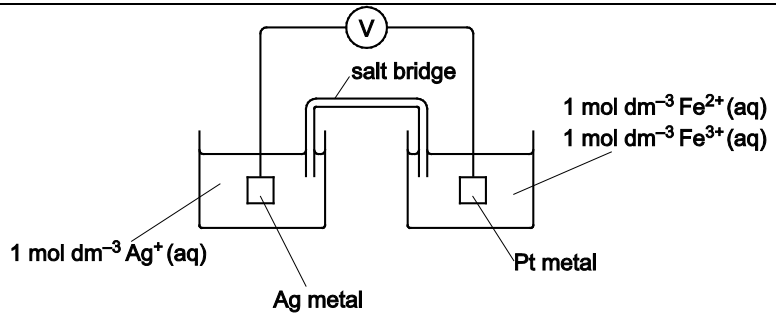
Mark Scheme

Question			Answer	Marks	Guidance
1	(a)	(i)	 **Half-cells (2 marks)** Ag(s) and 1 mol dm^{-3} Ag^{+}(aq) ✓ 1 mol dm^{-3} Fe^{2+}(aq) **AND** 1 mol dm^{-3} Fe^{3+}(aq) **AND** Pt metal ✓ **Complete circuit (1 mark)** salt bridge **AND** voltmeter **AND** wires ✓ **Standard conditions (1 mark)** 298 K / 25 ºC **AND** 100 kPa / 101 kPa pressure ✓	4	**ALLOW** 1 atm
		(ii)	(Electrode potential of) Ag^{+}/Ag becomes more positive ✓ therefore, E_{cell} becomes smaller **OR** less positive. ✓	2	**ALLOW** equilibrium Ag/Ag^{+} shifts to right **ALLOW** more negative 2nd mark only available if deduced from 1st mark **ALLOW ECF** for 2nd mark

Mark Scheme

Question			Answer	Marks	Guidance
	(b)		Ce^{3+} and Zn^{2+} ✓	**1**	
	(c)		Mn^{2+}, H_2O, Fe^{3+}, Br_2 Three species correct ✓ Four species correct ✓	**2**	
			Total	**9**	

Mark Scheme

Question	Answer	Marks	Guidance
2	C	1	

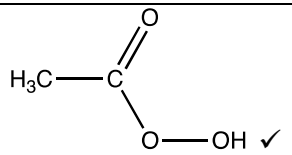
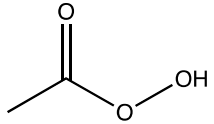
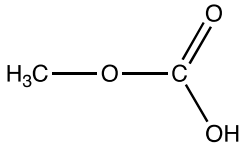
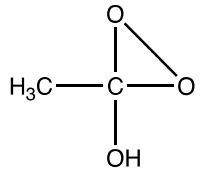
Mark Scheme

Question			Answer	Marks	Guidance
3	(a)	(i)	*Circuit*: complete circuit **AND** voltmeter **AND** *labelled* salt bridge linking two half-cells ✓ *Half cells*: Pt **AND** Fe^{2+} **AND** Fe^{3+} ✓ Zn **AND** Zn^{2+} ✓ *Standard conditions*: 1 mol dm^{-3} (solution(s)) **AND** 298 K / 25ºC ✓	4	Electrodes / salt bridge must at least touch the surface **ALLOW** small gaps in circuit wires **ALLOW** half cells drawn either way around **ALLOW** 1 mol/dm^3 **OR** 1 M **ALLOW** 1 mol dm^{-3}/1M if omitted here but shown for just one solution in diagram **IGNORE** pressure **DO NOT ALLOW** 1 mol(e) for concentration
		(ii)	1.53 (V) ✓	1	**IGNORE** sign
	(b)		*strongest reducing agent*: Zn ✓ *strongest oxidising agent*: MnO_4^- ✓	2	**NOTE**: H^+ has been ignored
	(c)		**AWARD 2 marks** for correct balancing **AND** all species cancelled on both sides of equation: $2MnO_4^- + 6H^+ + 5SO_3^{2-} \rightarrow 2Mn^{2+} + 3H_2O + 5SO_4^{2-}$ ✓ ✓ **AWARD 1 mark** for correct balancing but **not** all species (H_2O, H^+) cancelled on both sides of equation ✓ e.g. $2MnO_4^- + 16H^+ + 5SO_3^{2-} + 5H_2O \rightarrow 2Mn^{2+} + 8H_2O + 5SO_4^{2-} + 10H^+$	2	**ALLOW** correct multiples e.g. $MnO_4^- + 3H^+ + 2½SO_3^{2-} \rightarrow Mn^{2+} + 1½H_2O + 2½SO_4^{2-}$ **IGNORE** state symbols e.g. $MnO_4^- + 8H^+ + 2½SO_3^{2-} + 2½H_2O \rightarrow Mn^{2+} + 4H_2O + 2½SO_4^{2-} + 5H^+$
			Total	9	

Mark Scheme

Question			Answer	Marks		Guidance
4	(a)	(i)	*(rate =)* k $[H_2O_2]$ $[I^-]$ ✓ $k = \frac{rate}{[H_2O_2]\,[I^-]} = \frac{2.00 \times 10^{-6}}{0.0100 \times 0.0100}$ = 0.02(00) ✓ units: $dm^3\ mol^{-1}\ s^{-1}$ ✓	**3**		**Square brackets required** **IGNORE** any state symbols **IGNORE** $[H^+]^0$ **ALLOW ECF** from incorrect rate equation **BUT** units must fit with rate equation used **ALLOW** $mol^{-1}\ dm^3\ s^{-1}$ **OR** in any order **NOTE** K_c expression with calculation and units **0 marks**
	(a)	(ii)	Plot graph using ln k **AND** $1/T$ ✓ (Measure) gradient ✓ *Independent mark* E_a = (–)R × gradient **OR** (–)8.314 × gradient ✓ • *Independent mark, even if variables for graph are incorrect* • *Subsumes 'gradient' mark*	**3**		**Unless otherwise stated, assume, that ln k is on y axis and $1/T$ is on x axis** **IGNORE** intercept **ALLOW** gradient = $(-)\frac{E_a}{R}$ --- **NOTE: ALLOW 'Inverse graph' (special case)** Plot graph of $1/T$ against ln k ✓ (Measure) gradient ✓ *Independent mark* $E_a = (-)\frac{R}{\text{gradient}}$ **OR** $(-)\frac{8.314}{\text{gradient}}$ **OR** gradient = $(-)\frac{R}{E_a}$ ✓ *Subsumes 'gradient' mark*

Mark Scheme

Question			Answer	Marks		Guidance
	(b)		**ALLOW** equilibrium sign in equations provided reactants on left **Reaction of H_2O_2 with MnO_2:** $H_2O_2 + MnO_2 + 2H^+ \rightarrow O_2 + Mn^{2+} + 2H_2O$ ✓ **Reaction of H_2O_2 with Mn^{2+}:** $H_2O_2 + Mn^{2+} \rightarrow MnO_2 + 2H^+$ ✓ **Use of *E* data** Use of *E* data to support equation(s) above or half direction of provided half equations (one including MnO_2) ✓ *Also look for evidence around half equations* MnO_2 regenerated/reformed ✓ *Must be linked to an equation showing MnO_2 as reactant and an equation showing MnO_2 as product*	**4**		**ALLOW** correct multiples **IGNORE** state symbols --- **ALLOW** uncancelled H_2O and H^+ $H_2O_2 + MnO_2 + \mathbf{4}H^+ \rightarrow O_2 + Mn^{2+} + 2H_2O$ **+ $2H^+$** $H_2O_2 + Mn^{2+}$ **+ $2H_2O$ + $2H^+$** $\rightarrow MnO_2 + \mathbf{4}H^+$ **+ $2H_2O$** ***Examples*** • More negative *E* moves to left **ORA** • Reduction half equation to the right **ORA** • Most positive *E* is reduced **ORA** • Calculated *E* cell = +0.81 V (*from top 2*) **OR** *+0.27 V (from bottom 2)* **ALLOW** combining of equations above to show that MnO_2 is used and reformed
	(c)	(i)	 ✓ **ALLOW** skeletal **OR** displayed formula **OR** mixture of the above as long as non-ambiguous, e.g. 	**1**		**ALLOW**  **OR**  Structure must include OH as part of COOOH group **ALLOW** $-O^- H^+$ in structure

Mark Scheme

Question			Answer	Marks		Guidance
	(c)	(ii)	**FIRST CHECK THE ANSWER ON THE ANSWER LINE** **IF** answer = 0.023(125) (mol) award 3 marks for calculation --- ***K_c expression*** $(K_c =) \frac{[CH_3COOOH]}{[H_2O_2]\,[CH_3COOH]}$ ✓ **$[CH_3COOOH]$** $= 0.37 \times 0.500 \times 0.500 = 0.0925$ (mol dm^{-3}) ✓ *Subsumes K_c expression* ***n*(CH_3COOOH)** $= 0.0925 \times \frac{250}{1000} = 0.023(125)$ (mol) ✓	**3**		**If there is an alternative answer, check for any ECF credit** --- **ALLOW** $0.37 = \frac{[CH_3COOOH]}{0.500 \times 0.500}$ **ALLOW ECF** but **ONLY** if 0.37 **AND** 0.5×0.5 have been used **Common errors** **0.076** **2 marks** *Use of $[CH_3COOOH]^2$* **0.675** **2 marks** *Use of 0.5 for $[H_2O]$ on K_c* **0.169** **2 marks** *Inverted K_c* **0.338** **1 mark** *Inverted K_c AND 0.5 for $[H_2O]$* **5.78×10^{-3}** **2 marks** $\times \frac{250}{1000}$ *before $[CH_3COOOH]$*
			Total	**14**		

Mark Scheme

Question	Answer	Marks	AO element	Guidance
5	**D**	**1**	AO2.5	

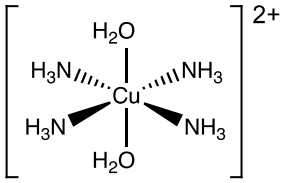
Mark Scheme

Question			Answer	Marks	Guidance
6	(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

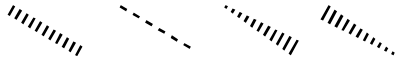
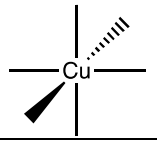
Mark Scheme

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'

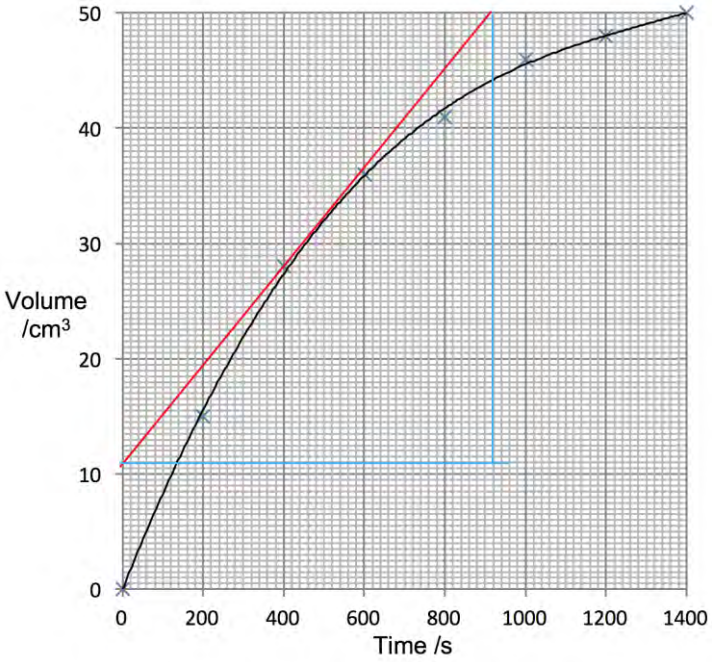
Mark Scheme

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
7	(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 Schemes

Question	Answer	Marks	AO element	Guidance
8	**C**	**1**	AO2.1	

Mark Scheme

Question			Answer	Marks	AO element	Guidance
9	(a)		**Circuit** Complete circuit **AND** voltmeter **AND** salt bridge linking two half-cells ✓ **Half cells** Ag **AND** Ag^+ **AND** 1 mol dm^{-3} solution ✓ Pt **AND** H^+ **AND** MnO_4^- **AND** Mn^{2+} **AND** 1 mol dm^{-3} /equimolar solution ✓	**3**	3.4× 1 1.2× 1 1.2×1	Voltmeter must be shown **AND** salt bridge must be labelled **ALLOW** small gaps in circuit If species in **BOTH** half cells are correct but concentration of 1 mol dm^{-3} omitted, **ALLOW** 1 mark for **BOTH** half cells. **ALLOW** acidified as an alternative for H^+ **IGNORE** stated pressure *Not relevant here as no gas*
	(b)		**Comparison of E values** *E* of redox system **4** (MnO_4^-/Mn^{2+}) is more positive/less negative than *E* of redox systems **2** (HCOOH/HCHO) **OR 1** (CO_2/HCOOH)✓ **Equilibrium shift related to *E* values** More negative/less positive/system **2** (HCOOH/HCHO) **OR** system 1 (CO_2/HCOOH) shifts left **OR** Less negative/more positive/system 4 (MnO_4^-/Mn^{2+}) shifts right ✓ • **2 and 4** $2MnO_4^- + 5HCHO + 6H^+ \rightarrow 2Mn^{2+} + 5HCOOH + 3H_2O$ ✓ • **1 and 4** $2MnO_4^- + 5HCOOH + 6H^+ \rightarrow 2Mn^{2+} + 5CO_2 + 8H_2O$ ✓	**4**	3.1× 2 3.2× 2	**IGNORE** higher/lower ALLOW Overall $E_{reaction}$ = (+)1.54V **OR** (+)1.62V For 'shifts left', **ALLOW** 'is oxidised' **OR** 'electrons are lost ' **OR** 'reducing agent' For 'shifts right', **ALLOW** 'is reduced' **OR** 'electrons are gained' **OR** 'oxidising agent' **IGNORE** state symbols **ALLOW** multiples **DO NOT ALLOW** un-cancelled species, e.g. H^+, on both sides **ALLOW** for 1 mark two balanced equations with uncancelled species. **ALLOW** combined equation for 2 marks: $4MnO_4^- + 5HCHO + 12H^+ \rightarrow 4Mn^{2+} + 5CO_2 + 11H_2O$

Mark Scheme

Question			Answer	Marks	AO element	Guidance
	(c)		$2H^+ + ½O_2 + 2e^- \rightarrow H_2O$ ✓ 1.34 + (–0.11) = (+)<u>1.23</u> (V) ✓	**2**	2.6 2.2×1	**IGNORE** state symbols **ALLOW** multiples
			Total	**9**		