Reactions and Applications of Transition Metals

Mark Scheme 2

Level	International A Level
Subject	Chemistry
Exam Board	Edexcel
Topic	Transition Metals & Organic Nitrogen Chemistry
Sub Topic	Reactions and Applications of Transition Metals
Booklet	Mark Scheme 2

Time Allowed: **69 minutes**

Score: **/57**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

Question Number	Acceptable Answers	Reject	Mark
1(a)(i)	In 21(a) IGNORE State symbols even if incorrect Working in half equations (e.g. multipliers & cancelled $e^{(-)}$) $MnO_4^- + 8H^+ + 5e^{(-)} \rightarrow Mn^{2+} + 4H_2O$($E^\ominus$=1.51V) OR Multiples ALLOW reversible and double headed arrows	Electrons omitted	**1**

Question Number	Acceptable Answers	Reject	Mark
1(a)(ii)	$H_2O \rightarrow ½O_2 + 2H^+ + 2e^{(-)}$ ($E^\ominus$=1.23V) OR Multiples ALLOW reversible and double headed arrows Equation reversed $H_2O - 2e^{(-)} \rightarrow ½O_2 + 2H^+$	Electrons omitted	**1**

Question Number	Acceptable Answers	Reject	Mark
1(a)(iii)	$4MnO_4^- + 12H^+ \rightarrow 4Mn^{2+} + 5O_2 + 6H_2O$ OR $2MnO_4^- + 6H^+ \rightarrow 2Mn^{2+} + 5/2O_2 + 3H_2O$ ALLOW reversible and double headed arrows other multiples uncancelled H^+ and H_2O TE **only** on MnO_4^-|MnO_4^{2-} in (a)(i): $2MnO_4^- + H_2O \rightarrow 2MnO_4^{2-} + ½O_2 + 2H^+$	Uncancelled $e^{(-)}$	**1**

Question Number	Acceptable Answers	Reject	Mark
1(a)(iv)	$E^{\ominus}_{cell}$ = 1.51 − 1.23 = (+)0.28 (V) ALLOW TE on $E^{\ominus}_{cell}$ = −0.67 (V) derived from using MnO_4^-|MnO_4^{2-} if correct equation in (a)(iii) is reversed (1) $E^{\ominus}_{cell}$ is **positive** so reaction is (thermodynamically) feasible / manganate(VII) oxidizes the water / water reduces manganate(VII) ALLOW so **thermodynamically** spontaneous so reaction goes / possible so MnO_4^- unstable (1) No TE on negative $E^{\ominus}_{cell}$ unless correct equation in (a)(iii) is reversed.	Just 'reaction goes'	**2**

Question Number	Acceptable Answers	Reject	Mark
1(b)(i)	Distilled / deionised water need only be mentioned once. Dissolve solid in (a suitable volume (< 150 cm^3) of) distilled / deionised water / dilute sulfuric acid in a **beaker** (1) Transfer solution to a volumetric / graduated flask (1) add washings (1) Make up to mark / 250 cm^3 **and** mix (1) Preparing the solution in the volumetric flask max 2 (MP2 and MP4) ALLOW Any indication of mixing (e.g. swirl / invert)	Just 'water' conc H_2SO_4 conical flask Just 'flask'	**4**

Question Number	Acceptable Answers	Reject	Mark
1(b)(ii)	colourless /pale yellow to (first permanent pale) pink	purple to pink Purple / mauve	**1**

Question Number	Acceptable Answers	Reject	Mark
1(b)(iii)	$MnO_4^- + 8H^+ + 5Fe^{2+} \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$ ALLOW multiples reversible and double headed arrows IGNORE state symbols even if incorrect	Uncancelled $e^{(-)}$	**1**

Question Number	Acceptable Answers	Reject	Mark
1(b)(iv)	Check the method: If the method is based on [MnO_4^-] being less than 0.02 mol dm^{-3} then correct answer with some working scores full marks. % MnO_4^- remaining = 98.6855 (%) with some correct working scores 3 Correct answer (1.31449 (%)) with no working scores 3 Calculation of the % of the Mohr's salt that has reacted before the titration (assumes [MnO_4^-] = 0.02 mol dm^{-3}) gives (about) the same value and scores max 3 Example of fully correct method Mol Fe^{2+} in 25 cm^3 = (10/392)x(25/250) (1) = 2.55102 x 10^{-3} (*) Mol MnO_4^- in 25.85 cm^3 = Answer */5 (1) = 2.55102 x 10^{-3} / 5 = 5.10204 x 10^{-4} (**) Conc^n of MnO_4^- = 1000 x Answer **/25.85 = 0.019737 mol dm^{-3} (***) (1) % reacted prior to the titration = 100 x (0.02 − Answer ***)/0.02 = 100 x (0.02 − 0.019737) / 0.02 = 1.31449 (%) (1) TE at each stage in the calculation unless conc^n MnO_4^- remaining greater than 0.02 (so % reacted negative) when max 2 **Continued on next page**		**4**

Question Number	Acceptable Answers	Reject	Mark
1(b)(iv) continued	A common incorrect calculation is Mol MnO_4^- in 25.85 cm^3 = 25.85 x 0.02/1000 = 5.17 x10^{-4} (0) Mol Fe^{2+} in 25 cm^3 = 5 x 5.17 x10^{-4} = 2.585 x 10^{-3} (1) Mol Fe^{2+} in 250 cm^3 = 10 x 5 x 5.17 x10^{-4} = 2.585 x 10^{-2} Then Actual mol Fe^{2+} in 250 cm^3 = 10/392 = 2.551 x10^{-2} Difference = 2.585x10^{-2} - 2.551 x10^{-2} =0.034 x10^{-2} OR Mass of Mohr's salt = 392 x 2.585 x 10^{-2} = 10.1332 g so difference = 10.1332 – 10 = 0.1332 g (1) Percentage =100 x 0.034 x10^{-2} / 2.585x10^{-2} = 1.3153 (1) Where the calculation breaks down, marks may often be possible for MP1 (mol Fe^{2+} in 25 cm^3) MP2 (**using** 5:1 reacting ratio for Fe^{2+}: MnO_4^-) Ignore SF except 1 SF	1.3333	

Total for Question 1 = 15 marks

Question Number	Acceptable Answers	Reject	Mark
2(a)(i)	If name and formula are given, both must be correct **A** = copper(II) chloride / $CuCl_2$ (1) **B** = tetrachlorocuprate(II) (ion) / $CuCl_4^{2-}$ ALLOW **B** = trichlorocuprate(II) / $CuCl_3^{-}$ (1) **C** = copper(II) hydroxide / $Cu(OH)_2$ / $Cu(OH)_2(H_2O)_4$ (1) **D** = tetraamminecopper(II) (ion) / $Cu(NH_3)_4^{2+}$ / $Cu(H_2O)_2(NH_3)_4^{2+}$ (1) **E** = copper(I) oxide / Cu_2O (1) **F** = iodine / I_2 / triiodide (ion) / I_3^{-} / KI_3 (1) IGNORE state symbols even if incorrect. **correct** oxidation numbers with formula. order of the ligands.	**B** = $CuCl_2$	**6**

Question Number	Acceptable Answers	Reject	Mark
2(a)(ii)	If name and formula are given, both must be correct **X** = (aqueous) ammonia / $NH_3(aq)$ ALLOW NH_3 / ammonium hydroxide (1) **Y** = potassium iodide / KI ALLOW other soluble iodides (1) IGNORE references to concentration	**X** = NaOH iodide / I^{-} KI **and** acid HI	**2**

Question Number	Acceptable Answers	Reject	Mark
2(a)(iii)	(Product is) ethanoic acid / CH_3COOH / ethanoate(ions) / CH_3COO^- (1) IGNORE carboxylic Ethanal is a reducing agent / reduces Cu^{2+} (1) Stand alone marks IGNORE references to oxidation of ethanol products of reduction (e.g. Cu)		**2**

Question Number	Acceptable Answers	Reject	Mark
2(a)(iv)	(Iodine is formed quantitatively and is determined by) titration against sodium thiosulfate solution (of known concentration)	Colorimetry	**1**

Question Number	Acceptable Answers	Reject	Mark
2(b)(i)	(3)d orbitals / (3)d subshell split (by the attached ligands) (1) Electrons are promoted (from lower to higher energy d orbital(s) / levels) OR Electrons move from lower to higher energy d orbital(s) / levels) ALLOW d—d transitions occur (1) Absorbing energy /photons of a certain frequency (in the visible region) ALLOW Absorbing light (1) Reflected / transmitted / remaining light is coloured / yellow / in the visible region ALLOW Complementary colour seen Reflected / transmitted / remaining light / frequency is seen (1) Penalise omission of (3)d once only. Ignore reference to electrons relaxing / dropping to the ground state	Orbital / shell is split	**4**

Question Number	Acceptable Answers	Reject	Mark
2(b)(ii)	Colour depends on the frequency /wavelength /energy of the absorbed light (1) Different **ligands** split the d orbitals to a different extent (1)		**2**

Question Number	Acceptable Answers	Reject	Mark
2(c)(i)	$2Cu^{+}(aq) \rightarrow Cu(s) + Cu^{2+}(aq)$ ALLOW reversible arrows	Electrons	**1**

Question Number	Acceptable Answers	Reject	Mark
2(c)(ii)	The copper(I) is oxidized to copper(II) and (in the same reaction) reduced to copper((0)) OR Copper changes from +1 to 0 and +2 IGNORE Reference to a Cu atom		**1**

Question Number	Acceptable Answers	Reject	Mark
2(c)(iii)	Relevant reduction potentials are $Cu^{2+} + e^{-} \rightleftharpoons Cu^{+}$ $E^{\ominus} = +0.15$ (V) $Cu^{+} + e^{-} \rightleftharpoons Cu$ $E^{\ominus} = +0.52$ (V) ALLOW single arrows (1) $E^{\ominus}_{cell} = 0.52 - 0.15 = (+)0.37$ (V) (1) TE on incorrect $E^{\ominus}$ values providing $E^{\ominus}_{cell}$ is positive (E^{o}_{cell} positive so reaction thermodynamically favourable)		**2**

Total for Question 2 = 21 marks

Question Number	Correct Answer	Reject	Mark
3(a)(i)	$3d^5$ $4s^1$ /$4s^1$ $3d^5$ ALLOW Complete configuration $1s^22s^22p^63s^23p^64s^13d^5$ ALLOW Capitals and subscripts		1

Question Number	Correct Answer	Reject	Mark
3 (a)(ii)	It is $4s^1$ rather than $4s^2$ because with two of the reasons below $3d^5$/ half-filled 3d sub shell is particularly stable **(1)** The paired electrons repel **(1)** All six electrons are in separate orbitals (minimizing repulsion) **(1)** ALLOW The energy required to promote/ transfer 4s to 3d is small OR The energy difference between 4s and 3d is small **(1)**		2

Question Number	Correct Answer	Reject	Mark
3(b)(i)	($E^{\ominus}$ Zn^{2+}(aq)| Zn(s) = -0.76 V $E^{\ominus}$ Cr^{3+}(aq), Cr^{2+}(aq)|Pt = -0.41 V $E^{\ominus}$ [$Cr_2O_7^{2-}$(aq) + $7H^+$(aq)], [$2Cr^{3+}$(aq) + $7H_2O$(l)]|Pt = +1.33 V) If no other mark is scored, data scores (1) however shown Calculation of $E^{\ominus}_{cell}$ values: $E^{\ominus}_{cell}$ for first step = 1.33 – -0.76 = (+)2.09 (V) **(1)** $E^{\ominus}_{cell}$ for second step = -0.41 – -0.76 = (+)0.35 (V) **(1)** As (both) values are positive, (both) reactions are spontaneous/feasible **(1)** Third mark is independent		3

Question Number	Correct Answer	Reject	Mark
3(b)(ii)	**Orange** to **green** to **blue** IGNORE qualifying words eg pale blue		1

Question Number	Correct Answer	Reject	Mark
3 (b)(iii)	The small amount of hydrogen produced (does not present a serious risk) ALLOW "Less" for small amount Indication of ventilation		1

Question Number	Correct Answer	Reject	Mark
3(c)(i)	It is bridging/ bidentate ligand	Polydentate	1

Question Number	Correct Answer	Reject	Mark
3(c)(ii)	Dative (covalent) (bonds)/ co-ordinate (bonds)		1

Question Number	Correct Answer	Reject	Mark
3 (c)(iii)	**Any two from:** Chromium atoms/ ions are covalently bonded/bonded to each other OR Two (chromium) ions/ chromium atoms in the complex **(1)** Each ethanoate ligand forms bonds to two different atoms/ ions **(1)** Ethanoate ions are not normally bidentate ligands **(1)** ALLOW Contains both monodentate and bidentate ligands **(1)** Allow six ligands **and** complex not octahedral **(1)**	Just "two different ligands"	2

Question Number	Correct Answer	Reject	Mark
3 (c)(iv)	The energies of the d electron levels are split to different extents (by different ligands) ALLOW d-d (orbitals) splitting is different OR d-d transitions are different **(1)** So different energy/ frequency/ wavelength light absorbed **(1)**	... (just) transmitted	2

Question Number	Correct Answer	Reject	Mark
3(c)(v)	There are two peaks as two different hydrogen environments **(1)** EITHER The areas due to hydrogen in water molecules compared to hydrogen in ethanoate ions is in the ratio 1 to 3/ 4 to 12 OR As there are 4 hydrogen atoms in water and 12 hydrogen atoms in ethanoate ions **(1)**		2

Question Number	Correct Answer	Reject	Mark
3(d)	**First mark** Dilution factor: moles of chromium(II) ethanoate in 25.0 cm^3 $= \frac{2.66 \times 10^{-3}}{10} = 2.66 \times 10^{-4}$ **(1)** **Second mark** Ratio of manganate(VII) to chromium 4 mol manganate(VII) react with 5 mol of chromium (II) OR 8 mol mangante(VII) react with 5 mol of chromium(II) ethanoate **(1)** **Third mark** moles of manganate(VII) ion $= \frac{4 \times 5.32 \times 10^{-4}}{5}$ OR $\frac{8 \times 2.66 \times 10^{-4}}{5}$ $= 4.256 \times 10^{-4}$ **(1)** **Fourth mark** Volume of manganate(VII) solution $= \frac{4.256 \times 10^{-4}}{0.00750} \times 1000$ = 56.75 cm^3 **(1)** Correct answer no working (4) 28.375 cm^3 gets (3) **Fifth mark** This is unsuitable/ inaccurate because it requires refilling the burette hence increasing burette error OR Better to use more concentrated potassium manganate(VII) OR less chromium ethanoate **(1)**		5

(Total for Question 3 = 21 marks)