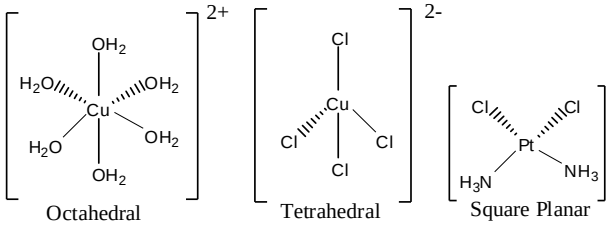
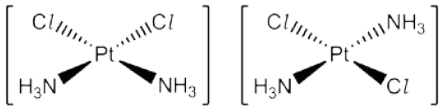
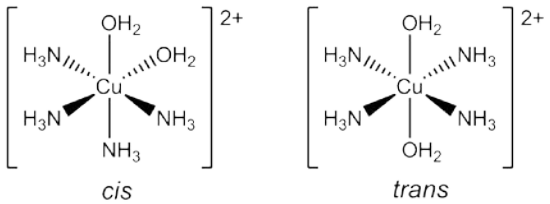
Mark Scheme

Question	Answer	Marks	Guidance
1	D	**1**	
2	B	**1**	

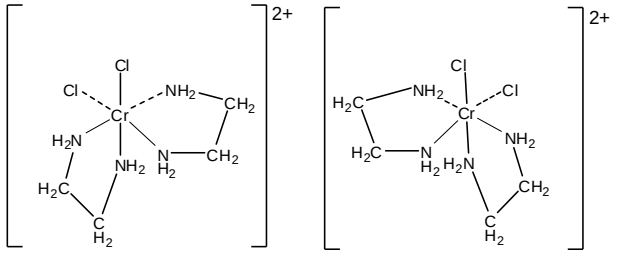
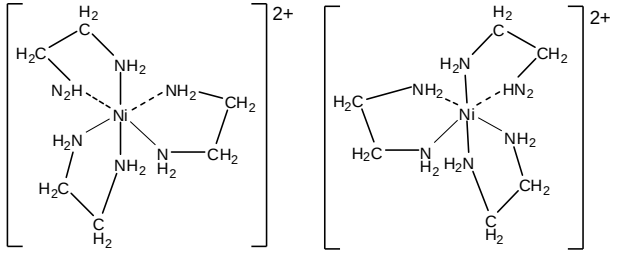
Mark Scheme

Question			Answer	Marks	Guidance
3	(a)		1. $n(AgCl)$ formed = $\frac{7.695}{143.5}$ = 0.05362 (mol) ✓ 2. 0.0180 mol of **B** forms 0.05362 mol of Cl^- No of Cl^- ions in formula of **B** = $\frac{0.05362}{0.0180}$ = 3 ✓ 3. Molar mass of **B** = $\frac{2.856}{0.0180}$ = 158.7 (g mol^{-1}) ✓ 158.7 – (3 × 35.5) = 52.2 which is chromium ✓ 4. $n(H_2O)$ = $\frac{1.944}{18}$ = 0.108 (mol) 0.0180 mol $CrCl_3$: 0.108 mol H_2O **OR** 1 mol $CrCl_3$: 6 mol H_2O ✓ **A** $CrCl_3 \cdot 6H_2O$ (from points 2, 3 and 4) ✓ **B** $CrCl_3$ (from points 2 and 3) ✓ **D** $[Cr(H_2O)_6]^{3+}$ (from determination of **A** and understanding of reaction with water) ✓ **E** $Cr(OH)_3$ (from understanding of reaction of **D** with aqueous hydroxide) ✓	9	**ALLOW** Alternative working throughout

Mark Scheme

Question	Answer	Marks	Guidance
(b)*	*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** Links together names of shapes with correct 3-D diagrams **AND** Appreciates the two different types of isomerism and labels diagrams appropriately *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* *Demonstrates clear and confident knowledge of relevant technical language using the terms* • *non-superimposable mirror images within optical isomerism* • *opposite and adjacent/same side in cis–trans* **Level 2 (3–4 marks)** Names and labels at least two of the shapes appropriately giving 3-D diagrams **AND** Appreciates that two types of isomerism exist in transition metal chemistry, gives diagrams to illustrate at least one pair of isomers and names them correctly *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* *Answers question with a sound grasp of relevant technical language using the terms*	**6**	**Indicative scientific points may include:** **Shapes of complex ions** • six coordinate bonds: octahedral • four coordinate bonds: tetrahedral or square planar • 3-D diagrams with charges linked to shapes  Octahedral Tetrahedral Square Planar ***cis–trans* isomerism** • found in octahedral and square planar complexes • *trans* – opposite; *cis* – adjacent / same side • 3-D diagrams to illustrate  *cis* *trans* **OR**  *cis* *trans*

Mark Scheme

Question			Answer	Marks	Guidance
			• *tetrahedral, octahedral* • *cis–trans **OR** optical* **Level 1 (1–2 marks)** Names and draws structures of two of the shapes **AND** Appreciates one type of isomerism that can be seen in transition metal chemistry *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* *Answers question with a basic grasp of relevant technical language* • *links octahedral to six ligands and tetrahedral to four ligands either in word or by diagram* • *correctly links one type of isomerism to a structure* **0 marks** No response or no response worthy of credit.		**Optical isomerism** • Found in octahedral complexes when bidentate ligands are present • Isomers are non-superimposable mirror images • 3-D diagrams to illustrate  **OR** 
			Total	**15**	

Mark Scheme

Question			Answer	Marks	Guidance
4	(a)*		*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** **Develops a plan that allows identification of all six ions** **AND** **includes essential detail and equations for all test procedures and observations, with three anion tests in the correct sequence, CO_3^{2-}, SO_4^{2-} then Cl^-** **AND** **includes cation test with essential detail and all equations** *There is a well-developed, detailed plan which is clear and logically structured. The plan is substantiated with relevant information, e.g. justification of the sequence of anion tests. There is a clear explanation of how the observations allow the ions to be identified.* **Level 2 (3–4 marks)** **Develops a plan that allows identification of at least three ions** **AND** **includes detail of at least three test procedures and observations, and three equations** *There is an appropriate plan presented with some structure. Parts of the fine detail, correct sequence, or reference to use of both samples may be missing. There is some attempt to explain how the observations allow the ions to be identified.*	**6**	**Indicative scientific points may include:** Use one sample for cation test, other sample for anion tests **Details of tests** *Cation test* add Aqueous sodium hydroxide Positive observations • for Mn^{2+} : pink/buff precipitate • for Fe^{2+} : green precipitate • for NH_4^+ : litmus paper held over the opening of the tube turns blue Fine detail: • (gentle) heating for NH_4^+ test Equations: $Mn^{2+} + 2OH^- \rightarrow Mn(OH)_2$ $Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$ $NH_4^+ + OH^- \rightarrow NH_3 + H_2O$ *Anion tests* CO_3^{2-}: • add nitric acid; positive observation: effervescence SO_4^{2-}: • add aqueous barium nitrate; positive observation: white precipitate Cl^-: • add silver nitrate solution; positive observation: white precipitate Fine detail for Cl^-:

Mark Scheme

Question			Answer	Marks	Guidance
			Level 1 (1–2 marks) **Develops a plan that allows identification of at least two ions** **AND** **includes detail of at least two test procedures and observations, and one equation** *The plan is basic and communicated in an unstructured way. The response lacks fine detail and no reference to correct sequence of anion tests. There is little or no attempt to explain how the observations allow the ions to be identified.* **0 marks** No response or no response worthy of credit.		• subsequent addition of dilute ammonia solution positive observation: precipitate dissolves. Fine detail: correct sequence of all three anion tests • carbonate test followed by sulfate test followed by halide test • justification of sequence • **ALLOW** splitting of solution over three boiling tubes/test tubes and performing each test on a different sample. Equations: $CO_3^{2-} + H^+ \rightarrow CO_2 + H_2O$ $Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$ $Ag^+ + Cl^- \rightarrow AgCl$
	(b)		K_w value from graph from 2.2 to 2.4 × 10^{-14} ($mol^2\ dm^{-6}$) ✓ Using 2.4 × 10^{-14}, $[H^+] = \sqrt{2.4 \times 10^{-14}}$ **OR** 1.55 × 10^{-7} ✓ pH = –log (1.55 × 10^{-7}) = 6.81 (using K_w = 2.4 × 10^{-14}) ✓	**3**	Actual K_w = 2.38 × 10^{-14} $mol^2\ dm^{-6}$ **ALLOW ECF** only if candidate uses a value between 2.0 and 2.6 × 10^{-14} ($mol^2\ dm^{-6}$), i.e. from the approximately correct region of the graph **ALLOW** 6.8 (1DP) up to calculator value **ALLOW ECF** only if candidate has generated a value of $[H^+]$ by attempting to take a square root of a value between 2.0 and 3.0 × 10^{-14}
	(c)	**(i)**	$Co : N : H : Cl = \frac{21.98}{58.9} : \frac{31.35}{14.0} : \frac{6.72}{1.0} : \frac{39.75}{35.5}$	**2**	

Mark Scheme

Question			Answer	Marks	Guidance
			= 0.373 : 2.24 : 6.72 : 1.12 ✓ = 1 : 6 : 18 : 3 Formula = $CoN_6H_{18}Cl_3$ ✓		
		(ii)	$[Co(NH_3)_6]^{3+}$ ✓	**1**	
			Total	**12**	

Mark Scheme

Question			Answer	Marks	Guidance
5	(a)	(i)	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$ ✓	1	
		(ii)	4	1	
	(b)		$[Fe(CN)_6]^{3-}$ shown as product in equation ✓ Remaining species and balancing correct balanced equation: $[Fe(H_2O)_6]^{3+} + 6CN^- \rightarrow [Fe(CN)_6]^{3-} + 6H_2O$ ✓	2	Notice different charges on complex ions: LHS 3+, RHS 3– **ALLOW** equations with KCN, i.e.: $[Fe(H_2O)_6]^{3+} + 6KCN \rightarrow [Fe(CN)_6]^{3-} + 6K^+ + 6H_2O$ $[Fe(H_2O)_6]^{3+} + 6K^+ + 6CN^- \rightarrow [Fe(CN)_6]^{3-} + 6K^+ + 6H_2O$ state symbols **not** required
	(c)	(i)	$K_a = \frac{[[Fe(H_2O)_5OH]^{2+}(aq)][H^+(aq)]}{[[Fe(H_2O)_6]^{3+}(aq)]}$ ✓	1	state symbols **not** required
		(ii)	$[H^+] = \sqrt{6.00 \times 10^{-3} \times 0.100}$ **OR** 0.0245 (mol dm^{-3}) ✓ pH = –log 0.0245 = 1.61 ✓	2	**ALLOW ECF** from calculated $[H^+]$ provided that **BOTH** 6.0×10^{-3} **AND** 0.100 only have been used **ALLOW** calculation via quadratic equation → pH 1.66
	(d)		..ClO^- + ..H_2O + **2**..e^- → ..Cl^- + **2**..OH^- ✓ Fe_2O_3 + **10**..OH^- → **2**..FeO_4^{2-} + **5**..H_2O + **6**..e^- ✓	3	**ALLOW** multiples throughout

Mark Scheme

Question			Answer	Marks	Guidance
			Fe_2O_3 + **3**..$C\ell O^-$ + **4**..OH^- → **2**..FeO_4^{2-} + **3**..$C\ell^-$ + **2**..H_2O ✓		
			Total	**10**	

Mark Scheme

Question			Answer	Marks	Guidance
6	(a)		$n(NH_2OH) = 4.32 \times 10^{-2} \times 0.0250 = 1.08 \times 10^{-3}$ mol ✓ $n(Fe^{3+}) = 3 \times 1.08 \times 10^{-3} = 3.24 \times 10^{-3}$ mol (assuming Equation 3) ✓ volume = $\frac{3.24 \times 10^{-2} \times 1000}{0.0400}$ = 81.0 cm^3 ✓ Explanation: minimum amount of Fe^{3+} required is maximum amount theoretically required to react with all NH_2OH, i.e. if Equation 3 is correct (greatest amount of Fe^{3+} required) (*owtte*) ✓	**4**	Factor **3** must be included in second mark for **ECF** on third mark. **ALLOW** 2 sig figs
	(b)		$n(MnO_4^-) = 2.00 \times 10^{-2} \times \frac{21.6}{1000} = 4.32 \times 10^{-4}$ (mol) ✓ $n(Fe^{2+}) = 4.32 \times 10^{-4} \times 5 = 2.16 \times 10^{-3}$ (mol) ✓ Ratio NH_2OH: Fe^{2+} **OR** NH_2OH: Fe^{2+} $= 1.08 \times 10^{-3} : 2.16 \times 10^{-3} = 1 : 2$ **AND** Equation 2 is correct ✓	**3**	**Working must be to at least 3 sig figs throughout until final numerical answer** **BUT** ignore trailing zeroes, e.g. for 0.490 allow 0.49 **ECF** answer above × 5 This mark is only possible from correct answers above, i.e. **no ECF**
	(c)	**(i)**	Boiling speeds up the reaction **OR** Ensures that reaction is complete ✓ (Titre is less because) there is less Fe^{2+} ✓	**2**	

Mark Scheme

Question			Answer	Marks	Guidance
		(ii)	In **Stage 1**, increase quantities so that there is sufficient solution for more than one titration ✓	**1**	**ALLOW** increase scale of **Stage 1**
			Total	**10**	

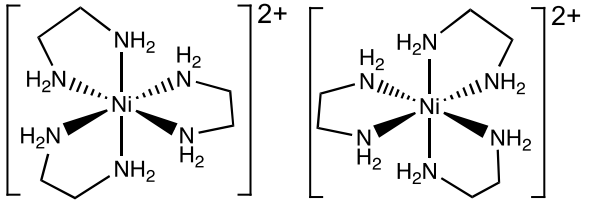
Mark Scheme

Question	Answer	Marks	Guidance
7	D	1	
8	A	1	

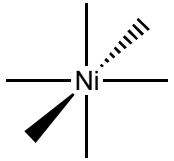
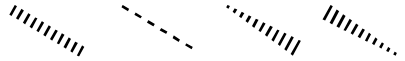
Mark Scheme

Question			Answer	Marks	Guidance
9	(a)	(i)	$CuCl_4^{2-}$ **OR** $[CuCl_4]^{2-}$ ✓ *yellow solution* $Cu(OH)_2$ ✓ *pale blue precipitate* $[Cu(NH_3)_4(H_2O)_2]^{2+}$ ✓ *deep blue solution* CuI ✓ I_2 ✓ *white solid* *brown solution*	5	**ALLOW** $Cu(Cl)_4^{2-}$ **ALLOW** $Cu(OH)_2(H_2O)_4$ Brackets required for $[Cu(NH_3)_4(H_2O)_2]^{2+}$ **NOTE:** Take great care to check that subscripted numbers and brackets are correct
		(ii)	*Reaction 1*: ligand substitution ✓ *Reaction 2*: redox ✓	2	**ALLOW** ligand exchange **ALLOW** reduction **AND** oxidation **ALLOW** precipitation

Mark Scheme

Question	Answer	Marks	Guidance
(b)*	*Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** A comprehensive conclusion using all data to obtain correct formulae for **A**, **B**, **C** and **D** **AND** optical isomers shown *There is a well-developed line of reasoning which is clear and logically structured with use of 3D structures for both optical isomers of **C**, use of wedges and bonding to N.* *The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Reaches a sound conclusion for the formula of **B** **AND** obtains the correct formula of the hydrated complex **A** **OR** a 3D diagram of one optical isomer of cation **C** *There is a line of reasoning and supported by some evidence. Calculations are clear and can be followed to obtain correct conclusions. 3D diagram, if present, should use wedges mostly correctly.* *Formula of **A** to show water separately or formula of **C** to show ligands separately, as appropriate.* **Level 1 (1–2 marks)** Reaches a simple conclusion to obtain the correct formula of anhydrous complex **B** **OR** shows that **A** contains $2H_2O$ *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant. Attempts more than one part of the problem.* **0 marks** *No response or no response worthy of credit.*	**6**	**Indicative scientific points may include:** **1. Formula of anhydrous complex B** $NiC_6N_6H_{24}Cl_2$ *Example of working* Ni : C : N : H : Cl $= \frac{18.95}{58.7} : \frac{23.25}{12.0} : \frac{27.12}{14.0} : \frac{7.75}{1.00} : \frac{22.93}{35.5}$ ***There may be other methods*** **2. Formula of hydrated complex A** $NiC_6N_6H_{24}Cl_2 \cdot 2H_2O$ **OR** $NiC_6N_6H_{24}Cl_2(H_2O)_2$ *Example of working* n(anhydrous salt) = $\frac{7.433}{309.7}$ = 0.02400 (mol) $n(H_2O) = \frac{0.864}{18.0}$ = 0.04800 (mol) ✓ ***There may be other methods*** **3. Formula of cation C** $[NiC_6N_6H_{24}]^{2+}$ **OR** $[Ni(H_2NCH_2CH_2NH_2)_3)]^{2+}$ (*could be in structures* 2+ charge can be shown on cation **OR** optical isomers (i.e. seen somewhere) • **Bidentate ligand D** $H_2NCH_2CH_2NH_2$ or displayed so that structure is clearly unambiguous. • **Optical isomers**  *Accuracy of structures*

Mark Scheme

Question			Answer	Marks	Guidance
					Bonding shown from Ni to N of $H_2NCH_2CH_2NH_2$ **ALLOW** $CH_3CH(NH_2)_2$ for ligand For $H_2NCH_2CH_2NH_2$ in optical isomers, **ALLOW** C–C without Hs and  Each structure to contain 2 'out wedges', 2 'in wedges' and 2 lines in plane of paper **OR** 4 lines, 1 'out wedge' and 1 'in wedge':  Bond into paper can be shown as: 
			Total	**13**	

Mark Scheme

Question	Answer	Marks	AO element	Guidance
10	**D**	**1**	AO1.1	

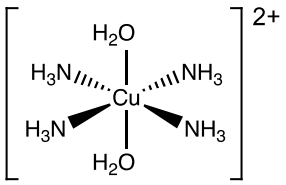
Mark Scheme

Question			Answer	Marks	Guidance
11	(a)		Ni: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8 4s^2$ ✓ Ni^{2+}: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8$ ✓	2	**ALLOW** 4s before 3d, ie $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^8$ **ALLOW** $1s^2$ written after answer prompt (*ie* $1s^2$ twice) **ALLOW** upper case D, etc and subscripts, e.g. ……$4S_2 3D_8$ **ALLOW** for Ni^{2+} **……..**$4s^0$ **DO NOT ALLOW** [Ar] as shorthand for $1s^2 2s^2 2p^6 3s^2 3p^6$ Look carefully at $1s^2 2s^2 2p^6 3s^2 3p^6$ – there may be a mistake
	(b)	(i)	*Circuit*: complete circuit **AND** voltmeter **AND** salt bridge linking two half-cells ✓ *Half cells*: Pt **AND** I^- **AND** I_2 ✓ Ni **AND** Ni^{2+} ✓ *Standard conditions*: 1 mol dm^{-3} solutions **AND** 298 K / 25ºC ✓	4	Voltmeter must be shown **AND** salt bridge must be labelled **ALLOW** small gaps in circuit **ALLOW** half cells drawn either way around **IGNORE 2** before I^-(aq) **DO NOT ALLOW** I_2(g) **OR** I_2(s) **OR** I_2(l) **ALL** conditions required **BUT ALLOW** 1 mol dm^{-3}/1M if omitted here but shown for just one solution in diagram Look on diagram in addition to answer lines **IGNORE** pressure *Not relevant for this cell* **DO NOT ALLOW** 1 mol for concentration
	(b)	(ii)	E = 0.79 (V) ✓	1	**IGNORE** sign
	(c)	(i)	$H_2O_2(aq) + 2H^+(aq) + 2Fe^{2+}(aq) \rightarrow 2Fe^{3+}(aq) + 2H_2O(l)$ ✓	1	**ALLOW** multiples **IGNORE** state symbols, even if wrong

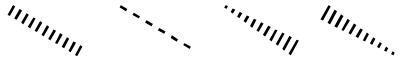
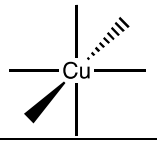
Mark Scheme

Question			Answer	Marks	Guidance
	(c)	(ii)	**Equations** $3Zn(s) + Cr_2O_7^{2-}(aq) + 14H^+(aq) \rightarrow 3Zn^{2+}(aq) + 2Cr^{3+}(aq) + 7H_2O(l)$ ✓ $Zn(s) + 2Cr^{3+}(aq) \rightarrow Zn^{2+}(aq) + 2Cr^{2+}(aq)$ ✓ **Comparison of *E* values (seen once)** *E* of Zn is more negative/less positive than *E* of $Cr_2O_7^{2-}$ **OR** *E* of Zn is more negative/less positive than *E* of Cr^{3+} ✓ **Equilibrium shift related to *E* values** More negative/less positive **OR** Zn system shifts left **OR** Less negative/more positive $Cr_2O_7^{2-}$ system shifts right **OR** Less negative/more positive Cr^{3+} system shifts right ✓	4	**ALLOW** multiples I**GNORE** state symbols, even if wrong **ALLOW** E_{cell} is (+) 2.09V for $Zn/Cr_2O_7^{2-}$ cell **OR** **ALLOW** E_{cell} is (+) 0.34V for Zn/Cr^{3+} cell **IGNORE** 'lower/higher' For 'shifts left': **ALLOW** '(Zn) is oxidised' **OR** 'electrons are lost (from Zn)' For 'shifts right', **ALLOW** '(Cr) is reduced' **OR** 'electrons are gained'

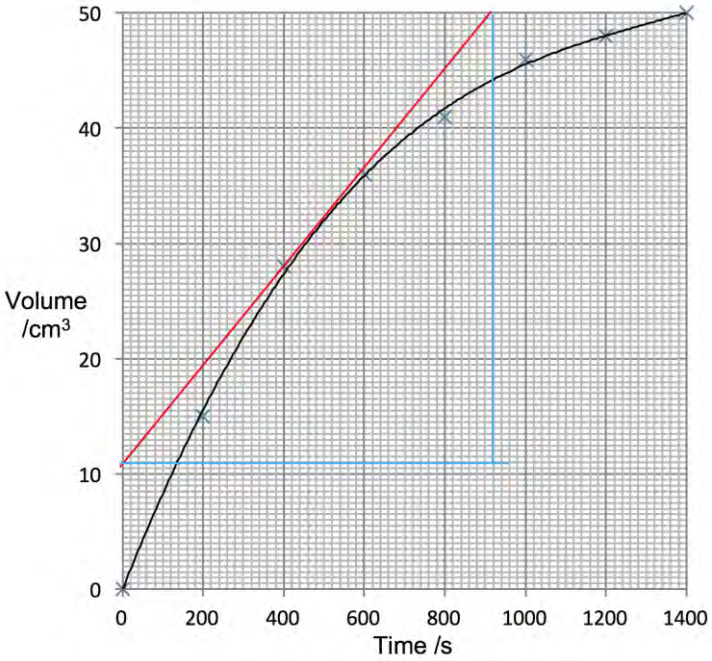
Mark Scheme

Question	Answer	Marks	Guidance
(d)	*Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** All three reactions are covered in detail with **C**, **D**, **E** and **F** identified with clear explanations. *There is a well-developed line of reasoning which is clear and logically structured with clear chemical communication and few omissions. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** All three reactions are covered but explanations may be incomplete **OR** Two reactions are explained in detail. *There is an attempt at a logical structure with a line of reasoning. The information is relevant e.g. formulae may contain missing brackets or numbers and supported by some evidence.* **Level 1 (1–2 marks)** Make two simple explanations from any one reaction. **OR** Makes one simple explanation from each of two reactions *There is an attempt at a logical structure with a line of reasoning The information is in the most part relevant.* **0 marks** No response worthy of credit.	6	**Indicative scientific points may include:** **REACTION 1 ($CuSO_4/NH_3$)** ***Product*** **C** : $[Cu(NH_3)_4(H_2O)_2]^{2+}$ ***Equation*** $[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4H_2O$ ***Structure of trans stereoisomer***  Correct connectivity **REACTION 2 (Cu_2O/H_2SO_4)** ***Products*** **D** : $CuSO_4$ **OR** $[Cu(H_2O)_6]^{2+}$ **E**: Cu ***Equation*** $Cu_2O + H_2SO_4 \rightarrow CuSO_4 + Cu + H_2O$ ***Oxidation numbers*** $Cu(+1) \rightarrow Cu(+2) + Cu(0)$ **REACTION 3 (CuO/HNO_3)** ***Equation*** $CuO + 2HNO_3 \rightarrow Cu(NO_3)_2 + H_2O$ ***Molar ratios*** $\text{Cu} : \text{H} : \text{N} : \text{O} = \frac{26.29}{63.5} : \frac{2.49}{1.0} : \frac{11.59}{14.0} : \frac{59.63}{16.0}$ ***Formula of F*** $CuH_6N_2O_9$ **F**: $Cu(NO_3)_2 \cdot 3H_2O$ (**OR** $Cu(NO_3)_2(H_2O)_3$)

Mark Scheme

Question			Answer	Marks	Guidance
					---------- **Further guidance on use of wedges** • Must contain 2 'out wedges', 2 'in wedges' and 2 lines in plane of paper **OR** 4 lines, 1 'out wedge' and 1 'in wedge': • For bond into paper, **ALLOW**:  • **ALLOW** following geometry: 
			Total	**18**	

Mark Scheme

Question			Answer	Marks	Guidance
12	(a)		**Graph** Graph of volume (y axis) against time (x axis) **AND** Axes labelled with correct units **AND** At least half graph paper in both directions **AND** Linear scales ✓ **Points** 7 points from 200–1400 s plotted ✓ *Point at 0,0 not required* **Line** **Curve** drawn through origin (0,0) ✓ **AND** **Curve** not drawn with straight lines between points. **Rate** Attempted tangent on graph drawn to curve at t = 500 ± 100 s ✓ Rate calculated in range 0.037–0.047 ($cm^3\ s^{-1}$) ✓ *e.g. for graph in guidance:* $\frac{50-11}{920-0} = 0.042$ --- **For tangents not drawn at 500 ± 100 s,** • **ALLOW ECF ONLY** for a tangent drawn to the candidate's line. • Then calculate the gradient from candidate's tangent. **For inverse graphs of time against volume,** • Graph mark will **not** be scored. • All other marks are available. • **BUT** rate = 1/ gradient = 0.037–0.047 ($cm^3\ s^{-1}$)	5	 **ALLOW** *V* **OR** Vol for volume **ALLOW** *t* for time For 's', **ALLOW** sec, seconds, etc **CARE:** Use of *x* and *y* coordinates at t = 500 s scores zero, e.g. For volume = 33 cm^3 and time = 500 s, *x* and *y* coordinates gives 33/500 = 0.066 ✗✗

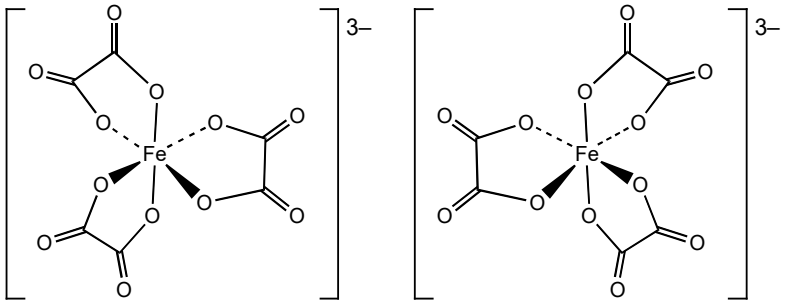
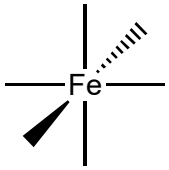
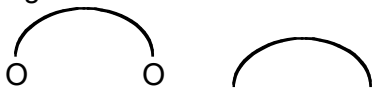
Mark Scheme

Question			Answer	Marks	Guidance
		(ii)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 0.092 (mol dm^{-3}) award 3 marks** --- $n(O_2) = \frac{55}{24000} = 2.29 \times 10^{-3}$ (mol) ✓ $n(H_2O_2) = 2.29 \times 10^{-3} \times 2 = 4.58 \times 10^{-3}$ (mol) ✓ $[H_2O_2] = \frac{4.58 \times 10^{-3} \times 1000}{50.0} = 0.092$ (mol dm^{-3}) ✓ (**2 SF**)	**3**	**ALLOW ECF** throughout **ALLOW** 2 SF up to calculator value of 2.291666667 $\times 10^{-3}$ **ALLOW** calculation using ideal gas equation provided that p = ~ 10^5 Pa and T in range 293–298 K. **ALLOW** use of 8.31 for R (gives same answer) **e.g.** $n(O_2) = \frac{1 \times 10^5 \times 55 \times 10^{-6}}{8.314 \times 298} = 2.22 \times 10^{-3}$ (mol) ✓ $n(H_2O_2) = 2.22 \times 10^{-3} \times 2 = 4.44 \times 10^{-3}$ (mol) ✓ $[H_2O_2] = \frac{4.44 \times 10^{-3} \times 1000}{50.0} = 0.089$ (mol dm^{-3}) ✓ (2 SF) **NOTE**: 293 K gives 0.090 (mol dm^{-3}) **Common errors** 0.046 → 2 marks no × 2 for $n(H_2O_2)$
	(b)		$2MnO_4^- + 5H_2O_2 + 6H^+ \rightarrow 2Mn^{2+} + 8H_2O + 5O_2$ Correctly balanced equation for MnO_4^-/H_2O_2 reaction but no cancelling of H^+ and/or e^- ✓ Overall equation correct with all species cancelled ✓	**2**	**ALLOW** multiples **ALLOW** ⇌ instead of → sign **ALLOW** 1 mark for final equation with correct balancing numbers **AND** **ONE** small slip in a formula **OR** charge **IGNORE** annotations around equations, i.e. treat as rough working **ALLOW** 1 mark for: $2H_2O_2 \rightarrow 2H_2O + O_2$ *(H_2O_2 is acting as both reducing and oxidising agent)*

Mark Scheme

Question			Answer	Marks	Guidance
	(c)	(i)	**Equation** $[Co(H_2O)_6]^{2+} + 4Cl^- \rightleftharpoons [CoCl_4]^{2-} + 6H_2O$ **OR** $[Co(H_2O)_6]^{2+} + 4HCl \rightleftharpoons [CoCl_4]^{2-} + 6H_2O + 4H^+$ ✓	1	**ALLOW** reverse equation: $[CoCl_4]^{2-} + 6H_2O \rightleftharpoons [Co(H_2O)_6]^{2+} + 4Cl^-$ but take care for subsequent explanations **IGNORE** state symbols (even if wrong) For $[CoCl_4]^{2-}$, **ALLOW** $CoCl_4^{2-}$, $(CoCl_4)^{2-}$ For other representations, contact TL
		(ii)	**Equilibrium shift** • equilibrium (shifts) **to right** at high **temperature**/100ºC **OR** equilibrium shifts to left at low temperature/0ºC ✓ **CARE: Direction of shift** depends on direction of equilibrium equation from 2c(i). Either look back or see the equation copied at bottom of 2c(ii) marking zone. --- **Enthalpy change** • Endothermic ✓	2	**Mark independently** **ALLOW** suitable alternatives for 'to right' e.g. towards products **OR** in forward direction **OR** 'favours the right' **ORA** for 'to left' **Temperature** required but **ALLOW** 'in ice for low temperature **OR** 'in boiling/hot water' for high temperature **IGNORE** shift to blue side or pink side ---
			Total	13	

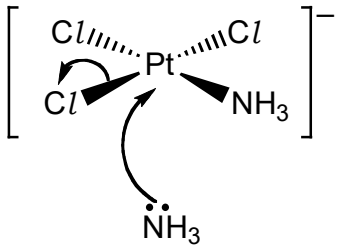
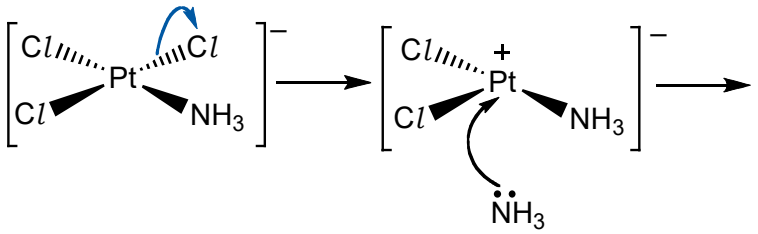
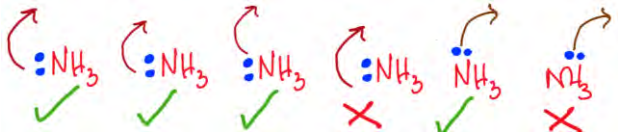
Mark Scheme

Question			Answer	Marks	Guidance
13	(a)		Overall 3– charge shown (outside brackets) for at least **ONE** isomer ✓ *3– must apply to the overall charge of structures*  1 mark for each isomer ✓✓ • *Bonds **must** go to O ligand atoms on **EACH** structure* • ***ALLOW** unambiguous structures; ethanedioate ions can include C atoms* **For other structures that might be creditworthy, contact TL**	**3**	**ALLOW** –3 for 3– **IGNORE** charges or dipoles on atoms within diagrams (even if wrong) Square brackets **NOT** required **----------** **3D** Must contain 2 'out wedges', 2 'in wedges' and 2 lines in plane of paper **OR** 4 lines, 1 'out wedge' and 1 'in wedge': For bond into paper, **ALLOW**:  **ALLOW** following geometry throughout:  **NOT ALLOW** structures showing a simplified loop for ethanedioate ligands e.g. 
	(b)	(i)	Colourless to yellow ✓	**1**	**IGNORE** clear for colourless

Mark Scheme

Question			Answer	Marks	Guidance
	(b)	(ii)	**Mean titre 1 mark** $= \frac{(23.15 + 23.25)}{2} = 23.2(0)\ (cm^3)$ ✓ **Analysis of results 5 marks** $n(Ce^{4+}) = 23.20 \times \frac{0.0500}{1000} = 1.16 \times 10^{-3}$ (mol) ✓ $n((COOH)_2)$ in 25.0 $cm^3 = \frac{1.16 \times 10^{-3}}{2} = 5.8(0) \times 10^{-4}$ (mol)✓ $n((COOH)_2)$ in 250 cm^3 $= 5.8(0) \times 10^{-4} \times 10 = 5.8(0) \times 10^{-3}$ (mol) ✓ Mass $(COOH)_2 = 5.8(0) \times 10^{-3} \times 90.0 = 0.522$ g ✓ % oxalic acid $= \frac{0.522 \times 100}{82.68} = 0.631\%$ ✓ Percentage **MUST** be expressed to **3 SF**	**6**	**Common error:** Incorrect mean from all 3 titres = 23.30 cm^3 **Use ECF throughout** Intermediate values for working to **at least 3 SF.** **TAKE CARE** as value written down may be truncated value stored in calculator. Depending on rounding, either can be credited. **----------** **COMMON ERRORS:** Mean of 23.30 (use of all 3 titres) → 0.634%: 5 marks **TAKE CARE** for final answer of 0.63 seen. • No final mark as only 2 SF • 0.63 may have been rounded from 0.631 (from correct mean) **OR** from 0.634 (using mean from all 3 titres) Check back to mean titre. No ÷2 to *obtain $n((COOH)_2)$* → 1.26%: 5 marks from 23.20 → 1.27% 4 marks from 23.30
			Total	**10**	

Mark Scheme

Question			Answer	Marks	Guidance
14	(a)	(i)	+2 **Sign required**	1	**ALLOW** 2+ **OR** +II **ALLOW** Pt^{2+}
		(ii)	 Curly arrow from lone pair on NH_3 to Pt ✓ $[PtCl_3(NH_3)]^-$ drawn with 1 Pt, 3 Cls and 1 NH_3 **AND** Curly arrow from **any** Pt–C*l* bond in the complex ✓ **ALLOW** S_N1 mechanism:  Mark curly arrows as above for S_N2 Requires + on platinum intermediate	2	For $[PtCl_3(NH_3)]^-$: • **IGNORE** dipoles • **IGNORE** absence of – charge • **IGNORE** – charge shown on atoms **ALLOW** any 4 coordinate shape for $[PtCl_3(NH_3)]^-$, e.g. tetrahedral; —Pt— **1st curly arrow** must • go to Pt **AND** start from, **OR** be traced back to **any point across width** of lone pair on N of NH_3  **DO NOT ALLOW** charge on NH_3 nucleophile, e.g. NH_3^- **2nd curly arrow** must start from, **OR** be traced back to, **any part of** Pt–Cl bond and go to one of the 3 Cl atoms 

Mark Scheme

Question			Answer	Marks	Guidance
	(b)	**(i)**	Phenol ✓ Amide ✓ • **IGNORE** attempt to classify amide, e.g. secondary	**2**	**IF > 2** functional groups are shown, • Mark 2 groups **ONLY** • Mark incorrect groups **first** Treat carbonyl with aldehyde **OR** with ketone as one functional group, i.e. • carbonyl, aldehyde • carbonyl, ketone • carbonyl **IGNORE** aryl **OR** alkyl group e.g. benzene, phenyl, aryl, arene, methyl **IGNORE** hydroxyl/hydroxy
	(b)	**(ii)***	*Refer to marking instructions on page 5 of mark scheme for guidance on marking this question.* **Level 3 (5-6 marks**) A correct calculation of the mass of 4-nitrophenol**.** **AND** Identifies the reagents **AND** intermediate. **AND** A **detailed** description of most purification steps. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3-4 marks)** Calculates the mass of 4-nitrophenol with some errors **AND** suggests reagents and intermediate with some omissions. **OR** Calculates the mass of 4-nitrophenol with some errors **AND** describes some purification steps, with some detail. **OR**	**6**	**Indicative scientific points may include:** **<u>Calculation of mass of 4-nitrophenol</u>** **Using moles** • n(paracetamol) = $\frac{5.00}{151}$ = 0.0331 (mol) • n(4-nitrophenol) = 0.0331 × $\frac{100}{40}$ = 0.0828 (mol) • Mass of 4-nitrophenol = 139 × 0.0828 = 11.5 g **ALLOW** 11.4–11.6 for small slip/rounding **Using mass** • Theoretical mass paracetamol = 5.00 × $\frac{100}{40}$ = 12.5 g • Theoretical n(4-nitrophenol) = $\frac{12.5}{151}$ = 0.0828 (mol) • Mass of 4-nitrophenol = 139 × 0.0828 = **11.5** g **NOTE**: Incorrect inverse ratio of $\frac{100}{40}$ gives:

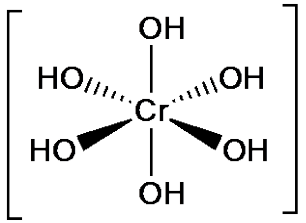
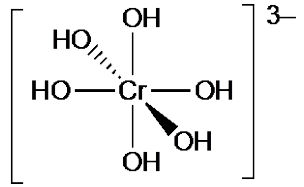
Mark Scheme

Question			Answer	Marks	Guidance
			Suggests reagents and intermediate with some omissions **AND** describes some purification steps, with some detail. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1-2 marks)** Attempts to calculate the mass of 4-nitrophenol **OR** Suggests reagents **OR** intermediate but may be incomplete **OR** Describes few purification steps. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** No response or no response worthy of credit.		• $0.0331 \times \frac{40}{100} = 0.0132$ (mol) • Mass = $139 \times 0.0132 = 1.84$ g **Reagents and intermediate** • **Reagents:** Sn + (conc) HCl (then NaOH) • **Intermediate***:* 4-aminophenol or structure **Purification** • Dissolve impure solid in **minimum volume of** hot solvent • **Cool** solution and filter solid • **Scratch with glass rod** • **Wash** with cold solvent/solvent and **dry** **Examples** of detail in **bold** (**NOT INCLUSIVE**) **NOTE**: 'Recrystallisation' on its own is **NOT** a detailed description
			Total	**11**	

Mark Schemes

Question	Answer	Marks	AO element	Guidance
15	**B**	**1**	AO2.1	
16	**C**	**1**	AO1.1	

Mark Schemes

Question			Answer	Marks	AO element	Guidance
17	(a)	(i)	$[Cr(NH_3)_6]^{3+}(aq)$ ✓	1	1.1	**IGNORE** state symbols
		(ii)	$CrCl_3(aq) + 3NaOH(aq) \rightarrow Cr(OH)_3(s) + 3NaCl(aq)$ or $Cr^{3+}(aq) + 3OH^-(aq) \rightarrow Cr(OH)_3(s)$ ✓ state symbols required	1	2.8	**IGNORE** square brackets around precipitate formulae **ALLOW** $[Cr(H_2O)_6]^{3+}(aq) + 3OH^-(aq) \rightarrow Cr(OH)_3(H_2O)_3(s)+3H_2O(l)$ **ALLOW** 'hybrid' equations, Eg $Cr^{3+}(aq) + 3NaOH(aq) \rightarrow Cr(OH)_3(s) + 3Na^+(aq)$ $[Cr(H_2O)_6]^{3+}(aq) + 3OH^-(aq) \rightarrow Cr(OH)_3(s) + 6H_2O(l)$ $[Cr(H_2O)]_6^{3+}(aq)+ 3NaOH(aq) \rightarrow$ $Cr(OH)_3(s) + 6H_2O(l) +3Na^+(aq)$
		(iii)	 3-D diagram with all bonds through O in OH ✓ 3– charge ✓	2	1.1 2.3	Must contain 2 'out wedges', 2 'in wedges' and 2 lines in plane of paper **OR** 4 lines, 1 'out wedge' and 1 'in wedge':  **ALLOW** dotted line **OR** unfilled wedge as alternatives for dotted wedge **IGNORE** charges inside brackets
		(iv)	CrO_4^{2-} ✓	1	3.1	**IGNORE** compounds e.g. Na_2CrO_4
		(v)	orange ✓	1	1.1	
	(b)	(i)	$(1s^2)2s^22p^63s^23p^63d^2$ ✓	1	1.1	**ALLOW** upper case D, etc. and subscripts, e.g. $3D_2$ If included, **ALLOW** $4s^0$
	b	(ii)	*Explanation of colours* VO^{2+} goes to V^{3+} (green) **AND** then V^{3+} goes to V^{2+}	3	3.1 ×2	

Mark Schemes

Question			Answer	Marks	AO element	Guidance
			(violet) ✓ *Explanation using $E^{\ominus}$ values* ($E^{\ominus}$ of) system 4 (VO^{2+}/V^{3+}) is more positive / less negative than system 2 (Fe^{2+}/Fe) **OR** ($E^{\ominus}$ of) system 3 (V^{3+}/V^{2+},) is more positive / less negative than system 2 (Fe^{2+}/Fe) ✓ *Equilibrium shift related to $E^{\ominus}$ values* More positive/less negative system 4 (VO^{2+}/V^{3+}) shifts right **AND** More positive/less negative system 3 (V^{3+}/V^{2+}) shifts right		**3.2 ×1**	**IGNORE** 'lower/higher' **ALLOW** reverse argument System 2 more negative than system 4 etc E = (+)0.78 V for system 4 + system 2 reaction **OR** E = (+)0.18 V for system 3 + system 2 reaction For shifts right' **ALLOW** (VO^{2+}) is reduced **OR** gains electrons (maybe seen as an equation) **AND** 'For shifts right' **ALLOW** (V^{3+}) is reduced **OR** gains electrons (maybe seen as an equation) **IGNORE** Fe oxidised
		(iii)	$Fe + 4H^+ + 2VO^{2+} \rightarrow Fe^{2+} + 2H_2O + 2V^{3+}$	**1**	**2.8**	**IGNORE** state symbols **ALLOW** multiples **ALLOW** '⇌'
	(c)	**(i)**	(0.00200 mol dm^{-3} solution gives) a large titre which leads to a small (percentage) error / uncertainty ✓	**1**	**3.4**	**ALLOW** (0.0200 mol dm^{-3} solution gives) a small titre which leads to a large (percentage) error / uncertainty Assume 'it' means dilute solution **ALLOW** 13.50 cm^3 gives a lower percentage error than 1.35 cm^3
	c	**(ii)**	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 301 mg award 5 marks**	**5**	**2.8 ×5**	**ALLOW ECF** throughout **ALLOW** working to 3SF **minimum** throughout

Mark Schemes

Question			Answer	Marks	AO element	Guidance
			$n(MnO_4^-) = \frac{13.50}{1000} \times 0.00200 = 2.7(0) \times 10^{-5}$ (mol) ✓ $n(Fe^{2+})$ (in.25.0 cm^3) = $2.7(0) \times 10^{-5} \times 5 = 1.35 \times 10^{-4}$ (mol) ✓ $n(Fe^{2+})$ (in 250 cm^3) = $1.35 \times 10^{-4} \times 10 = 1.35 \times 10^{-3}$ ✓ Mass $C_{12}H_{22}FeO_{14}$ in 2 tablets $= 1.35 \times 10^{-3} \times 445.8 = 0.6018$ (g) ✓ Mass $C_{12}H_{22}FeO_{14}$ in 1 tablet = 301 (mg) **AND** to **3 SF** ✓			Common errors 602 (mg) (not dividing by 2) = 4 marks 37.7 (using 55.8 instead of 445.8) = 4 marks Last mark involves dividing by two and converting g to mg. These steps may be seen earlier
		(iii)	**A**: Mass Fe = $\frac{180 \times 55.8}{151.8}$ = 66 mg **B**: Mass Fe = $\frac{210 \times 55.8}{169.8}$ = 69 mg **Iron supplement:** **B** provides more Fe per tablet ✓	**1**	**3.1 ×1**	**ALLOW** correct working if iron supplement is not named **ALLOW** iron(II) fumarate or $C_4H_2FeO_4$
				18		

Mark Scheme

Question			Answer	Marks	AO element	Guidance
18	(a)	(i)	**A**: $Fe(OH)_3(s)$ ✓ **B**: $Ag_2S(s)$ ✓	**2**	AO3.1 ×2	**ALLOW** $Fe(OH)_3(H_2O)_3$ **IGNORE** state symbols
		(ii)	Student is incorrect **AND** No oxidation numbers change **OR** example, e,g, Fe stays as +2 ✓	**1**	AO3.2	**ALLOW** no electron transfer
		(iii)	$2[Fe(H_2O)_6]^{2+} + Cl_2 \rightarrow 2[Fe(H_2O)_6]^{3+} + 2Cl^-$ ✓	**1**	AO3.1	**ALLOW multiples** **e.g.** $[Fe(H_2O)_6]^{2+} + ½Cl_2 \rightarrow [Fe(H_2O)_6]^{3+} + Cl^-$ **ALLOW** $2[Fe(H_2O)_6]^{2+} + Cl_2 \rightarrow 2[Fe(H_2O)_5OH]^{2+} + 2HCl$ **OR** $2[Fe(H_2O)_6]^{2+} + Cl_2 \rightarrow 2[Fe(H_2O)_5Cl]^{2+} + 2H_2O$ **NOTE:** equation **MUST** be balanced by charge and oxidation number **IGNORE** state symbols
		(iv)	$5H_2S + 2MnO_4^- + 6H^+ \rightarrow 2Mn^{2+} + 5S + 8H_2O$ ✓✓ **1st mark** **ALL** Correct species (**SIX**) **OR** Equation containing Mn and S species correctly balanced i.e. $5\ H_2S\ +\ 2\ MnO_4^-$ ……. $\rightarrow\ 2\ Mn^{2+}\ +\ 5\ S$ …….. **2nd mark** Complete correct balanced equation	**2**	AO3.1 ×2	**ALLOW** multiples, e.g. $2½\ H_2S + MnO_4^- + 3H^+ \rightarrow Mn^{2+} + 2½\ S + 4H_2O$ **ALLOW** equation with S^{2-}, e.g. $5S^{2-} + 2MnO_4^- + 16H^+ \rightarrow 2Mn^{2+} + 5S + 8H_2O$ **IGNORE** extra electrons for 1st mark

Mark Scheme

Question	Answer	Marks	AO element	Guidance
(b)*	*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** Reaches a comprehensive conclusion to determine the correct formulae of **almost all** of **C**, **D**, **E**, **F**, **G AND 9H_2O** *There is a well-developed line of reasoning which is clear and logically structured.* *The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Reaches a sound conclusion to determine the correct formulae of **at least half** of **C**, **D**, **E**, **F, G AND 9H_2O**. *There is a line of reasoning presented with some structure.* *The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Reaches a simple conclusion to determine the correct formulae of **some** of **C**, **D**, **E**, **F**, **G AND 9H_2O**. *There is an attempt at a logical structure with a line of reasoning.* *The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*	**6**	AO1.2 ×2 AO3.1 ×2 AO3.2 ×2	**Indicative scientific points may include:** **Formula of C, D, E, F and G** • **C**: $Fe(NO_3)_3 \cdot 9H_2O$ **OR** $FeN_3O_9 \cdot 9H_2O$ • **D**: FeN_3O_9 **OR** $Fe(NO_3)_3$ • **E**: Fe_2O_3 • **F**: NO_2 • **G**: O_2 • **9**H_2O *Examples of evidence* $n(H_2O) = \frac{0.486}{18.0} = 0.027$ (mol) 0.027 : 0.003 = 1 : 9 → **9H_2O** n(**F**) $= \frac{270-54}{24000} = \frac{216}{24000} = 0.009(00)$ (mol) M(**E**) = 55.8 × 2 + 16.0 × 3 = 159.6 M(**F**) $= \frac{0.414}{0.009(00)} = 46$ (g mol^{-1}) **G**: oxygen linked to relighting glowing split ***NOTE**: Equations could include evidence* e.g $Fe(NO_3)_3 \cdot 9H_2O \rightarrow Fe(NO_3)_3 + 9H_2O$ $FeN_3O_9 \cdot 9H_2O \rightarrow FeN_3O_9 + 9H_2O$ $2Fe(NO_3)_3 \rightarrow Fe_2O_3 + 6NO_2 + 1½O_2$
	Total	**12**		

Mark Scheme

Question	Answer	Marks	AO element	Guidance
19	**A**	**1**	1.1	
20	**C**	**1**	1.1	

Mark Scheme

Question			Answer	Marks	AO element	Guidance
21	(a)*	(i)	*Refer to marking instructions on page 5 of mark scheme for guidance on marking this question.* **Level 3 (5–6 marks)** All three tests are covered in detail, with at least **six** of **B** to **H** identified correctly and equations mostly correct. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** All three tests are covered with at least **four** of **B** to **H** identified correctly. Some attempt at writing equations, but with several omissions or incorrect formulae. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Only two tests covered with at least **two** of **B** to **H** identified correctly, and little attempt at writing equations. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*	**6**	3.3×3 3.4×3	**Indicative scientific points may include:** **Identification of unknowns** Can be identified within labelled equation. **B** is $FeSO_4$ **OR** Iron(II) sulfate • Test 1: Fe^{2+} present • Test 2: SO_4^{2-} present **D** is $Fe(OH)_2$ **OR** $[Fe(H_2O)_4(OH)_2]$ **OR** iron(II) hydroxide **G** is $BaSO_4$ OR barium sulfate **C** is $CrCl_3$ **OR** chromium(III) chloride • Test 1: Cr^{3+} present • Test 3: Cl^- present **E** is $Cr(OH)_3$ **OR** $[Cr(H_2O)_3(OH)_3]$ **OR** chromium(III) hydroxide **F** is $[Cr(NH_3)_6]^{3+}$ **H** is silver chloride OR $AgCl$ **Equations** **D**: $[Fe(H_2O)_6]^{2+} + 2OH^- \rightarrow Fe(OH)_2 + 6H_2O$ **OR** $Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$ **OR** $[Fe(H_2O)_6]^{2+} + 2OH^- \rightarrow [Fe(H_2O)_4(OH)_2] + 2H_2O$ **OR** $[Fe(H_2O)_6]^{2+} + 2NH_3 \rightarrow [Fe(H_2O)_4(OH)_2] + 2NH_4^+$ **OR** $[Fe(H_2O)_6]^{2+} + 2NH_3 \rightarrow Fe(OH)_2 + 4H_2O + 2NH_4^+$ **E**: $[Cr(H_2O)_6]^{3+} + 3OH^- \rightarrow Cr(OH)_3 + 6H_2O$ **OR** $Cr^{3+} + 3OH^- \rightarrow Cr(OH)_3$ **OR** $[Cr(H_2O)_6]^{3+} + 3OH^- \rightarrow [Cr(H_2O)_3(OH)_3] + 3H_2O$ **OR** $[Cr(H_2O)_6]^{3+} + 3NH_3 \rightarrow [Cr(H_2O)_3(OH)_3] + 3NH_4^+$ **OR**

Mark Scheme

Question			Answer	Marks	AO element	Guidance
						$[Cr(H_2O)_6]^{3+} + 3NH_3 \rightarrow Cr(OH)_3 + 3H_2O + 3NH_4^+$ **F**: $[Cr(H_2O)_6]^{3+} + 6NH_3 \rightarrow [Cr(NH_3)_6]^{3+} + 6H_2O$ **OR** $Cr(OH)_3 + 6NH_3 \rightarrow [Cr(NH_3)_6]^{3+} + 3OH^-$ **OR** $[Cr(H_2O)_3(OH)_3] + 6NH_3 \rightarrow [Cr(NH_3)_6]^{3+} + 3H_2O + 3OH^-$ **G**: $Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$ **H**: $Ag^+ + Cl^- \rightarrow AgCl$

Mark Scheme

Question			Answer	Marks	AO element	Guidance
	(b)	**(i)**	Ni : S : N = $\frac{16.26}{58.7} : \frac{35.36}{32.1} : \frac{31.0}{14}$ **OR** 0.277 : 1.10 : 2.21 **OR** 1 : 4 : 8 ✓ x = 4 ✓ 2 + x + y = 8 y = 2 ✓	**3**	3.1×1 3.2×2	**ALLOW** any correct method **ALLOW** NiS_4N_8 for ratio **ALLOW ECF** for y from incorrect x
		(ii)	+2 ✓	**1**	2.1	+ required **ALLOW** 2+
	(c)		$n(MnO_4^-)$ in titration $= 0.01 \times \frac{12.6}{1000} = 1.26 \times 10^{-4}$ ✓ $n(SO_3^{2-})$ in 25.0 cm^3 $= 1.26 \times 10^{-4} \times 2.5 = 3.15 \times 10^{-4}$ (mol) ✓ $n(SO_3^{2-})$ in 250 cm^3 $= 10 \times 3.15 \times 10^{-3} = 3.15 \times 10^{-3}$ (mol) ✓ mass Na_2SO_3 in 525 g meat $= 3.15 \times 10^{-3} \times 126.1 = 0.397$ (g) ✓ mass Na_2SO_3 in 1 kg of meat $= 0.397215 \times \frac{1000}{525} = 0.7566$ g **OR** 756.6 mg **AND** less than the maximum permitted level **OR** AW ✓	**5**	 1.2×1 2.8×3 3.2×1	**ALLOW** 3 SF or more throughout **ALLOW ECF** throughout Calculator = 0.397215 g **ALLOW** within range: 756 to 757 mg **ALLOW** 0.397 g<0.446 g per 525 g meat.
			Total	**15**		

Mark Scheme

Question			Answer	Marks	AO element	Guidance
22			*Refer to marking instructions on page 5 of mark scheme for guidance on marking this question.* **Level 3 (5-6 marks)** Comprehensive explanation of the terms, ligand and coordination number and ligand substitution **AND** 3D diagrams of suitable examples of 6 **AND** 4 coordinate complex ions with different shapes **AND** Ligand substitution illustrated with a balanced equation *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3-4 marks)** Explanation of the terms, ligand and coordination number and ligand substitution with some errors or omissions **AND:** Diagrams of suitable examples of 6 **AND** 4 coordinate complex ions with different shapes **OR** A 3D wedged diagram of a suitable example of 6 **OR** 4 coordination **OR** A diagram of a suitable example of 6 **OR** 4 coordination **AND** ligand substitution illustrated with an equation **OR** Ligand substitution illustrated with a balanced equation *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence*	**6**	1.1×4 2.1×2	**Indicative scientific points may include:** **Terms** • **Ligand:** Donates a lone pair to metal ion Forms dative covalent (coordinate) bond with metal ion • **Coordination number:** Number of coordinate bonds to metal ion. Could be implicit in annotated diagrams **NOTE:** For monodentate ligands, 'number of ligands' is the same as the number of coordination number • **Ligand substitution:** One **ligand** replacing another **Suitable examples of complex ions with different shapes** • ***Coordination no 6*** **Octahedral** e.g. $[Cu(H_2O)_6]^{2+}$, $[Fe(H_2O)_6]^{3+}$ • ***Coordination no 4*** **Tetrahedral** e.g. $CuCl_4^{2-}$, $CoCl_4^{2-}$ **OR Square planar** Pt complexes, e.g. $Pt(NH_3)_2Cl_2$ **Diagrams and equations** • ***Diagrams of complex ions (may be 3D)*** • ***Equation for ligand substitution*** e.g. $[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow CuCl_4^{2-} + 6H_2O$ $[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4H_2O$ ***NOTE:** A clear and logically structured response would link shapes with some of: coordination number, names of shapes, connectivity, involvement of lone pairs, bond angles, etc. (not inclusive)* **ALLOW** minor slips **NOTE: Levels and the mark within a level is a 'best-fit', not perfection**

Mark Scheme

Question			Answer	Marks	AO element	Guidance
			Level 1 (1-2 marks) Explanation of some terms: ligand, coordination number and ligand substitution with some errors or omissions. **AND** A suitable example of a complex ion **OR** Ligand substitution illustrated with an equation with some errors *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** No response or no response worthy of credit.			
			Total	**6**		