawn **(1)** Because the graph is a straight line (through the origin)/ rate is proportional to $[S_2O_8^{2-}]$ OR As concentration increases by (factor of) 2 rate increases by 2 (or any other numbers, including 'x') OR Rate increases linearly (with concentration) OR Gradient of line is constant **(1)** Second mark depends on first order	Just 'as concentration increases rate increases'	**2**

Question Number	Correct Answer	Reject	Mark
(c)(iii)	Rate = $k[S_2O_8^{2-}][I^-]$ **(1)** TE from (c)(ii) Units - $dm^3\ mol^{-1}\ s^{-1}$ ALLOW Internal TE from rate equation **(1)** Units in any order	Incorrect formulae	**2**

Q11.

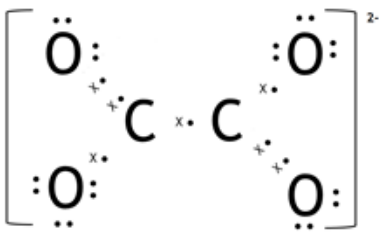
Question Number	Acceptable Answers	Reject	Mark
(i)	$2Cu^{+}(aq) \rightarrow Cu(s) + Cu^{2+}(aq)$ IGNORE Eqm sign for →	Reverse equation Any equation involving electrons	1

Question Number	Acceptable Answers	Reject	Mark
(ii)	Both white ALLOW (both) Colourless (1) COMMENT Ignore states eg solution/precipitate As have $3d^{10}$ / have a full 3d sub-shell /**ALL** 3d orbitals are full (1) IGNORE Does not have partially filled d orbitals They do not absorb light No d-d transitions occur		2

Q12.

Question Number	Correct Answer	Reject	Mark
(a)	C		**1**
(b)	A		**1**

Q13.

Question Number	Answer	Additional Guidance	Mark
(i)	• double C=O bond on left and right hand side **(1)** • rest of diagram **(1)**		(2)

Question Number	Answer	Additional Guidance	Mark
(ii)	• (+) 3	Allow 3+ / +III / III+ / III / three Ignore working out Do not award ±3	(1)

Q14.

Question Number	Correct Answer	Reject	Mark
	A		1

Q15.

Question Number	Correct Answer	Reject	Mark
	C		1

Q16.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• phosphate(III) (ion)	Name **and** oxidation number are required Allow gap between name and oxidation number Allow phosphate and +3 Ignore missing brackets around oxidation number Do not award phosphorus / trioxide / phosphite(III)	(1)

Q17.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	• MnO_2, MnO_4^-, OH^- and MnO_4^{2-} species correct in a single equation **(1)** • H_2O on right **and** balancing **(1)**	Example of equation $MnO_2 + 2MnO_4^- + 4OH^- \rightarrow 3MnO_4^{2-} + 2H_2O$ Ignore state symbols, even if incorrect Do not award M1 if H^+ is on the left Allow cancelled electrons Allow multiples	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(ii)	An answer that makes reference to: • 2 different species are oxidised and reduced (to form the same species) **or** there is not 1 species that is being oxidised and reduced **or** 2 different oxidation states are not produced from one oxidation state **or** only 1 oxidation state / +6 is formed as a product **or** Mn changes from +4 and +7 to +6 (only)	This mark can be awarded even if (i) is incorrect Allow manganate(VI) / MnO_4^{2-} is oxidised and reduced in the reverse reaction Allow Mn in the same species is not being oxidised and reduced Ignore just 'Mn is not simultaneously oxidised and reduced' Ignore this is reverse disproportionation / comproportionation Do not award O / H is oxidised / reduced Do not award molecules / compounds for species	**(1)**

Q18.

Question Number	Answer	Additional guidance	Mark
(a)	• $C_6H_5COOH + CaO \rightarrow C_6H_6 + CaCO_3$	Accept $C_6H_5COOH + CaO \rightarrow C_6H_6 + CaO + CO_2$	1
(b)	An answer that makes reference to the following points: • -2 in cyclohexane and -1 in benzene (1) • so (carbon is) oxidised (1)	2nd mark stands alone	2

Q19.

Question Number	Answer	Additional Guidance	Mark
	• $KClO_3$	Allow $K^+ClO_3^-$	(1)

Q20.

Question Number	Correct Answer	Reject	Mark
	C		**1**

Q21.

Question Number	Answer	Mark
	The only correct answer is C ***A*** *is not correct because it is +1 not +3* ***B*** *is not correct because it is +2 not +3* ***D*** *is not correct because it is +2 not +3*	**(1)**

Q22.

Question Number	Answer	Additional Guidance	Mark
(i)	• chlorine is oxidised **and** from 0 to +1 (in NaClO) **(1)** • chlorine is reduced **and** from 0 to -1 (in NaCl) **(1)**	Check the equation Allow (1) for three correct oxidation numbers if no other mark is awarded. Allow (1) max for general definition of disproportionation	**(2)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• equation	$6\ NaOH + 3\ Cl_2 \rightarrow NaClO_3 + 5\ NaCl + 3\ H_2O$ Allow multiples	**(1)**

Question Number	Answer	Mark
(iii)	**The only correct answer is C** (hot alkali) **A** *is not correct because high temperature is required* **B** *is not correct because high temperature is required* **D** *is not correct because high temperature and not excess chlorine is required*	**(1)**

Q23.

Question Number	Correct Answer	Reject	Mark
	D		**1**

Q24.

Question Number	Acceptable Answers	Additional Guidance	Mark
	+5	Allow 5+ / +V / V+ / (V) / 5 Do not award V^+	**(1)**

Q25.

Question number	Answer	Additional Guidance	Marks
(a)	**C** ([Ar] $3d^6 4s^0$)		**1**

Question number	Answer	Additional Guidance	Marks
(b)(i)	**D** (+6)		**1**

Question number	Acceptable Answer	Additional Guidance	Marks
(b)(ii)	• $E^\ominus$ for the reaction is +0.97 V (1) • because $E^\ominus$ is positive FeO_4^{2-} will react and so is unstable (in acidic conditions) (1) • $4FeO_4^{2-} + 20\ H^+ \rightarrow 4Fe^{3+} + 10\ H_2O + 3O_2$ – correct species (1) – balancing (1)	Accept correct use of 'anti-clockwise rule' Award 1 mark for: $4FeO_4^{2-} + 32H^+ + 6H_2O \rightarrow 4Fe^{3+} + 16H_2O + 3O_2 + 12H^+$ Ignore state symbols	**4**

Question number	Answer	Additional Guidance	Marks
(c)	**B** ($Cl_2(g)$)		**1**

Q26.

Question Number	Answer	Mark
(i)	**The only correct answer is A** ***B*** *is not correct because* Cl^- *is not an oxidising agent* ***C*** *is not correct because* I_2 *is not a powerful enough oxidising agent* ***D*** *is not correct because* Mn^{2+} is not an oxidising agent	**(1)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• all species on correct sides of equation **and** no electrons / electrons cancelled **(1)** • balancing correct species **(1)** • $E^{\ominus}_{cell}$ value **(1)**	Example of ionic equation $2MnO_4^- + 16H^+ + 10Br^- \rightarrow 2Mn^{2+} + 8H_2O + 5Br_2$ Allow ⇌ Allow correct species if shown in working with half-equations but slip made in final equation e.g. charge missing Ignore state symbols Allow multiples Allow M2 for almost correct species $E^{\ominus}_{cell}$ (= 1.51 − 1.09) = (+)0.42 (V) No TE on incorrect equation	(3)

Q27.

Question Number	Acceptable Answers	Reject	Mark
(a)(i)	$Cr_2(SO_4)_3(aq) = Cr(H_2O)_6^{3+}$ ALLOW $Cr^{3+}(aq)$ / Cr^{3+} **(1)** A = $Cr(H_2O)_3(OH)_3$ / $Cr(OH)_3$ **(1)** B = $Cr(H_2O)_2(OH)_4^-$ / $Cr(OH)_4^-$ / $Cr(OH)_6^{3-}$ **(1)** C = CrO_4^{2-} **(1)** IGNORE SO_4^{2-} and/or Na+		**4**

Question Number	Acceptable Answers	Reject	Mark
(a)(ii)	$H_2O_2 + 2e^{(-)} \rightarrow 2OH^-$		**1**

Question Number	Acceptable Answers	Reject	Mark
(a)(iii)	Sulfuric acid / H_2SO_4 ALLOW Name or formula of any strong acid (e.g. HCl) IGNORE H^+ and 'an acid' Dilute or concentrated		**1**

Question Number	Acceptable Answers	Reject	Mark
(a)(iv)	$2CrO_4^{2-} + 2H^+ \rightarrow Cr_2O_7^{2-} + H_2O$ ALLOW Equation showing Na^+ and anion on both sides IGNORE State symbols even if incorrect	Non-ionic equations	**1**

Question Number	Acceptable Answers	Reject	Mark
(b)	**First mark for both half equations** Mentions / some evidence for the use of BOTH half equations in any way even if reversed or left unbalanced $Cr^{3+}(aq) + e^- \rightarrow Cr^{2+}(aq)$ ($E^\ominus = -0.41$ V) $Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^-$ $\rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$ ($E^\ominus = +1.33$ V) **(1)** **Second mark for** $8Cr^{3+}(aq) + 7H_2O(l) \rightarrow 6Cr^{2+}(aq) + Cr_2O_7^{2-}(aq) + 14H^+(aq)$ **(1)** **Third mark for** $E^\ominus_{cell} = -0.41 - 1.33 = -1.74$ (V) For **second** and **third marks,** ALLOW reverse equation and $E^\ominus_{cell}$ = **+**1.74 (V) (for **reverse** reaction) **(1)** ALLOW 1.74 (V) only if 'positive' stated in words elsewhere **Fourth mark for** EITHER Disproportionation / (proposed) reaction / "it is" **not feasible** (because its $E^\ominus_{cell}$ is negative) OR Reverse of disproportionation **is feasible** (because its $E^\ominus_{cell}$ is positive) **(1)** IGNORE state symbols even if incorrect ALLOW $\rightleftharpoons$ instead of $\rightarrow$ Third and fourth marks can be awarded CQ on incorrect half equation(s) and stated $E^\ominus$ values		**4**

Q28.

Question number	Answer	Additional guidance	Marks
(a)	$Cl_2 + 2NaOH \rightarrow NaOCl + NaCl + H_2O$	Accept $Cl_2 + 2OH^- \rightarrow OCl^- + Cl^- + H_2O$ Ignore state symbols	1
(b)	An explanation that makes reference to the following points: • Cl has oxidation number +4 to in ClO_2 (1) • Cl (in ClO_2) changes oxidation number to +3 (ClO_2^-) and +5 (ClO_3^-) (1) • (therefore) chlorine/it (in ClO_2) has been both oxidised and reduced (1)	Accept 4+ Accept 3+ and 5+ Allow answers in any order	3
(c)(i)	A		1
(c)(ii)	An answer that makes reference to the following points: • Mn changes from +7 to +2 and Cl changes from -1 to 0 (1) • therefore ratio is MnO_4^- to $5Cl^-$ /the ratio of MnO_4^- to Cl^- is 1 to 5 (1)	Accept 7+ and 2+ Accept 1–	2
(d)(i)	An explanation that makes reference to the following points: • the HBr dissolves in water (in the air) (1) • and forms droplets (of hydrobromic acid) (1)		2
(d)(ii)	• the (conc.) H_2SO_4 is reduced to SO_2 (1)	Accept redox	1

Q29.

Question Number	Acceptable Answer	Additional guidance	Mark
(a)(i)	correct equation	Example of equation: $2NaN_3 \rightarrow 2Na + 3N_2$ Allow multiples Ignore state symbols even if incorrect	(1)

Question Number	Acceptable Answer	Additional guidance	Mark
(a)(ii)	• conversion of volume and temperature to correct units **(1)** • rearrangement of ideal gas equation so n=$pV \div RT$ and calculation of n(N_2) in moles **(1)** • evaluation of n(NaN_3) **(1)** • answer converted into mass to 2/3 SF **(1)** Allow TE at each stage	Example of calculation: 67 dm^3 = 0.067 m^3, 300°C = 573 K n(N_2) = 140 000 x 0.067 = 8.31 x 573 = 1.9699…..(mol) n(NaN_3) = (2/3 x 1.9699…..=) 1.313….(mol) m= (1.313 …. x 65 = 85.3629..=) = 85.4 / 85 (g) Correct answer without working scores (4)	**(4)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)	An answer that makes reference to the following points: • Nitrogen (is reduced) from +5 to 0 **(1)** • Sodium (is oxidised) from 0 to +1 **(1)** • Balanced equation **(1)**	Look for oxidation numbers annotated on the equation Do not award potassium oxidised Penalise omission of "+" sign, once only Example of balanced equation: **10**Na +**2**$KNO_3 \rightarrow K_2O$+ **5**Na_2O + N_2 Allow multiples	**(3)**

Question Number	Acceptable Answer	Additional guidance	Mark
(c)	An answer that makes reference to the following points: • Neutralisation reaction / acid base reaction **(1)** • Sodium and/or potassium oxides are caustic / corrosive **(1)** • Salts (silicates) formed are inert / unreactive **(1)**	Allow salt formation Allow "metal oxides" Ignore "harmful" / "alkaline" Allow "not harmful"/ "not caustic" Ignore "neutral"	**(3)**

Question Number	Acceptable Answer	Mark
(d)	The only correct answer is **A** ***B*** *is incorrect because the peak would shift to the left and be higher* ***C*** *is incorrect because the peak would shift to the left not to the right* ***D*** *is incorrect because the peak would be shift to the left not to the right*	**(1)**

Q30.

Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • N changes from (+)5 to (+)4 **(1)** • O changes from −2 to 0 (in O_2) **(1)** • so nitrogen / N is reduced (as the oxidation number has decreased) **and** oxygen / O (in forming O_2) is oxidised (as the oxidation number has increased) **(1)**	These numbers may be written under the formulae in the equation Allow oxidation numbers written as 5+, 4+, 2− Ignore unchanged oxidation numbers of magnesium and oxygen Allow this mark if incorrect / missing oxidation numbers in M1 and M2 Ignore general statement about redox Ignore redox explained in terms of electron gain or loss	**(3)**

Q31.

Question Number	Correct Answer	Reject	Mark
(a)	C		**1**
(b)	A		**1**

Q32.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• (a reducing agent) increases in oxidation number **and** loses electron(s)	Allow oxidation number becomes more positive / gets larger Allow donates / gives electrons / number of electrons decreases Ignore a reducing agent decreases the oxidation number of another substance	**(1)**

Q33.

Question number	Acceptable Answer	Additional Guidance	Marks
(a)	An answer that makes reference to the following points: • a species that gains electrons **OR** a species that removes (one or more) electrons from another species		**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)	An explanation that makes reference to one of the following pairs: **either** • oxidation number of Cl changes from +5 to +4 (1) • therefore ClO_3^- is the oxidising agent (because Cl (in ClO_3^-) has been reduced) (1) **or** • oxidation number of S changes from +4 to +6 (and oxidation number of H does not change) (1) • (therefore S (in SO_2) has been oxidised) therefore ClO_3^- is the oxidising agent (1)	Allow oxidation number of Cl goes down by 1 Allow oxidation number of S goes up by 2 (and oxidation number of H does not change)	**2**

Question number	Acceptable Answer	Additional Guidance	Marks
(c)(i)	$2ClO_2 + 2OH^- \rightarrow ClO_2^- + ClO_3^- + H_2O$ • species (1) • balanced (1)	Ignore state symbols	**2**

Question number	Acceptable Answer	Additional Guidance	Marks
(c)(ii)	An answer that makes reference to the following point: • because chlorine (in ClO_2) is both oxidised and reduced	Allow chlorine has gone from +4 to +3 and +5 (maybe shown underneath the equation in ci)	**1**

Q34.

Question Number	Answer	Additional guidance	Mark
(i)	• calculation of moles of $VCl_2(aq)$ **(1)** • calculation of moles of $Cl_2(g)$ **(1)** • deduction of whole number ratio of V^{2+} : Cl_2 **(1)** • deduction of electrons lost per vanadium ion **(1)** • deduction of final oxidation number of V **(1)**	Example of calculation $(40/1000) \times 0.100 = 4 \times 10^{-3}$ / 0.004 (mol) $(144/24000) = 6 \times 10^{-3}$ / 0.006 (mol) $2V^{2+} : 3Cl_2$ allow $V^{2+} : 1.5Cl_2$ 6 electrons lost by $2V^{2+}$, so 3 lost per V^{2+}, (+)5 Allow TE throughout Correct answer with no working scores M5 only	**(5)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• purple / lilac / violet **(1)** • to yellow (solution) **(1)**	Ignore references to blue / green / turquoise or similar, as intermediate colours, regardless of order If no final oxidation state given in (d)(i) do not award M2 Allow lavender / mauve for M1 Mark consequentially from (d)(i) Do not award colourless Use list principle for additional inappropriate intermediate colours e.g. red / pink For consequential marking from (d)(i) V(IV) – blue ; V(III) – green If both colours are given but the wrong way round, allow 1 mark out of 2	**(2)**

Q35.

Question Number	Correct Answer	Reject	Mark
	C		**1**

Q36.

Question Number	Correct Answer	Reject	Mark
	A		1

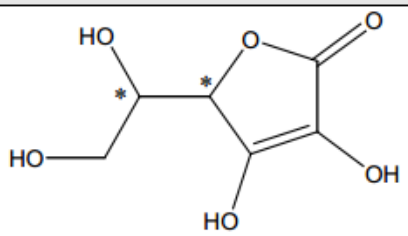
Q37.

Question Number	Acceptable Answers	Reject	Mark
15 (a)(i)	(vitamin C / ascorbic acid) oxidation / oxidized / oxidised ALLOW oxidisation	Redox / oxidation-reduction / reduction-oxidation	**1**

Question Number	Acceptable Answers	Reject	Mark
15 (a)(ii)	(very) pale yellow / straw coloured **(1)** IGNORE 'just before the end-point' blue-black to colourless (both needed) **(1)** Accept (dark) blue or black ALLOW pale yellow / straw coloured to colourless for 1/2	Just 'yellow' Clear	**2**

Question Number	Acceptable Answers	Reject	Mark
15 (a)(iii)	Moles $S_2O_3^{2-}$ = 27.85 x 10^{-3} x 0.0631 **(1)** (= 1.757335 x 10^{-3}) moles of I_2 remaining = Moles $S_2O_3^{2-}$ ÷ 2 = 27.85 x 10^{-3} x 0.0631 ÷ 2 = 8.786675 x 10^{-4} = 8.79 x 10^{-4} **(1)** Moles ascorbic acid = moles I_2 at start – moles I_2 remaining = 2.00 x 10^{-3} – 8.786675 x 10^{-4} = 1.1213325 x 10^{-3} = 1.12 x 10^{-3} **(1)** M_r (ascorbic acid) = 176 Mass ascorbic acid in 250 cm^3 = 10 x M_r x moles ascorbic acid = 10 x 176 x 1.1213325 x 10^{-3} **(1)** (= 1.97355) Percentage ascorbic acid in tablet 100 x mass ascorbic acid in 250 cm^3 ÷ 2 = 100 x 10 x 176 x 1.1213325 x 10^{-3} ÷ 2 = 98.67726 = 98.7% **(1)** IGNORE SF except 1 SF Premature rounding gives 98.5% (5) Correct answer with no working scores full marks TE at each stage of the calculation.	Answers greater than 100%	**5**

Question Number	Acceptable Answers	Reject	Mark
15(a)(iv)	EITHER Using larger **mass** reduces the percentage error / uncertainty (in weighing) OR Using larger amount reduces the percentage error / uncertainty in **weighing** OR Reverse discussion of two tablets ALLOW using four tablets gives a more representative sample	Just 'reduces the percentage error' Titration value will be larger (with four tablets) so reduces the percentage error (in volume measurement)	**1**

Question Number	Acceptable Answers	Reject	Mark
15 (b)(i)	 **(2)** Mark independently ALLOW any clear indication of chiral centres		**2**

Question Number	Acceptable Answers	Reject	Mark
15 (b)(ii)	**First mark** Use of (plane-)polarized light (mentioned somewhere) **(1)** ALLOW Use a polarimeter **Second mark** Pure optical isomer / enantiomer) **rotates** the **plane** of (plane-) polarized light OR racemic mixture has no effect on the **plane** of (plane-) polarized light **(1)** IGNORE optically active / inactive ALLOW rotates plane-polarized light scores 2		**2**

Question Number	Acceptable Answers	Reject	Mark
15(b)(iii)	(Ester group / vitamin C / it) is hydrolysed ALLOW Vitamin C is oxidized Ester / vitamin C is broken down to form carboxylic acid **and** alcohol (groups) IGNORE Just 'breaks down'	C=O is broken Just 'oxidation'	1