Question	Expected answers	Marks	Additional guidance
1 (a) (i)	(Enthalpy change of) formation (of magnesium oxide) (1); (Enthalpy change of) atomisation (of magnesium) (1); First ionisation enthalpy (of magnesium) (1)	3	**Allow** (enthalpy change of) sublimation (of magnesium) **Allow** first ionisation energy
(ii)	$Mg^{2+}(g)$ and $O^{2-}(g)$ (1)	1	State symbols **essential**
(iii)	Electron being gained is repelled by the negative charge of the ion / aw (1)	1	
(b) (i)	Lattice enthalpy = –149 – 736 – 1450 – 248 – 650 – 602 (1); = –3835 ($kJ\ mol^{-1}$) (1)	2	**Allow** ecf from one error (1)
(ii)	Lattice enthalpy of barium oxide is less exothermic than that of magnesium oxide / lattice enthalpy is smaller in magnitude / ora (1); Mg^{2+} has a smaller ionic radius than Ba^{2+} / Mg^{2+} has a higher charge density than Ba^{2+} / ora (1); So stronger attraction between the positive and negative ion (1)	3	**Not** bigger or smaller lattice enthalpy Correct particles must be used e.g. **not** Mg has a smaller radius **Allow** so has stronger ionic bonds
(c)	High melting point / (very) large lattice enthalpy / aw (1)	1	**Not** resistant to heat
(d) (i)	$BaCO_3 \rightarrow BaO + CO_2$ (1)	1	State symbols **not** essential
(ii)	Decomposition temperature higher for $BaCO_3$ / ora (1) Polarising ability of cation decreases from Mg^{2+} to Ba^{2+} (1); Polarisation causes distortion of the charge cloud around the carbonate ion / polarisation weakens the covalent bonds within the carbonate ion (1)	3	Particles used must be correct e.g. not Mg is more polarising **Allow** marks via a diagram
		Total = 15	

Question	Expected answers	Marks	Additional guidance
2 (a)	Often are catalysts (1)	1	**Allow** compounds are often paramagnetic **Not** metallic properties
(b) (i)	Tetrahedral / or a clear drawing of a tetrahedral ion (1); Bond angle of 109.5 ± 0.5° (1)	2	**Allow** square planar (1) with bond angle of 90° (1) Tetrahedral structure must have at least one wedge
(ii)	Cl^- (1)	1	
(iii)	(Concentrated) hydrochloric acid / (concentrated) solution of an ionic chloride (1)	1	**Allow** correct formula
(iv)	Suitable equation e.g. $[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CuCl_4]^{2-} + 6H_2O$ Or $[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(H_2O)_2(NH_3)_4]^{2+} + 4H_2O$; Reaction in which a ligand is swapped or displaced by another ligand / aw (1)	2	**Not** ligand is substituted
		Total = 7	

Question	Expected answers	Marks	Additional guidance
3 (a)	Oxidation - Oxidation number of oxygen changes from –1 to 0; Reduction – oxidation number of oxygen changes from -1 to –2 (1)	2	**Allow** one mark if all the oxidation numbers for oxygen (and hydrogen) are correct
(b) (i)	$2MnO_4^- + 6H^+ + 5H_2O_2 \rightarrow 2Mn^{2+} + 8H_2O + 5O_2$ Correct reactants and products (1); Balancing (1)	2	**Ignore** electrons for the first mark
(ii)	Moles of MnO_4^- = $17.5 \times 10^{-3} \times 0.0200 / 3.5 \times 10^{-4}$ (1); Moles of H_2O_2 = 2.5 x moles of $MnO_4^- / 8.75 \times 10^{-4}$ (1); Conc of $H_2O_2 = \frac{8.75 \times 10^{-4}}{0.025}$ = 0.0350 (mol dm^{-3}) (1)	3	**Allow** ecf within question **Allow** 0.035 **Not** 0.04 / 0.03
(c)	Aqueous sodium hydroxide / potassium thiocyanate / ammonium thiocyanate (1); Appropriate observation e.g. orange-red / brown / brown-red / foxy-red ppt with NaOH(aq) or (blood) red with KSCN (1)	2	**Allow** hydroxide (ions) or thiocyanate (ions)
		Total = 9	

2(a) labels on diagram to show

Ni(s) and $Ni^{2+}(aq)$ (1)

salt bridge and suitable circuit (1)

platinum electrode (1)

I_2 and I^- (1)

concentration of 1 mol dm^{-3} for at least one solution/ 298K (1) [5]

(b)(i) 0.79V (1) [1]

(ii) $Ni \rightarrow Ni^{2+} + 2e^-$ (1)

$I_2 + 2e^- \rightarrow 2I^-$ (1) [2]

(iii) $Ni + I_2 \rightarrow Ni^{2+} + 2I^-$ (1) [1]

(iv) from nickel towards iodine since nickel half-cell standard electrode potential is more negative (1) [1]

[Total: 10]

4 (a) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^2$ / $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2 4s^2$ (1)

$1s^2 2s^2 2p^6 3s^2 3p^6$ (1) [2]

(b) colour due to energy being absorbed (1)

when electrons are promoted (1)

energy lies within visible part of spectrum/ complementary colour seen (1)

E = hf (1)

transition metal ions have incomplete d shells (1)

d sub-shell split into 2 energy levels (1)

titanium(IV) has no d electrons (1) [6 max]

QWC for use of scientific language

account to include at least 2 of
electron excitation
energy absorption
complementary colour
d shell/ d sub-shell (1) [1]

[Total:9]

5(a) Mr of $KCr(SO_4)_2 = 283$ (1)

$KCr(SO_4)_2 : H_2O = \frac{0.98}{283} : \frac{0.75}{18}$ (1)

$= 0.00346 : 0.0417 = 1 : 12$ (1)

other valid methods credited [3]

(b)(i) 3D diagram to show octahedral shape (1)

bond angle marked as 90^o (1) [2]

(ii) octahedron/ octahedral (1) [1]

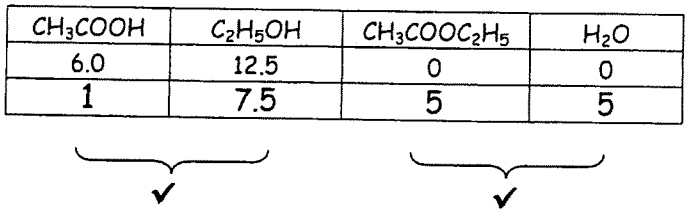
(c)(i) $[Cr(H_2O)_4Cl_2]^+$ (1) [1]

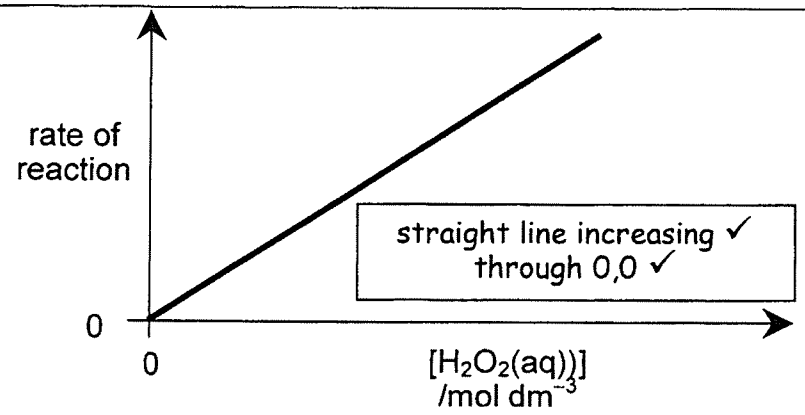
(ii) cis isomer drawn (1)

trans isomer drawn (1)

correct labels cis and trans (1) [3]

[Total: 10]

Question	Expected Answers	Marks
1 (a)	$K_c = \frac{[CH_3COOC_2H_5]\,[H_2O]}{[CH_3COOH]\,[C_2H_5OH]}$ ✓✓ *award 1 mark if upside down*	[2]
(b) (i)	 	[2]
(ii)	$K_c = \frac{5 \times 5}{1 \times 7.5}$ = 3.3 ✓ no units ✓ (or ecf based on answers to (i) and/or (a))	[2]
(c)	leave experiment longer ✓ monitor compositions and repeat until constant value ✓	[2]
(d) (i)	more $CH_3COOC_2H_5$ & H_2O / less CH_3COOH & C_2H_5OH ✓ equilibrium ⟶ right ✓ AW	[2]
(ii)	K_c stays same ✓	[1]
(e)	stays the same/ catalyst does not shift equilibrium position ✓ forward & reverse reactions altered by same amount/ equilibrium achieved in less time ✓	[2]
(f) (i)	equilibrium ⟶ left ✓ more reactants / less products ✓	[2]
(ii)	forward reaction is exothermic ✓	[1]
		Total: 16

Question	Expected Answers	Marks
2 (a)	$H_2O_2 + 2I^- + 2H^+ \longrightarrow I_2 + 2H_2O$ equation includes H_2O, I^-, H^+ as reactants and I_2 as product ✓ equation balanced ✓	[2]
(b) (i)	Exp 2 has twice $[I^-]$ as Exp 1 and rate has quadrupled ✓, so order = 2 with respect to I^- ✓ Exp 3 has twice $[H^+]$ as 2 and rate is unchanged ✓, so order = 0 with respect to H^+ ✓ .....AW	[4]
(ii)	rate = $k\,[H_2O_2]\,[I^-]^2$ ✓✓ 1 mark for: rate = k x concs (ecf from (i))	[2]
(iii)	k = rate/$[H_2O_2][I^-]^2$ ✓(ecf from (ii)) From one of expts, e.g. Exp 1: k = 1.15 x 10^{-6}/(0.01)(0.01)^2 = 1.15 ✓ $dm^6\ mol^{-2}\ s^{-1}$ ✓ (ecf from (ii))	[3]
(c)		[2]
(d) (i)	$2H_2O_2 \longrightarrow 2H_2O + O_2$ ✓	[1]
(ii)	1 dm^3 $H_2O_2 \longrightarrow$ 20 dm^3 O_2 ✓ amount of O_2 = 20/24 mol ✓ concentration of H_2O_2 = 2 x 20/24 = 1.67 mol dm^{-3} ✓	[3]
		Total: 17

Question			Expected Answers	Marks
3	(a)	(i)	a proton donor ✓	[1]
		(ii)	partially dissociates ✓	[1]
		(iii)	$pH = -\log[H^+]$	[1]
		(iv)	A solution that minimises changes/resists change in pH after addition of acid/alkali ✓ NOT 'maintains constant pH' or 'cancel out'	[1]
	(b)		H_2CO_3 reacts with added alkali / added alkali reacts with H^+ / $H^+ + OH^- \longrightarrow H_2O$ ✓ The base or HCO_3^- reacts with added acid ✓ $H_2CO_3 + OH^- \longrightarrow HCO_3^- + H_2O$ ✓ $HCO_3^- + H^+ \longrightarrow H_2CO_3$ ✓.....AW QoWC: equilibrium position moves to counteract change / explanation in terms of le Chatelier's principle ✓	[4] [1]
	(c)		$K_a = \frac{[H^+]\,[HCO_3^-(aq)]}{[H_2CO_3(aq)]}$ ✓ $[H^+] = 10^{-pH}$ ✓ $= 10^{-7.4} = 3.98 \times 10^{-8}$ ✓ $\frac{[HCO_3^-(aq)]}{[H_2CO_3(aq)]} = \frac{K_a}{[H^+]} = \frac{4.17 \times 10^{-7}}{3.98 \times 10^{-8}} = 10.5$ ✓	[4]
				Total: 13