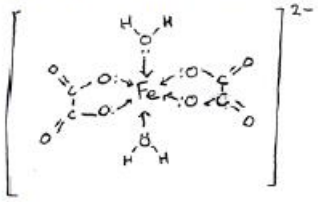
Mark Scheme

Q1.

Question Number	Answer	Additional Guidance	Mark
	An answer that makes reference to the following points (Justification) • two moles of chloride ions in aqueous solution so one mole of chloride ion is in the complex (1) • complex ion formula (1)	$[Cr(H_2O)_5(Cl)]^{2+}$	(2)

Q2.

Question Number	Answer	Additional Guidance	Mark
(i)	• 2 water ligands joined between O and Fe **(1)** • 2 ethanedioate ligands drawn correctly showing all the bonds **and** joined between single-bonded O atoms and Fe as shown **(1)**	Example of structure  Allow water ligands arranged as *cis* or *trans* Allow delocalised bonds in ethanedioate ions Allow bonds not shown in H_2O, provided the ligands are attached to Fe^{2+} through oxygen atoms Ignore bond lengths and angles Ignore wedges and dotted lines to show shape Ignore missing lone pairs and arrowheads Ignore missing square brackets and charge / incorrect charge Ignore –ve charges on ethanedioate ions / +ve charge on Fe	**(2)**

Question Number	Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to the following points: • (there are) more particles / moles / species on the right of the equation (than on the left) **or** (there is an increase from) 3 particles on the left of the equation to 5 on the right **(1)** • so ΔS_{system} increases / is positive (and $\Delta S_{surroundings}$ is unchanged so ΔS_{total} increases) **(1)**	Do not allow incorrect numbers of particles Do not allow 3 molecules on the left and 5 molecules on the right Allow ΔS_{total} is positive / increasing Allow entropy / ΔS increases Allow there is a positive entropy change Ignore just there is an increase in disorder (from left to right) Ignore $\Delta S_{surroundings}$ changes Ignore just 'entropy is positive' Ignore references to free energy	(2)

Q3.

Question Number	Answer	Additional Guidance	Mark
(i)	• ammonium ions do not have a lone pair (of electrons for bonding)	Allow ammonium ions are positive and so are repelled (by the positive metal cation) Ignore reference to it already having a dative/coordinate bond	(1)

Question Number	Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to • d orbitals/d sub-shell split (into two different energies) (1) • difference in energy depends on the ligands (1) • difference in energy leads in different frequencies/wavelengths/photons of light absorbed (1) • (so) the unabsorbed frequencies/wavelengths/photons are reflected/transmitted (1)	Ignore 'distort' Do not award splitting of singular d orbital Allow 'colour seen' for reflected/transmitted Do not award 'emission' Do not award M3 nor M4 if reference to electron 'falling' releases energy is stated	(4)

Q4.

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)**

Q5.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	A description that makes reference to the following points: • (blue solution initially forms pale) blue precipitate **(1)** • (which dissolves to) form dark/deep/royal blue solution **(1)**	Allow 'solid' / 'ppt' for 'precipitate' Do not award for 'blue crystals' Do not allow dark blue ppt	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(ii)	$[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4H_2O$ • LHS of equation correct **(1)** • RHS of equation correct **(1)**	Ignore state symbols even if incorrect Ignore balanced sulfate ions Do not award just Cu^{2+} on LHS Allow $[Cu(OH)_2(H_2O)_4] + 4NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 2H_2O + 2OH^-$ Do not award for $[Cu(NH_3)_4]^{2+}$ / $[Cu(NH_3)_6]^{2+}$ on RHS	**(2)**

Q6.

Question Number	Answer	Additional Guidance	Mark
	An answer that makes reference to the following points • **adsorption** of CO and/or NO molecules on the catalytic surface **(1)** • weakening of bonds (and chemical reaction between CO and NO) **(1)** • desorption of CO_2 and/or N_2 /product (molecules) from the catalytic surface **(1)**	Allow 'active site' for surface Do not award **absorption** Do not award weaken the bonds between molecules Allow bonds break (within CO and NO) Allow de-adsorption for desorption Do not award desorption of the reactants Do not award reference to incorrect products such as $H_2/O_2/C/NO_2$ Penalise omission of catalytic surface once only	**(3)**

Q7.

Question Number	Answer	Additional Guidance	Mark
	An answer that makes reference to the following point: • there is only a gradual / steady increase in (successive ionisation energies)	Allow they / the (successive) ionisation energies are close in value / similar Allow the extra ionisation energy to increase oxidation state is similar to the increase in hydration enthalpy / lattice energy Ignore chromium is a transition element Ignore 3d (and 4s) orbitals have similar energy Ignore Cr is [Ar]$3d^5 4s^1$ so can lose 6 electrons Ignore reference to electrons being removed from the d-orbital	**(1)**

Q8.

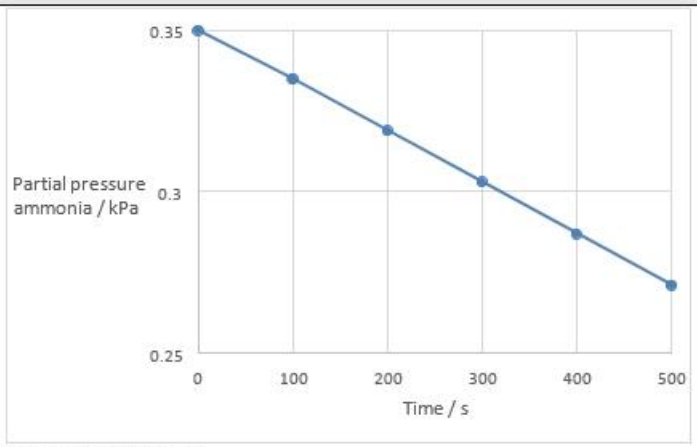
Question Number	Answer	Additional Guidance	Mark
(i)	• correct species **(1)** • balancing **(1)**	Example of equation $Cr_2O_7^{2-} + 14H^+ + 3Zn \rightarrow 2Cr^{3+} + 7H_2O + 3Zn^{2+}$ Allow multiples Allow ⇌ provided equation written in direction shown Ignore state symbols even if incorrect Do not award uncancelled electrons	**(2)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• calculation of $E^{\ominus}_{cell}$	Example of calculation ($E^{\ominus}_{cell}$ = 1.33 – (–0.76)) = (+) 2.09 (V) Allow –2.09 (V) if equation written in reverse in (c) (i) Correct answer with no working scores (1)	(1)

Question Number	Answer	Additional Guidance	Mark
(iii)	yes/zinc and acid will reduce chromium(III) ions to chromium(II) ions **and** because $E^{\ominus}_{cell}$ for the reaction between Zn and Cr^{3+} is (+) 0.35 (V) **or** Zn^{2+} / Zn electrode potential / SEP / $E^{\ominus}$ value is more negative / less positive / lower than the Cr^{3+} / Cr^{2+} value **or** Zn/ Zn^{2+} electrode potential / SEP / $E^{\ominus}$ value is less negative / more positive / higher than the Cr^{3+} / Cr^{2+}	Allow positive or >0 if not calculated Allow explanations in terms of the anti-clockwise rule	(1)

Question Number	Answer	Additional Guidance	Mark
(iv)	An explanation that makes reference to the following points: • the energy difference between the two sets of d orbitals is different in the two ions / Cr^{3+} and Cr^{2+} **or** there is different splitting of the d orbital**s** / d subshell **(1)** • electrons undergo different d-d transitions/ are promoted to a higher d-orbital absorbing/requiring a different amount of energy **or** a different amount of energy is absorbed the frequency / wavelength/colour of (visible) light absorbed is different **(1)**	Allow the d orbital energies are different Allow different charges / oxidation numbers alter the d orbital energies differently Do not award reference to a single d orbital splitting/ d orbital splitting Ignore references to charges/charge density/oxidation numbers/electron configurations of the ions Do not award references to electrons being excited and falling back to the ground state (or words to that effect) Allow the frequency / wavelength of (visible) light transmitted / reflected is different Do not award emitted instead of absorbed Ignore reference to different ligands	**(2)**

Q9.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)		 <u>Example of graph</u>	(2)
	• axes with time on x axis **and** labelled, including units **and** suitable scale **(1)**	Allow y axis labelled with partial pressure / pressure and unit Do not allow partial pressure axis starting at 0 Both axes must cover at least half the graph paper	
	• **all** points plotted correctly **and** best fit line **(1)**	Allow ± ½ square M2 can be awarded if axes the wrong way around in M1	

Question Number	Acceptable Answers	Additional Guidance	Mark
(ii)	• rate = k / rate = k x $p(NH_3)^0$ **(1)**	Allow r for rate Allow $-\text{rate} = k$ / rate = $k[NH_3]^0$ Ignore $[H_2]^0$ or $[N_2]^0$	(2)
	• (zero / 0 order) because the rate is independent of the partial pressure of ammonia / rate is constant **or** because the graph is a straight line / linear **(1)**	Conditional on M1 Allow because the gradient is constant	

Question Number	Acceptable Answers	Additional Guidance	Mark
(iii)	• calculation of gradient of graph / rate / rate constant **(1)** • corresponding units for rate constant **(1)**	Example of calculation $\frac{(0.271 - 0.350)}{500} = (-)\frac{0.079}{500}$ $k = 1.58 \times 10^{-4} / 0.000158$ Allow any value in the range 1.50 to 1.65 x 10^{-4} $1.58 \times 10^{-4} / 0.000158$ kPa s^{-1} Allow 158 x 10^{-6} kPa s^{-1} / 0.158 Pa s^{-1} / 1.58 x 10^{-1} Pa s^{-1} Do not award units of mol dm^{-3} s^{-1} Ignore SF except 1 SF Ignore negative value for k Correct answer with corresponding units and no working scores (2)	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(iv)	A description that makes reference to the following points: • adsorption of ammonia / reactant onto surface of tungsten / catalyst **(1)** • breaking bonds in ammonia / reactant **or** breaking N-H bonds **(1)** • desorption of nitrogen and hydrogen / products / gases from surface of tungsten / catalyst **(1)**	Ignore reference to heterogeneous / homogeneous / active sites Allow gas for ammonia Allow adsorb / adsorp for adsorption Ignore "stick" Do not award absorption Allow bonds weaken instead of break Ignore mention of atoms / radicals Allow products released / detached from catalyst surface Allow de-adsorbed / desorped for desorption Do not award desorption of ammonia	**(3)**

Q10.

Question Number	Answer	Additional Guidance	Mark
	A description that makes reference to • green ppt. **(1)** • ppt dissolves (in excess NaOH) to give a green solution **(1)**	Accept 'green solid' Allow 'grey-green ppt Do not award blue-green Ignore shades M2 dependent upon M1 or near-miss	**(2)**

Q11.

Question Number	Acceptable Answers	Additional Guidance	Mark
	A description that makes reference to the following points: **M1 and M2 –colours** Yellow → blue → green → violet / lavender / purple / mauve 2 or 3 colours linked to correct species / oxidation states / reactions **(1)** 4 colours linked to correct species / oxidation states / reactions **(1)** **M3 - statement** Statement that sequence is from +5 to +4 to +3 to +2 **or** (step-wise) reduction / zinc is a reducing agent **(1)** **M4, M5 and M6 - equations** These three equations, **with** appropriate $E^{\ominus}$ values $Zn + 2VO_3^- + 8H^+ \rightarrow Zn^{2+} + 2VO^{2+} + 4H_2O$ **and** $E^{\ominus} = (+)1.76$ (V) **(1)** $Zn + 2VO^{2+} + 4H^+ \rightarrow Zn^{2+} + 2V^{3+} + 2H_2O$ **and** $E^{\ominus} = (+)1.1(0)$ (V) **(1)**	M3 can be implied from species in explanation or equations Allow multiples Ignore state symbols even if incorrect 3 correct equations with incorrect $E^{\ominus}$ scores 2 2 correct equations with incorrect $E^{\ominus}$ scores 1 3 correct $E^{\ominus}$ with incorrect equations scores 1	**(7)**
	$Zn + 2V^{3+} \rightarrow Zn^{2+} + 2V^{2+}$ **and** $E^{\ominus} = (+)0.5(0)$ (V) **(1)** **M7 – stops at V^{2+}** No (further) reduction (feasible) to V metal / V(0) **or** $Zn + V^{2+} \rightarrow Zn^{2+} + V$ not feasible **or** $E^{\ominus} = -0.42$ (V) **(1)**		

Q12.

Question Number	Answer	Additional Guidance	Mark
	Tungsten • (because) adsorption is too strong and so desorption would be too slow	Ignore references to oxidation or reactivity series or cost Do not award 'absorption'	(1)

Q13.

Question Number	Answer	Additional Guidance	Mark
	• Fe^{2+} oxidised to Fe^{3+} in reaction with $S_2O_8^{2-}$ **(1)** • Fe^{3+} reduced to Fe^{2+} in reaction with I^- **(1)**	Examples of equations $2Fe^{2+} + S_2O_8^{2-} \rightarrow 2Fe^{3+} + 2SO_4^{2-}$ $2Fe^{3+} + 2I^- \rightarrow 2Fe^{2+} + I_2$ Ignore state symbols Allow equations in either order Allow multiples Penalise uncancelled electrons once only **Note** If no other mark is awarded, allow (1) for all correct species in 2 unbalanced equations	**(2)**

Q14.

Question Number	Answer	Additional Guidance	Mark
(i)	• concentration of NO in experiment 2 (1) • concentration of Cl_2 in experiment 3 (1)	Example of calculation 0.244 0.121 Do not award 0.1205 **Both** values must be to **3SF**	(2)

Question Number	Answer	Additional Guidance	Mark
(ii)	**M1** rearrangement of rate equation to find *k* (1) **M2** calculation of *k* (1) **M3** correct units for *k* (1)	Example of calculation $k = \frac{\text{rate}}{[NO]^2[Cl_2]}$ 1.09×10^{-2} $(0.122 \times 0.122 \times 0.241)$ $=3.03871 = 3.04$ Ignore SF Correct numerical answer for *k* scores both M1 and M2 $dm^6\ mol^{-2}\ s^{-1}$ Allow units in any order M3 stand alone mark	(3)

Question Number	Answer	Additional Guidance	Mark
(iii)	An explanation that makes reference to the following points: *k* increases because • the catalyst provides an alternative pathway of lower activation energy (1) • so a greater proportion of molecules / more molecules have energy greater than the activation energy (so faster reaction) (1)	Award 'particles' instead of 'molecules' Do not award "atoms" instead of 'molecules'	(2)

Question Number	Answer	Additional Guidance	Mark
(iv)	An explanation that makes reference to the following points: Catalysts will be less effective because • **M1** impurities **ad**sorb onto (catalyst) surface **or** impurities occupy active sites **or** impurities bond / bind to (catalyst) surface (1) • **M2** impurities prevent bond weakening in the reactants **or** less surface area (of catalyst) / fewer active sites available for reaction (1) • **M3** impurities form strong bonds (to surface) **or** impurities less likely to desorb (from surface) (1)	Do not award "**ab**sorb" for M1 Ignore impurities "react" Allow 'no active sites available' Allow 'impurities remain on surface'	(3)

Q15.

Question Number	Answer	Additional Guidance	Mark
(i)	Correct equation	$2NO + 2CO \rightarrow N_2 + 2CO_2$ Accept multiples Ignore catalysts and conditions if stated	(1)

Question Number	Answer	Additional Guidance	Mark
(ii)	A description that makes reference to the following points: • **adsorption** of gases to catalytic surface **(1)** • weakening of bonds (and chemical reaction) on catalytic surface **(1)** • desorption of products from catalytic surface **(1)**	Absence of reference to the catalytic surface results in a deduction of one mark Do not award absorption or "stick" Allow bonds break (and reaction occurs) on catalytic surface Ignore the type of interaction referred to between the reactants and the catalytic surface Allow 'release' of products from catalytic surface Allow de-adsorbed	**(3)**

Q16.

Question Number	Acceptable Answers	Additional Guidance	Mark
*	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. Number of indicative marking points seen in answer / Number of marks awarded for indicative marking points 6 / 4 5–4 / 3 3–2 / 2 1 / 1 0 / 0 The following table shows how the marks should be awarded for structure and lines of reasoning.	Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages). In general it would be expected that 5 or 6 indicative points would score 2 reasoning marks, and 3 or 4 indicative points would score 1 reasoning mark. A total of 2, 1 or 0 indicative points would score 0 marks for reasoning. If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).	**(6)**

Indicative content (IPs)	Allow omission of square brackets throughout
IP1: • $[Cu(H_2O)_6]^{2+}(aq) + 2OH^-(aq) \rightarrow [Cu(OH)_2(H_2O)_4](s) + 2H_2O(l)$	Allow for IP1 $Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)$ Only penalise incorrect or missing state symbols in this equation (IP1)
IP2: • blue ppt / blue solid (when $[Cu(OH)_2(H_2O)_4](s)$ is formed)	
IP3: • $[Cu(H_2O)_6]^{2+}(aq) + 4NH_3(aq) \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+}(aq) + 4H_2O(l)$	Allow for IP3 $Cu^{2+}(aq) + 4NH_3(aq) \rightarrow [Cu(NH_3)_4]^{2+}(aq)$
IP4: • Deep blue solution / dark blue solution (when $[Cu(NH_3)_4(H_2O)_2]^{2+}(aq)$ is formed)	$[Cu(OH)_2(H_2O)_4](s) + 4NH_3(aq) \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+}(aq) + 2H_2O(l) + 2OH^-(aq)$
IP5: • $[Cu(H_2O)_6]^{2+}(aq) + 4Cl^-(aq) \rightarrow [CuCl_4]^{2-}(aq) + 6H_2O(l)$	$[Cu(OH)_2(H_2O)_4](s) + 6NH_3(aq) \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+}(aq) + 2NH_4^+(aq)\ 2H_2O(l) + 2OH^-(aq)$
IP6: • Yellow / green (solution when $[CuCl_4]^{2-}(aq)$ is formed)	Ignore formation of initial precipitate $Cu(OH)_2(s)$ Do not award $[Cu(NH_3)_6]^{2+}(aq)$

	Do not award 'yellow precipitate' Allow equilibrium sign ⇌ in any reaction Ignore any initial colours, even if incorrect

Q17.

Question Number	Answer	Additional Guidance	Mark
(i)	• titres calculated and both ticks correct **(1)** • mean calculated **(1)**	<table><tr><td>Run</td><td>Trial</td><td>One</td><td>Two</td><td>Three</td></tr><tr><td>Final volume / cm^3</td><td>17.50</td><td>34.10</td><td>17.20</td><td>34.10</td></tr><tr><td>Initial volume / cm^3</td><td>0.00</td><td>17.30</td><td>0.00</td><td>17.20</td></tr><tr><td>Titre / cm^3</td><td>17.50</td><td>16.80</td><td>17.20</td><td>16.90</td></tr><tr><td>Concordant titres (✓)</td><td></td><td>✓</td><td></td><td>✓</td></tr><tr><td>Mean titre / cm^3</td><td colspan="4">**16.85**</td></tr></table>Both titres to 2 dp mean = (16.90+16.80)÷2 = 16.85 (cm^3) allow TE for M2 for mean of One, Two and Three = 16.97 (cm^3)	**(2)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• calculation of moles of $Na_2C_2O_4$(aq) **(1)** • calculation of moles of $KMnO_4$ in titre **(1)** • calculation of moles of $KMnO_4$ in 100 cm^3 **(1)** • calculation of M_r for $KMnO_4$ **(1)** • calculation of mass of 1 tablet in mg to 2 or 3SF **(1)**	Example of calculation (25.0÷1000) x 0.200 = 0.005 / 5.00 x 10^{-3} (mol) 5.00 x 10^{-3} x 2÷5 = 0.002 / 2.00 x 10^{-3} (mol) 2.00 x 10^{-3} x (100÷16.85) = 0.011869 (mol) 158 0.011869 x 158 = 1.8754 g (1.8754÷5) x 1000 = 375.07 mg = 380 / 375 (mg) Correct answer with or without working scores 5 marks 0.38 g scores 4 marks (M5 not awarded) TE at each stage and on mean titre 379 mg from 0.012 scores (5)	**(5)**

Question Number	Answer	Additional Guidance	Mark
(iii)	An explanation that makes reference to the following points • (reaction is slow initially) as MnO_4^- and $C_2O_4^{2-}$ are (both) negative (ions) so will repel (each other) **(1)** • when (sufficient) Mn^{2+} ions form they (auto) catalyse the reaction **(1)** • Mn^{2+} ions will reduce MnO_4^- ions (as $E^\ominus$ is more negative) forming Mn^{3+} ions OR $MnO_4^- + 8H^+ + 4Mn^{2+} \rightarrow 5Mn^{3+} + 4H_2O$ ($E^\ominus = +0.02$V) **(1)** • Mn^{3+} ions then oxidise $C_2O_4^{2-}$ ions (reforming Mn^{2+}) (as $E^\ominus$ is more positive) OR $C_2O_4^{2-} + 2Mn^{3+} \rightarrow 2Mn^{2+} + 2CO_2$ ($E^\ominus = +0.85$V) **(1)**	Allow 'heat is required to overcome high activation energy when catalyst is absent' Allow Mn^{2+} ions will react with MnO_4^- ions as $E^\ominus$ is more negative Allow Mn^{3+} ions then react with $C_2O_4^{2-}$ ions (reforming Mn^{2+}) as $E^\ominus$ is more positive May be shown in equations and / or by calculating $E^\ominus$	**(4)**

Q18.

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)**

Q19.

Question Number	Acceptable Answers	Additional Guidance	Mark
	A explanation that makes reference to the following points: M1 V changes (its oxidation state / oxidation number) from +5 to +4 (as it oxidises the sulfur dioxide) OR The oxidation number of V decreases in the reaction OR Vanadium is reduced in the reaction with SO_2	Ignore any references to heterogeneous catalysis Allow Forms V_2O_4 / VO_2 (as an intermediate) Do not award VO^{2+} or VO_3^- or VO_2^+	**(2)**
	OR V_2O_5 oxidises the SO_2 / S OR $V_2O_5 + SO_2 \rightarrow V_2O_4 + SO_3$ **(1)** M2 (Then) returns to +5 (oxidation state / oxidation number) by reacting with oxygen OR $2\ V_2O_4 + O_2 \rightarrow 2\ V_2O_5$ **(1)**	Allow (re-) forms V_2O_5	

Q20.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	• All species and balancing correct **(1)** • All state symbols correct **(1)**	Examples of equation $Cr(OH)_3(s) + 3H_2O(l) + 3H^+(aq) \rightarrow [Cr(H_2O)_6]^{3+}(aq)$ **Or** $Cr(OH)_3(s) + 3H_3O^+(aq) \rightarrow [Cr(H_2O)_6]^{3+}(aq)$ **Or** $[Cr(OH)_3(H_2O)_3](s) + 3H^+(aq)$ on LHS as an alternative Allow correct equations for sequential protonation e.g. $[Cr(OH)_3(H_2O)_3](s) + H^+(aq) \rightarrow [Cr(H_2O)_4(OH)_2]^+(aq)$ M2 consequential on M1 being awarded, or a 'near-miss' e.g. Cl^- on both sides / one missing charge	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(ii)	A description that makes reference to the following points: • green solid / grey-green solid **(1)** • forms green solution **(1)**	 Allow ppt/precipitate for solid Allow purple /violet /ruby solution Do not award yellow-green / red / blue-green bubbles etc means MP2 should not be awarded Ignore adjectives to describe green e.g. pale	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(iii)	• all species and balancing correct **(1)** • all state symbols correct **(1)**	<u>Examples of equation</u> $Cr(OH)_3(s) + 3OH^-(aq) \rightarrow [Cr(OH)_6]^{3-}(aq)$ **Or** [Cr(OH)3(H2O)3](s) + 3OH−(aq) → [Cr(OH)6]3−(aq) + 3H2O(l) Allow $Cr(OH)_3(s) + OH^-(aq) \rightarrow [Cr(OH)_4]^-(aq)$ **Or** $[Cr(OH)_5(H_2O)]^{2-}(aq)$ as complex ion on RHS, with rest of equation correctly balanced M2 consequential on M1 being awarded, or a 'near-miss'	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(iv)	An answer that makes reference to the following point: • green **and** solution	Ignore 'Qualifiers' for any colour (e.g. 'dark', 'deep', etc)	**(1)**