2)	(a)(i)	**H^+(aq):** Exp 3 has 2 x [H^+(aq)] as Exp 1 and rate has increased by 4✓ so order = 2 with respect to H^+(aq) ✓	[2]
		BrO_3^-(aq): Exp 2 has 2 x [BrO_3^-] as Exp 1 and rate increases by 2 ✓ so order = 1 with respect to BrO_3^-(aq) ✓	[2]
		Br^-(aq): Exp 4 has 3 x [BrO_3^-(aq)] as Exp 1 which increases rate by 3 and Exp 4 has 2 x [Br^-(aq)] as Exp 1 rate has increased by 6 so doubling [Br^-(aq)] doubles rate ✓ so order = 1 with respect to Br^-(aq) ✓	[2]
	(ii)	rate = $k\,[H^+]^2\,[BrO_3^-]\,[Br^-]$ ✓	[1]
	(iii)	$k = \frac{\text{rate}}{[H^+]^2\,[BrO_3^-]\,[Br^-]}$ / $\frac{1.68 \times 10^{-5}}{0.30^2 \times 0.05 \times 0.25}$ ✓ = 0.0149/0.015 ✓ units: $dm^9\,mol^{-3}\,s^{-1}$ ✓ answer to 2 or 3 sig figs ✓ (calculator: 0.0149333333) **mark consequentially from (a)(ii)** common ecfs: From expt 1: rate = $k\,[H^+]^2\,[BrO_3^-] \longrightarrow 0.00373\ dm^6\,mol^{-2}\,s^{-1}$	[4]
	(b)	gradient at t=0/start ✓	[1]
	(c)	Overall equation has different stoichiometry/number of moles to rate equation ✓	[1]
			13

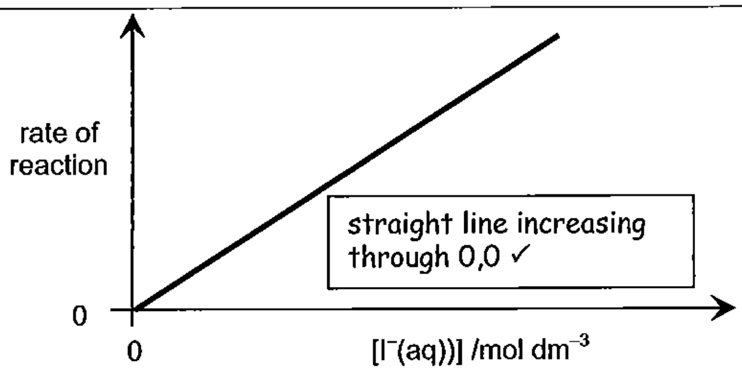
3) (a)		partially dissociates/ionises ✓	[1]
(b)		$CH_3COO^-(Na^+)$ /(sodium) ethanoate ✓	[1]
(c)		Equations with H_2 and CO_2 produced ✓ $Na_2CO_3 + 2CH_3COOH \longrightarrow 2CH_3COONa + CO_2 + H_2O$ ✓ $Mg + 2CH_3COOH \longrightarrow (CH_3COO)_2Mg + H_2$ ✓	[3]
(d)(i)		amount of NaOH used = 0.200 x 22/1000 = 4.4×10^{-3} / 0.0044 ✓ concentration = 0.0044 x 1000/25 = 0.176/0.18 mol dm^{-3} ✓	[2]
	(ii)	metacresol purple because ...... indicator has a pH range coinciding with steepest part of titration curve / 7-10 / equivalence point ✓	[1]
(e)		$n(CH_3COOH) = n(C_2H_5OH)$ = 79.2/46 = 1.72 ✓ (calculator: 1.72173913) $[CH_3COOH]$ = 1.72 x 1000/750 = 2.29 mol dm^{-3} ✓ (calculator: 2.295652174) $K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]}$ ✓ $= \frac{[H^+]^2}{[CH_3COOH]}$ $[H^+] = \sqrt{(K_a \times [CH_3COOH])} = \sqrt{(1.70 \times 10^{-5} \times 2.29)}$ ✓ $= 6.24 \times 10^{-3}$ mol dm^{-3} ✓ (calculator: $6.247086277 \times 10^{-3}$) pH = $-\log(6.24 \times 10^{-3})$ = 2.20/2.21 ✓ (calculator: 2.204322496) **No square root → 4.41: does not score 4th and 5th marks** **No scaling from 750 cm^3 → 2.27: does not score 2nd mark** **Use of 60 instead of 46 → 2.26: does not the 1st mark**	[2] [4]

(f)(i)	CH_3COONa / NaOH / Na ✓	[1]
(ii)	equilibrium: $CH_3COOH \rightleftharpoons CH_3COO^- + H^+$ ✓ CH_3COOH reacts with added alkali / $CH_3COOH + OH^- \rightarrow$ / added alkali reacts with H^+ / $H^+ + OH^- \rightarrow H_2O$✓ $\rightarrow H_2O + CH_3COO^-$ / Equil $\rightarrow$ right (to counteract change) ✓ CH_3COO^- reacts with added acid or H^+ ✓ Equil $\rightarrow$ left (to counteract change) ✓ Large amounts/reservoirs/ of HA and A^- ✓	[5 max]
		20

4)	(a)	mass of H_2S per day = 100 x 10^6 x 1.80/100 = 1.80 x 10^6 g / 1.8 tonnes ✓ $n(H_2S)$ per day = 1.8 x 10^6 /34.1 = 5.3/5.28 x 10^4 ✓ (calculator: 52785.92375) Same number of moles H_2SO_4 formed, mass H_2SO_4 = 5.28 x 10^4 x 98.1 = 5.18 x 10^6 g / 5.18 tonnes ✓ (Rounding in previous stage may give 5.19/5.2 = accept.	[3]
	(b)	step 1 $2H_2S + 3O_2 \longrightarrow 2SO_2 + 2H_2O$ / $H_2S + O_2 \longrightarrow SO_2 + H_2$ ✓ step 2: $2H_2S + SO_2 \longrightarrow 3S + 2H_2O$ / $4H_2S + 2SO_2 \longrightarrow 6S + 4H_2O$ ✓ overall: $6H_2S + 3O_2 \longrightarrow 6S + 6H_2O$ / $2H_2S + O_2 \longrightarrow 2S + 2H_2O$ ✓	[3]
	(c)	In step 1, S (oxidised) from –2 to +4 ✓ In step 2, S in H_2S (oxidised) from –2 to 0 ✓ S in SO_2 (reduced) from +4 to 0 ✓	[3]
	(d)	$H_2S + CO_3^{2-} \rightleftharpoons HCO_3^- + HS^-$ ✓ acid 1: H_2S; base 1: HS^- ✓ acid 2: HCO_3^-; base 2: CO_3^{2-} ✓	[3]
	(e)	$CH_3CH_2CH_2CH_2SH$ ✓ A reagent chosen that would react with a butane-1-thiol (eg O_2, Na, alcohol, HBr, H_2SO_4, PCl_5) ✓ correct equation for chosen reagent ✓	[3]
			15

2816/01 Unifying Concepts in Chemistry/ Experimental Skills 2 Written Paper

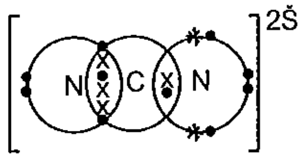
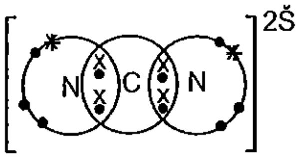
Question	Expected Answers	Marks
1 (a)	$K_c = \dfrac{[CH_3COOH]\,[C_2H_5OH]}{[CH_3COOC_2H_5]\,[H_2O]}$ ✓ Square brackets required. Do **not** award if *p* used anywhere	[1]
(b)(i)	component $CH_3COOC_2H_5$ / H_2O / CH_3COOH / C_2H_5OH initial amount /mol: 8.0 / 5.0 / 0.0 / 0.0 ⇌ amount /mol: *6.0* / *3.0* / 2.0 / *2.0* ✓ ✓ Allow 6, 3, 2 and 2 (ie without '.0')	[2]
(ii)	$\dfrac{\text{moles of component}}{\text{total number of moles}}$ ✓ For 'component', **allow** a specific example or 'substance' moles of a component relative to *OR* compared with total number of moles **credit** 'amount' in place of 'moles' 2/total moles in (i) = 2/13 *OR* 0.15(4) ✓ ie answer depends on total moles in (i) allow 0.153846153 and any correct rounding back to 2 sig figs If 2/13 is shown, then ignore anything that follows.	[2]
	$K_c = \dfrac{2.0 \times 2.0}{6.0 \times 3.0}$ = 4.0/18.0 = 0.22222.... ✓ = 0.22 (ie to 2 sig figs) ✓ no units *OR* '–' *OR* 'none' ✓ **Credit** units if shown cancelled in working For ECF, the values used should be the candidate values from (b)(i). If K_c expression is incorrect, then the **only** acceptable *ECF* response is from an 'upside-down' expression.	[3]
(c)	**equilibrium/reaction** has **shifted** to the right/in favour of products ✓ forward reaction is endothermic ✓ **allow** 'it is endothermic' *OR* 'the reaction is endothermic' K_c has increased ✓	[3]
		11

2	(a)(i)	Expt 2: initial rate = 4.6×10^{-6} mol dm^{-3} s^{-1} ✓ Expt 3: initial rate = 2.3×10^{-6} mol dm^{-3} s^{-1} ✓ Expt 4: initial rate = 5.75×10^{-6} mol dm^{-3} s^{-1} ✓ If powers of ten are not shown, then do **not** credit on the first occasion. Then treat as *ECF*.	[3]
	(ii)	$k = \frac{\text{rate}}{[H_2O_2]\,[I^-]}$ *OR* $\frac{2.30 \times 10^{-6}}{0.020 \times 0.010}$ ✓ = 1.15×10^{-2} / 0.0115 / 0.012 ✓ units: $dm^3\,mol^{-1}\,s^{-1}$ ✓ **allow**: $mol^{-1}\,dm^3\,s^{-1}$ Correct numerical value automatically gets the 1st mark also, even if values from a **different** experiment have been used. If an incorrect rate value is used from (a)(i), then mark 2nd mark and units mark are available (ie *ECF*)	[3]
	(iii)	Overall reaction: 1 mol H_2O_2 reacts with 2 mol I^- and 2 mol H^+ / shows stoichiometry/shows mole ratio ✓ 2nd order (overall) OR 1st order wrt H_2O_2 *and* 1st order wrt I^- / rate determining step involves H_2O_2 and I^- ✓ rate is not affected by H^+ / the reaction is zero order wrt H^+ / the rate determining step does not involve H^+ ✓ Note that '$[H^+]$ is a catalyst' will *CON* this marking point. reaction must proceed via more than one step ✓	**4 marking points giving 3 max**
	(b)	 Allow 2 mm tolerance on 0,0	[1]

(c)	H : O : N : C = 6.38/1 : 51.06/16 : 29.79/14 : 12.77/12 *OR* = 6.38 : 3.19 : 2.13 : 1.06 ✓ empirical/molecular formula = $H_6O_3N_2C$✓ Correct empirical formula automatically gets 1st mark M_r = 6 + 48 + 28 + 12 = 94 ✓ 150 cm^3 of solution needs 2.30 x 150/1000 = 0.345 mol ✓ mass required = 94 x 0.345 = 32.43 g ✓ -- Upside down expression can gain final 4 marks ECF from 1st marking point gives $C_6N_3O_2H$ ✓ M_r = 147 ✓ 150 cm^3 of solution needs 2.30 x 150/1000 = 0.345 mol ✓ mass required = 147 x 0.345 = 50.715 g ✓ (or *ECF* from 2 steps above) -- Use of atomic numbers can gain final 4 marks ECF from 1st marking point gives $H_3O_3N_2C$ ✓ M_r = 91 ✓ 150 cm^3 of solution needs 2.30 x 150/1000 = 0.345 mol ✓ mass required = 91 x 0.345 = 31.395 g ✓ (or *ECF* from 2 steps above) -- **For all possible routes, allow rounding back to 2 sig figs in final answer**	[5]
		15

3	(a)	partly dissociates/ionises ✓ proton/H^+ donor ✓	[2]
	(b)	(K_w =) $[H^+(aq)]\ [OH^-(aq)]$ ✓ *state symbols not needed*	[1]
		$[H^+(aq)] = 10^{-pH} = 10^{-12.72} = 1.91/1.9 \times 10^{-13}$ mol dm^{-3} ✓ [KOH] / $[OH^-(aq)] = \frac{K_w}{[H^+(aq)]} = \frac{1.0 \times 10^{-14}}{1.91 \times 10^{-13}}$ = 0.0524 mol dm^{-3} ✓ (calculator: 0.052480746) Accept any value between 0.052 and 0.053 (answer depends on degree of rounding for H^+ but 2 sig fig minimum.) Alternatively via pOH pOH = 14 – 12.72 = 1.28 ✓ [KOH] / $[OH^-(aq)] = 10^{-pOH}$ = 0.0524 mol dm^{-3} ✓ (calculator: 0.052480746)	[2]
	(c)	*n*(vitamin C) = 0.500/176 = 2.84 x 10^{-3} ✓ [vitamin C] = 1000/125 x 2.84 x 10^{-3} = 0.0227(2) mol dm^{-3} ✓ $K_a = \frac{[H^+]\,[C_6H_7O_6^-]}{[C_6H_8O_6]}$ ✓ $= \frac{[H^+]^2}{[C_6H_8O_6]}$ $[H^+] = \sqrt{(K_a \times [C_6H_8O_6])}$ *OR* $\sqrt{(6.76 \times 10^{-5} \times 0.0227)}$ ✓ = 1.24 x 10^{-3} mol dm^{-3} ✓ (must involve a square root of two numbers multiplied together) pH = –log(1.24 x 10^{-3}) = 2.91 ✓ Accept a calculated value between 2.90 to 2.91 Common incorrect responses: 4.41 would score 5 marks (uses cm^3 instead of dm^3) 5.91 would score 5 marks (conversion multiplies by 1000 instead of dividing by 1000) 5.81 would score 5 marks (no square root) 2.1 would score 1 mark in isolation ($[H^+] = \sqrt{K_a}$)	[6]
			13

4	**Buffer** A buffer solution minimises/resists/opposes pH changes ✓ Do not **allow** 'keeps pH constant'. **How a buffer works** *Mark this part for any of the possible buffer systems above.* equilibrium: HA □ $H^+ + A^-$ ✓ HA reacts with added alkali / HA + $OH^- \rightarrow$ / added alkali reacts with H^+ / $H^+ + OH^- \rightarrow$ ✓ $\rightarrow A^-$ / Equil $\rightarrow$ right ✓ A^- reacts with added acid / $[H^+]$ increases ✓ $\rightarrow$ HA / Equil $\rightarrow$ left ✓ **Components** methanoic acid / HCOOH ✓ sodium methanoate / HCOONa ✓ *ECF*: salt of weak acid chosen above. Do **not** allow a carboxylate ion **Quality of Written Communication** A correct equation and a correct chemistry sentence related to buffers ✓ *Write Q by equation and tick through QWC prompt*	[1] [5] [2] [1]
		9

5	(a)	stage 1 $CaCO_3 \longrightarrow CaO + CO_2$ ✓ stage 2 $2CaO + 5C \longrightarrow 2CaC_2 + CO_2$ / $CaO + 3C \longrightarrow CaC_2 + CO$ ✓ stage 3 $CaC_2 + N_2 \longrightarrow CaCN_2 + C$ ✓ ignore state symbols. These are the **only** acceptable equations. For stage 2, O_2 is **not** an acceptable product.	[3]
	(b)	 *OR*  *'dot-and-cross'* correct except for extra two electrons ✓ two extra electrons shown as dots, crosses or as other symbols so that there are 8 electrons around each atom with a 2– charge shown ✓	[2]
	(c)	$CaCN_2 + 3H_2O \longrightarrow CaCO_3 + 2NH_3$ / $CaCN_2 + 3H_2O \longrightarrow CaO + CO_2 + 2NH_3$ / $CaCN_2 + 4H_2O \longrightarrow Ca(OH)_2 + CO_2 + 2NH_3$ / $CaCN_2 + 2H_2O \longrightarrow CaO + CO(NH_2)_2$ / $CaCN_2 + 3H_2O \longrightarrow Ca(OH)_2 + CO(NH_2)_2$ / $CaCN_2 + 4H_2O \longrightarrow CaO + (NH_4)_2CO_3$ / $CaCN_2 + 5H_2O \longrightarrow Ca(OH)_2 + (NH_4)_2CO_3$ or other correct alternative. Products **must** be compounds, **not** elements such as N_2 and H_2, O_2, Ca and C. Equation that forms a sensible calcium compound, eg $CaCO_3$, CaO, $Ca(OH)_2$, $Ca(HCO_3)_2$, $Ca(NO_3)_2$ ✓ complete balanced equation (see above for examples) ✓ $CaCO_3$/CaO/$Ca(OH)_2$/$Ca(HCO_3)_2$/NH_3 react with acid soils ✓ NH_3 / $(NH_4)_2CO_3$ / $CO(NH_2)_2$ acts as fertiliser ✓	[4]
	(d)	$CaC_2 + 2H_2O \longrightarrow C_2H_2 + Ca(OH)_2$ / $CaC_2 + H_2O \longrightarrow C_2H_2 + CaO$: ✓ $M(CaCO_3) = 100.1$ (g mol^{-1}) ✓ **Not** 100 $n(CaCO_3) = 20 \times 10^3 / 100.1 = 199.8$ mol ✓ allow 200 mol Same number of moles C_2H_2 formed, volume $C_2H_2 = 199.8 \times 24 = 4795.2$ dm^3 ✓ allow 4800 dm^3 Calc value = 4795.204795 dm^3 $2C_2H_2 + 5O_2 \longrightarrow 4CO_2 + 2H_2O$ / $C_2H_2 + 2\frac{1}{2}O_2 \longrightarrow 2CO_2 + H_2O$ / $2C_2H_2 + 3O_2 \longrightarrow 4CO + 2H_2O$ / $C_2H_2 + 1\frac{1}{2}O_2 \longrightarrow 2CO + H_2O$ ✓	[5]
			14

2816/01 Unifying Concepts in Chemistry/ Experimental Skills 2 Written Paper

Question	Expected Answers	Marks
1(a)	$K_c = \frac{[H_2]\,[I_2]}{[HI]^2}$ ✓	1
1(b)(i)	HI: 0.28 ✓ H_2: 0.11 ✓	2
1(b)(ii)	Use of $K_c = \frac{0.11 \times 0.11}{0.28^2}$ to generate a calculated value ✓ = 0.15 ✓ (2 significant figures) (calc. value: 0.154336735) no units ✓ *There must be some response here, not left blank.* If [HI] = 0.39 mol dm^{-3} (common mistake), K_c = 0.07955292571 (calc value) = 0.080 to 2 sig figs Do **NOT** accept 0.08 mol dm^{-3} (1 significant figure)	3
1(c)	K_c doesn't change ✓ Composition stays the same **OR** equilibrium does not move ✓	2
1(d)	K_c increases ✓ (forward) reaction is endothermic **OR** reverse reaction is exothermic ✓	2
1(e)	I : Cl = $\frac{78.15}{127} : \frac{21.85}{35.5}$ **OR** 0.615 : 0.615 ✓ **A**: ICl **OR** any multiple, eg I_2Cl_2, etc ✓ *ICl with no working scored 2 marks.* $HI + Cl_2 \longrightarrow ICl + HCl$ ✓ **ACCEPT** $2HI + Cl_2 \longrightarrow 2ICl + H_2$ *Accept multiples from identification of* **A**. *Accept equation based on an incorrect formula for A but ONLY if a compound of I and Cl* **B**: I_2Cl_6 ✓ $2HI + 4Cl_2 \longrightarrow I_2Cl_6 + 2HCl$ ✓ **ACCEPT** $2HI + 3Cl_2 \longrightarrow I_2Cl_6 + H_2$ ✓ *Accept equation based on an incorrect formula for B but ONLY if a compound of I and Cl*	5
	Total:	**15**

Question	Expected Answers	Marks
2(a)	3 ✓	1
2(b)	$k = \frac{6.90 \times 10^{-7}}{(2.80 \times 10^{-4})^2 \times 1.44 \times 10^{-3}}$ ✓ = 6.11×10^3 ✓ (calculator 6.111819728×10^3) units: $dm^6\ mol^{-2}\ s^{-1}$ ✓ **ACCEPT** 6.1×10^3 up to calculator value If expression is upside down, calculated value = 1.636173913 1.6 up to calculator value would score 1 mark for the numerical value **ECF** units $dm^{-6}\ mol^2\ s^1$ If square is missed, calculated value = 1.711309524 1.7 up to calculator value would score 1 mark for the numerical value **ECF** units $dm^3\ mol^{-1}\ s^{-1}$	3
2(c)(i)	Curve downwards with slope gradually levelling off ✓	1
2(c)(ii)	Measure its gradient **OR** slope ✓ (Tangent) at $t = 0$ **OR** at start ✓ *Either mark could be from triangle shown on graph with y/x*	2
2(c)(iii)	Half-life is constant ✓	1
2(d)(i)	Curve upwards with slope gradually getting steeper ✓	1
2(d)(ii)	rate × 9 **OR** 3^2 ✓ order = 2 (with respect to NO) ✓ *Each marking point is independent*	2
2(d)(iii)	rate × 2^2 × 3 = × 12 ✓	1
	Total:	**12**

Question	Expected Answers	Marks
3(a)	pK_a = 2.82 ✓ calculated value = 2.823908741 **ACCEPT** 2.8 up to calculator value	1
3(b)(i)	$K_a = \frac{[H^+]\,[HSO_3^-]}{[H_2SO_3]}$ ✓	1
3(b)(ii)	$1.50 \times 10^{-3} \approx \frac{[H^+]^2}{0.0265}$ ✓ *('=' sign is acceptable)* $[H^+] = \sqrt{1.50 \times 10^{-3} \times 0.0265} = 6.30 \times 10^{-3}$ mol dm^{-3} ✓ pH = $-$log[H^+] = $-$log 6.30×10^{-3} = 2.20 ✓ *(Stand alone mark; ie* pH $-$log(0.0265) = 1.58 can be awarded 1 mark*)* If all figures kept in calculator, value = 2.200331434 **ACCEPT** 2.2 up to calculator value If no square root, pH =. 4.40	3
3(b)(iii)	a small amount of second dissociation **OR** it is a diprotic acid ✓ **ACCEPT** equilibrium concentration H_2SO_3 is less than the initial concentration.	1
3(c)(i)	ionic product (of water) ✓	1
3(c)(ii)	$K_w = [H^+]\,[OH^-]$ ✓	1
3(d)	$[H^+] = \frac{1.0 \times 10^{-14}}{0.0265}$ **OR** 3.77×10^{-13} **OR** pOH $-$log(0.0265) = 1.58 ✓ pH = $-$log(3.77×10^{-13}) **OR** 14 – 1.58 = 12.42 ✓ calculated value = 12.42324587 **ACCEPT** 12.4 up to calculator value	2
3(e)	**C**: $KHSO_3$ ✓ $KOH + H_2SO_3 \longrightarrow KHSO_3 + H_2O$ ✓ **D**: K_2SO_3 ✓ $2KOH + H_2SO_3 \longrightarrow K_2SO_3 + 2H_2O$ / $KOH + KHSO_3 \longrightarrow K_2SO_3 + H_2O$ ✓ If **C** and **D** are the wrong way around award 3 max by **ECF** If H_2SO_4 used throughout, award 3 max by **ECF**	4
	Total:	14

Question	Expected Answers	Marks
4(a)	$C_2H_4O_3$ ✓	1
4(b)	**Stage 1:** $ClCH_2COOH + 2NaOH \longrightarrow HOCH_2COONa + NaCl + H_2O$ scores two marks ✓✓ $ClCH_2COOH + NaOH \longrightarrow HOCH_2COONa + HCl$ scores one mark ✓ $ClCH_2COOH + NaOH \longrightarrow ClCH_2COONa + H_2O$ scores one mark ✓ $ClCH_2COOH + NaOH \longrightarrow HOCH_2COOH + NaCl$ scores one mark ✓ **Stage 2:** $HOCH_2COONa + H^+ \longrightarrow HOCH_2COOH + Na^+$ ✓ **ACCEPT ECF** from $ClCH_2COONa$ forming $ClCH_2COOH$	3
4(c)	buffer minimises **OR** resists pH changes ✓ $HOCH_2COOH \rightleftharpoons HOCH_2COO^- + H^+$ ✓	2
	For explanation below, accept HA and A^- OR other weak acid added alkali reacts with H^+ / $H^+ + OH^- \rightarrow H_2O$ ✓ $\rightarrow HOCH_2COO^-$ / Equil $\rightarrow$ right (to counteract change) ✓ $HOCH_2COO^-$ reacts with added acid or H^+ ✓ $\rightarrow HOCH_2COOH$ / Equil $\rightarrow$ left (to counteract change) ✓	4
	$[H^+] = 10^{-pH} = 10^{-4.4} = 3.98 \times 10^{-5}$ ✓ $\frac{[HOCH_2COOH]}{[HOCH_2COO^-]} = \frac{[H^+]}{K_a}$ **OR** $\frac{[HOCH_2COO^-]}{[HOCH_2COOH]} = \frac{K_a}{[H^+]}$ ✓ $\frac{[HOCH_2COOH]}{[HOCH_2COO^-]} = \frac{3.98 \times 10^{-5}}{1.48 \times 10^{-4}}$ **OR** 0.27 **OR** $\frac{[HOCH_2COO^-]}{[HOCH_2COOH]} = \frac{1.48 \times 10^{-4}}{3.98 \times 10^{-5}}$ **OR** 3.7 ✓	3
	QWC: Buffer explanation includes discussion of equilibrium shift ✓	1

Question	Expected Answers	Marks
4(d)	moles $CO_2 = \frac{5.119}{44} = 0.116$ ✓ moles $H_2O = \frac{1.575}{18} = 0.0875$ **OR** moles H = 2 x 0.0875 = 0.175 ✓ moles **A** = $\frac{4.362}{150} = 0.0291$ ✓ Molar ratio **A** : C : H = 1 : $\frac{0.116}{0.0291}$: $\frac{0.175}{0.0291}$ = 1 : 4 : 6 ✓ O = 150 – (4 x 12 + 6 x 1) = 96 moles O = $\frac{96}{16} = 6$ molecular formula = $C_4H_6O_6$ ✓ **ACCEPT** suitable alternatives methods e.g. moles C = $\frac{5.119}{44} = 0.116$ ✓ moles H = $2 \times \frac{1.575}{18} = 0.175$ ✓ (mass C = 1.396 g; mass H = 0.175 g; mass O = 2.791 g) moles O = $\frac{2.791}{16} = 0.174$ ✓ empirical formula = C : H : O = $C_2H_3O_3$ ✓ molecular formula = $C_4H_6O_6$ (related to 150) ✓	5
	Total:	**19**

Qu.	Expected Answers	Mark
2(a)(i)	OH^-: When $[OH^-]$ increases by 2.5, rate increases by 2.5 ✓, so order = 1 (with respect to OH^-) ✓ ClO_2: When $[ClO_2]$ increases by 3, rate increases by $9/3^2$ ✓, so order = 2 (with respect to ClO_2) ✓ *For both OH^- and ClO_2, explanation and order to be marked independently*	4
2(a)(ii)	rate = $k[OH^-]\,[ClO_2]^2$ ✓ **ALLOW** $r = k[OH^-]\,[ClO_2]^2$ **ALLOW ECF** from **(a)(i)** *rate* = **is essential**	1
2(a)(iii)	$k = \dfrac{rate}{[OH^-]\,[ClO_2]^2}$ **OR** $\dfrac{6.00 \times 10^{-4}}{0.0300 \times 0.0100^2}$ ✓ = 200 ✓ *200 without working scores the first 2 marks* ***ALLOW ECF** from an incorrectly rearranged equation* units: $dm^6\ mol^{-2}\ s^{-1}$ ✓ **ALLOW ECF** from rate equation **(a)(ii) but** the units **must** be derived from the rate equation	3
2(b)(i)	rate equation shows (2 ClO_2 and) 1 OH^- and overall equation shows (2 ClO_2 and) 2 OH^- **OR** Rate equation has a different number of moles of OH^- from overall equation ✓	1
2(b)(ii)	$2ClO_2(aq) + 2OH^-(aq) \longrightarrow ClO_3^-(aq) + ClO_2^-(aq) + H_2O$ 1 mark for ClO_3^- ✓ 1 mark for total equation (conditional on 1st mark) ✓	2
	Total:	**11**

Qu.	Expected Answers	Mark
3(a)	$C_6H_5COOH \rightleftharpoons H^+ + C_6H_5COO^-$ ✓ Accept $C_6H_5COOH + H_2O \rightleftharpoons H_3O^+ + C_6H_5COO^-$ ✓ Accept molecular formulae, *ie* $C_6H_5COOH \rightleftharpoons H^+ + C_6H_5COO^-$ Equilibrium sign **essential**	1
3(b)	$K_a = \frac{[H^+][C_6H_5COO^-]}{[C_6H_5COOH]}$ ✓	1
3(c)	concentration = $\frac{3.40}{122}$ ✓ = 0.0279 (mol dm^{-3}) ✓ Accept 0.028 up to calculator value of 0.027868852(46) *(first mark for M_r of benzoic acid – incorrect answer here will give ecf for remainder of question)* $[H^+] = \sqrt{(K_a \times [C_6H_5COOH])}$ **OR** $\sqrt{(6.30 \times 10^{-5} \times 0.0279)}$ ✓ = 1.33×10^{-3} (mol dm^{-3}) ✓ pH = –log $[H^+]$ = –log 1.33×10^{-3} = 2.89 ✓ answer = 2.88 if no rounding. **DO NOT ALLOW** 2.9 unless more d.p. shown elsewhere pH **must** be greater than 1 and less than 7 If no square root, pH = 5.76 4 marks If g dm^{-3} used instead on mol dm^{-3}, pH = 1.83–1.84 3 marks *Watch out for evidence of correct M_r as there may be another mark*	5
3(d)	buffer minimises pH changes ✓ **DO NOT ALLOW** pH is constant HA discussion is OK here C_6H_5COOH reacts with added alkali / $C_6H_5COOH + OH^- \rightarrow H_2O + C_6H_5COO^-$ / added alkali reacts with H^+/$H^+ + OH^- \rightarrow H_2O$ ✓ $\rightarrow C_6H_5COO^-$/$C_6H_5COOH \rightleftharpoons H^+ + C_6H_5COO^- \rightarrow$ right (counteracts change)✓ $C_6H_5COO^-$ reacts with added acid or H^+ ✓ $\rightarrow C_6H_5COOH$/ $C_6H_5COOH \rightleftharpoons H^+ + C_6H_5COO^- \rightarrow$ left (counteracts change) ✓ $[H^+] = K_a \times \frac{[C_6H_5COOH]}{[C_6H_5COO^-]}$ ✓ = $6.30 \times 10^{-5} \times \frac{0.105}{0.125}$ **OR** 5.292×10^{-5} ✓ pH = –log (5.292×10^{-5}) = 4.28 ✓ (calculator: 4.276380164) **ALLOW** 4.3 **OR** ALTERNATIVE APPROACH USING H.H. EQUATION: pK_a = –log 6.30×10^{-5} = 4.20 ✓	1 **EXPL 4** **CALC 3**

	$pH = pK_a + \log\frac{[C_6H_5COO^-]}{[C_6H_5COOH]}$ **OR** $pH = -\log K_a + \log\frac{[C_6H_5COO^-]}{[C_6H_5COOH]}$ ✓ pH = 4.20 + 0.08 = 4.28 ✓ QWC: correct equilibrium shift discussed at least once ✓	1
	Total:	**16**

Qu.	Expected Answers	Mark
4(a)(i)	0.1 mol dm^{-3} ✓	1
4(a)(ii)	final pH (approximately) 11/equivalence point <7 ✓ **ALLOW** correct reference to shape of curve: ie No vertical part after 7/starts to curve at 7	1
4(a)(iii)	NH_4NO_3 ✓ **ALLOW** $N_2H_4O_3$	1
4(a)(iv)	resazurin ✓	1
4(a)(v)	sharp rise after addition of 12.5 cm^3/half the volume of NH_3 ✓ final pH higher ✓ For 'sharp rise', **ALLOW** neutralisation/equivalence/end point	2
4(b)(i)	$Mg + 2HNO_3 \longrightarrow Mg(NO_3)_2 + H_2$ ✓ $Mg + 2H^+ \longrightarrow Mg^{2+} + H_2$ ✓ **IGNORE** state symbols **DO NOT ALLOW** $2NO_3^-$ added to both sides of ionic equation	2
4(b)(ii)	With dilute HNO_3: H (reduced) from +1 to 0 ✓ With conc. HNO_3: N (reduced) from +5 to +4 ✓	2
	Total:	**10**

Qu.	Expected Answers	Mark
5(a)	moles $CaSO_4.0.5H_2O = \frac{500}{145.2}$ or 3.44 mol ✓ mass H_2O = 1.5 x 3.44 x 18 = 92.88/92.9/93 g /92.98 g with no rounding ✓ Correct units of g required **ALLOW** 3.44 x 27 = 92.88 (watch **ECF**) **ALLOW** 1 mark for 78.4 g (2nd mark above from 500/172.2 x 1.5 x 18) ***ALLOW*** *$M(CaSO_4.0.5H_2O)$ = 145 g mol^{-1}*	2
5(b)	M_r unknown gas = $\frac{28 \times 1.52}{0.60}$ = 71 ✓ molecular formula = Cl_2 ✓ **ALLOW** any gas that exists with an M_r of 71 (if you can think of one) *If M_r is incorrect then gas chosen must have this value for M_r BUT Cl_2 will always automatically score 2nd mark irrespective of what has come before.*	2
5(c)(i)	$C_6H_8O_7$	1
5(c)(ii)	**Moles NaOH** amount of NaOH in titration = $\frac{0.00425 \times 21.35}{1000}$ or 9.07 x 10^{-5} mol ✓ (calc: 9.07375 x 10^{-5}) **Moles citric acid** amount of citric acid in 25.0 cm^3 = $\frac{\text{mol NaOH}}{3}$ or 3.02 x 10^{-5} mol ✓ (calc: 3.024583333 x 10^{-5}) **Scaling** amount of citric acid in 250 cm^3 = 10 x 3.02 x 10^{-5} or 3.02 x 10^{-4} ✓ **Molar mass** molar mass of citric acid = 192 g mol^{-1} ✓ (or M_r of citric acid is 192) ***Allow ECF from incorrect molecular formula in 5(c)(i)*** **Mass of citric acid in drink** mass citric acid in 250 cm^3 of drink = 3.02 x 10^{-4} x 192 = 0.0580 g ✓ *If calculator value held throughout, mass = 0.0581 g* *allow **ECF** throughout*	5
	Total:	**10**

Qu.	Expected answers	Marks
2(a)	$H_2O_2 + 2I^- + 2H^+ \longrightarrow I_2 + 2H_2O$ equation includes H_2O_2, I^-, H^+ as reactants and I_2 as product ✓ equation balanced ✓	2
2(b)(i)	order = 1 with respect to I^- ✓ When $[I^-]$ doubles, rate doubles ✓ order = 0 with respect to H^+ ✓ When $[I^-]$ doubles, rate doubles **OR** when $[I^-]$ quadruples, rate quadruples ✓	4
2(b)(ii)	rate = $k\,[H_2O_2]\,[I^-]$ ✓ *[ECF from (i)]*	1
2(b)(iii)	From one of experiments, e.g. Experiment 1: $k = \dfrac{5.75 \times 10^{-6}}{0.05 \times 0.01}$ ✓ = 1.15×10^{-2} ✓ $dm^3\,mol^{-1}\,s^{-1}$ ✓ *[ECF from (ii)]. Accept 1.2×10^{-2}*	3
2(c)(i)	$2H_2O_2 \longrightarrow 2H_2O + O_2$ ✓	1
2(c)(ii)	$1\,dm^3\,H_2O_2 \longrightarrow 40\,dm^3\,O_2$ ✓ amount of $O_2 = \dfrac{40}{24}$ **OR** 1.67 mol ✓ concentration of $H_2O_2 = \dfrac{2 \times 40}{24} = 3.3\,mol\,dm^{-3}$ **OR** $2 \times 1.67 = 3.34$ ✓ *Accept 3.3'*	3
		14

Qu.	Expected answers	Marks
3(a)(i)	$I_2(aq) + H_2S(g) \longrightarrow 2HI(aq) + S(s)$ species and balance ✓ state symbols: accept (s) for I_2; (aq) for H_2S ✓	2
(ii)	moles HI = $\frac{47.2}{128}$ = 0.36875 mol ✓ *accept rounding back to 0.369 mol* [HI] = $\frac{0.36875 \times 1000}{225}$ = 1.64 mol dm^{-3} pH = -log 1.64 = -0.21 ✓	2
3(b)(i)	$CH_3COOH \rightleftharpoons H^+ + CH_3COO^-$ ✓ *Equilibrium sign is required*	1
(ii)	$K_a = \frac{[H^+(aq)]\ [CH_3COO^-(aq)]}{[CH_3COOH(aq)]}$ **OR** $[H^+] = \sqrt{([CH_3COOH]\,[K_a])}$ ✓ $[H^+] = \sqrt{\{(1.70 \times 10^{-5}) \times (2.74 \times 10^{-3})\}}$ = 2.16×10^{-4} mol dm^{-3} ✓ *(or 2 marks if no expression given before)* pH = $-\log[H^+(aq)]$ = $-\log 2.16 \times 10^{-4}$ = 3.67 ✓ *ECF: pH Must be from both [CH_3COOH] AND K_a* ***DO NOT ALLOW*** *3.7* *If no square root, ECF answer = 7.33*	3
(iii)	HI + CH_3COOH $\rightleftharpoons$ I^- + $CH_3COOH_2^+$ ✓ acid 1 base 2 base 1 acid 2 ✓ *Mark acid base pairs ECF from equation showing ethanoic acid as proton donor*	2
3(c)(i)	$NaHCO_3$ is an alkali or base / neutralises acid ✓ $HCOOH + NaHCO_3 \longrightarrow HCOONa + CO_2 + H_2O$ ✓ Allow H_2CO_3 instead of $CO_2 + H_2O$	2
(ii)	vinegar is acidic ✓ neutralises alkali in wasp sting ✓	2
(iii)	$[H^+] = \frac{K_a \times [HCOOH(aq)]}{[HCOO^-(aq)]} = \frac{1.60 \times 10^{-4} \times 0.75}{1.92}$ **OR** 6.25×10^{-5} mol dm^{-3} ✓ pH = $-\log[H^+]$ = $-\log(7.5 \times 10^{-5})$ = 4.20 / 4.2 ✓ *ECF: pH Must be from [CH_3COOH], [CH_3COO^-]* ***AND*** *K_a* *If fraction inverted, ECF answer = 3.39*	2
		16

Qu.	Expected answers	Marks
4(a)	moles of NaOH = $\frac{0.152 \times 19.80}{1000}$ / 3.01×10^{-3} mol ✓ moles of acid = 3.01×10^{-3} mol ✓ (3.0096×10^{-3}) moles of acid in flask = $4 \times 3.00 \times 10^{-3} = 1.20 \times 10^{-2}$ mol ✓ (0.0120384) molar mass of compound = $\frac{mass}{n} = \frac{1.368}{1.20 \times 10^{-2}}$ = 114 ✓ Molecular formula = $C_6H_{10}O_2$ ✓ A six carbon carboxylic acid (e.g. hexanoic acid) shown (bod) ✓ Any 2 possible **structural** isomers ✓✓ eg: $CH_3CH_2CH_2{=}CH(CH_3)COOH$ $CH_3CH_2{=}CH(CH_3)CH_2COOH$ *Accept structural formulae or displayed formulae as long as they are unambiguous.*	8
4(b)	**Rate–concentration graphs** Zero order: horizontal line ✓ First order: straight rising line going through origin ✓ Second order: curve rising upwards going through origin OR straight line in a rate vs conc^2 graph ✓ correct labeled axes shown once ✓ *Marks can be obtained by three clear sketch graphs* **pH curves** Sketch graph with a sharp rise for strong acid and strong base with line vertical part of curve centred at about pH 7 Must be some indication of pH numbers fitting the vertical part of curve ✓ Sketch graph with a sharp rise for strong acid and strong base with line vertical part of curve centred at a pH greater than 7 Must be some indication of pH numbers fitting the vertical part of curve ✓ **Vertical** section in strong/strong graph is larger than **vertical** section for weak/strong graph **AND** pH curve for weak starts at higher pH than for strong ✓ correct labeled axes shown once ✓ (For *x* axis, accept 'volume **OR** amount of what is added')	8
QWC	For pH titration pH curve, a statement that the colour change of suitable indicator range matches the vertical section ✓	1
		17

<table>
<tr><th>Qu.</th><th>Expected Answers</th><th>Marks</th></tr>
<tr><td>1 (a)</td><td>$K_c = \frac{[CH_3COOC_2H_5]\,[H_2O]}{[CH_3COOH]\,[C_2H_5OH]}$ ✓</td><td>1</td></tr>
<tr><td>(b)(i)</td><td>
<table>
<tr><th>CH_3COOH</th><th>C_2H_5OH</th><th>$CH_3COOC_2H_5$</th><th>H_2O</th></tr>
<tr><td>8.0</td><td>14.5</td><td>0</td><td>0</td></tr>
<tr><td>1.5</td><td>8.0</td><td>6.5</td><td>6.5</td></tr>
</table>
(first two columns) ✓ (last two columns) ✓</td><td>2</td></tr>
<tr><td>(ii)</td><td>$K_c = \frac{6.5 \times 6.5}{1.5 \times 8.0}$ ✓ = 3.5 ✓ (calc. value 3.520833333)
ALLOW 2 significant figures upwards
DO NOT ALLOW numerical answer if units given
[or ECF based on answers to **(i)** and/or **(a)**]</td><td>2</td></tr>
<tr><td>(c)(i)

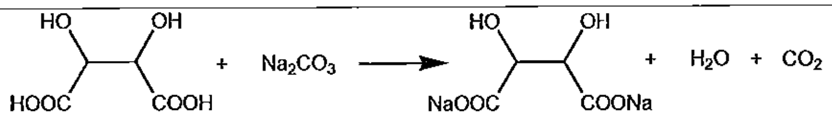
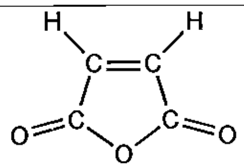
(ii)</td><td>More $CH_3COOC_2H_5$ & H_2O **OR** less CH_3COOH & C_2H_5OH **OR** /equilibrium ⟶ right
AND
to oppose increase in ethanol **OR** to decrease the ethanol **OR** to oppose the change ✓ AW

K_c stays same ✓</td><td>1

1</td></tr>
<tr><td>(d)</td><td>Stays that same **OR** catalyst does not shift equilibrium position ✓
forward and reverse reactions affected by same amount **OR** equilibrium is reached in less time **OR** catalyst not in K_c expression ✓</td><td>2</td></tr>
<tr><td>(e)</td><td>Equilibrium ⟶ left **OR** more reactants **OR** less products ✓
(forward) reaction is exothermic ✓</td><td>2</td></tr>
<tr><td></td><td>**Total:**</td><td>11</td></tr>
</table>

Qu.	Expected Answers	Marks
2(a)(i)	Time for half a reactant to react ✓	1
2(a)(ii)	Evidence from graph, either drawn or stated with 2 half-lives ✓ Half-life 52 ± 2 s (50–54) ✓	2
2(a)(iii)	No effect ✓	1
2(b)(i)	Rate = $k[N_2O(g)]$ ✓	1
2(b)(ii)	Evidence of tangent on graph at 70 s ✓ rate = 0.00524 ✓ mol dm^{-3} s^{-1} (dependent on tangent) (**ALLOW** ±0.0005: i.e. values in range 0.0047–0.0058 mol dm^{-3} s^{-1}) **ALLOW** ECF on tangent drawn	2
2(b)(iii)	k = 0.0131 ✓ s^{-1} ✓ (from 0.00524/0.4) **ALLOW** 2 significant figures up to calculator value **ALLOW** answer to **(ii)** / conc. used in get answer in **(ii)**	2
2(c)	Rate determining step **OR** rate equation has 1 molecule of N_2O ✓ (overall) equation shows 2 mol N_2O reacting ✓	2
2(d)(i)	moles N_2O = moles NH_4NO_3 = 100/80 = 1.25 mol **OR** 80 g $NH_4NO_3 \longrightarrow$ 44 g N_2O ✓ mass N_2O = 1.25 x (28 + 16) = 55 g ✓	2
2(d)(ii)	nitrogen in NH_4^+: −3 $\longrightarrow$ +1 / increases by 4 ✓ nitrogen in NO_3^-: +5 $\longrightarrow$ +1 / decreases by 4 ✓	2
2(e)(i)	$4NH_3(g) + 5O_2(g) \longrightarrow 4NO(g) + 6H_2O(l)$ ✓	1
2(e)(ii)	molar masses NH_3 = 17; HNO_3 = 63 ✓ mass = 700 000 x 17/63 = 1.89 x 10^5 tonnes OR 1.89 x 10^{11} g ✓ calc. value 1.888888.... x 10^5 *ans: mark could be consequential on incorrect molar masses.* **ALLOW** 2 significant figures up to calculator value	2
	Total:	**18**

Qu.	Expected Answers	Marks
3(a)(i)	HCl is a strong acid and CH_3COOH a weak acid ✓	1
3(a)(ii)	$[H^+] = 10^{-3.23} = 5.89 \times 10^{-4}$ mol dm^{-3} ✓ $K_a = [H^+]^2 / [HA] = (5.89 \times 10^{-4})^2 / 0.0200 = 1.73 \times 10^{-5}$ ✓ mol dm^{-3} ✓ **ALLOW** 2 significant figures up to calculator value	3
3(a)(iii)	conc HCl = 0.00500 mol dm^{-3} ✓ pH = 2.31 ✓ (calc: 2.306029996)	2
3(b) (i)	$K_w = [H^+(aq)]\,[OH^-(aq)]$ ✓ state symbols not needed ✓	1
3(b)(ii)	$[H^+(aq)] = \frac{K_w}{[OH^-(aq)]} = \frac{1.0 \times 10^{-14}}{0.015} = 6.7 \times 10^{-13}$ mol dm^{-3} ✓ pH = $-\log(6.7 \times 10^{-13}) = 12.18$ ✓ *pH ECF from [H$^+$]* **ALLOW** one decimal place up to calculator value	2
3(c)(i)	Shape: small rise, sharp rise small rise ✓ Sharp rise at approx 33.3 cm^3 ✓ Finish is nearer to 14 than start is to 0 ✓	3
3(c)(ii)	Thymol blue as pH range matches pH change during sharp rise ✓ **ALLOW** ECF from incorrect titration curve	1
3(d)	A solution that minimises pH changes/resists pH changes/opposes pH changes ✓ (**not** pH is kept constant/pH maintained/pH cancelled out)	1
	equilibrium: $CH_3COOH \rightleftharpoons CH_3COO^- + H^+$ ✓	1
	ALLOW HA from now on CH_3COOH reacts with added alkali / $CH_3COOH + OH^- \rightarrow H_2O + CH_3COO^-$ / added alkali reacts with H^+ / $H^+ + OH^- \rightarrow H_2O$✓ $\rightarrow CH_3COO^-$ / Equil → right (to counteract change) ✓	2
	CH_3COO^- reacts with added acid or H^+ ✓ $\rightarrow CH_3COOH$ / Equil → left (to counteract change) ✓	2
	pH increases as $[H^+]$ is less ✓ $[H^+] = K_a\,[CH_3COOH]/[CH_3COONa]$ **OR** equilibrium shifts left ✓ Quality of Written Communication mark is subsumed within discussion for last mark	2
	Total:	21

Qu.	Expected Answers	Marks
4(a) (i)	C_4H_{10} + 3½O_2 ⟶ $C_4H_2O_3$ + 4H_2O ✓	1
4(a) (ii)	moles butane = 30 x 1 000/24 = 1 250 ✓ mass maleic anhydride = moles x M_r = 1 250 x 98 = 122,500 g / 122.5 kg ✓	2
4(b)	Empirical formula = $C_2H_3O_3$ ✓	1
4(c) (i)	 CO_2 and H_2O ✓ complete equation ✓	2
4(c) (ii)	Any chemical that reacts: e.g. metal more reactive than Pb / base / alkali carboxylic acid / alcohol / hydrogen halide ✓ Equation to match chemistry of chemical added; organic product ✓ balanced ✓	3
4(d)	 ✓ **ALLOW** any other cyclic version	1
	Total:	10

4. **A** K : Cl : O = 31.9/39.1 : 29.0/35.5 : 39,1/16 = 0.82 : 0.82 : 2.44 ✓

= $KClO_3$ ✓

B Addition of $Ag^+(aq)$ with white ppt is test for Cl^- ✓

= KCl ✓

C AgCl ✓

1.1h, 1.5c [5]

- write balanced equations for all reactions that took place,

$4KClO_3 \longrightarrow 3KClO_4 + KCl$ ✓

$KClO_4 \longrightarrow KCl + 2O_2$ ✓

$Ag^+ + Cl^- \longrightarrow AgCl$ ✓

1.1i [3]

- calculate the mass of **B** formed from 0.250 g of $KClO_4$.

amount of $KClO_4$ = 0.250/138.6 = 1.80×10^{-3} mol ✓

mass KCl = 74.6 x 1.80×10^{-3} mol = 0.134 g ✓

(or 0.135 g *if moles are not rounded)*

✓✓ 1.1h [2]

- calculate the volume of oxygen formed, at r.t.p..

amount of O_2 = 2 x (1.80×10^{-3}) = 3.60×10^{-3} mol ✓

volume of O_2 = 24/1000 x (3.60×10^{-3}) = 86 cm^3 ✓

(or 87 cm^3 *if moles are not rounded)*

1.1h[2]

Clear, well-organised [1]

[Total: 13]

4. (a)

Pressure: 3 marks

high pressure ✓ fewer gaseous moles on right ✓

Compromise: pressure used but too much is requires too much energy/high costs/causes safety issues/thick pipes ✓

Temperature: 4 marks

low temperature ✓ reaction is exothermic ✓

Increased temperature needed to increase the rate/low temperature gives a slow rate ✓

Compromise: idea of a compromise between rate and equilibrium amount ✓

7 marking points ⟶ 6 max

Clear, well-organised, using specialist terms ✓

[7]

(b) (i)

what citric acid does: citric acid dissociates ✓

H^+ released / H_2O accepts H^+/behaves as a base ✓

equation: $H_3A + 3H_2O \longrightarrow 3H_3O^+ + A^{3-}$
or $H_3A \longrightarrow 3H^+ + A^{3-}$
or $H_3A + H_2O \longrightarrow H_3O^+ + H_2A^-$
or $H_3A \longrightarrow H^+ + H_2A^-$ ✓ (or other intermediate dissociation)

The equation alone will also score the 2 'what citric acid does' marks.

how H^+ reacts: H^+ now reacts with HCO_3^- ions/$NaHCO_3$ ✓

equation: $H^+ + HCO_3^- \longrightarrow H_2O + CO_2$ ✓

The equation alone will also score the 'how H^+ reacts' mark.

5 marks ⟶[4] max

(ii) Molar mass of $NaHCO_3$ = 84.0 ✓

amount of $NaHCO_3$ = 0.5/84.0 = 5.95 x 10^{-3} mol ✓

3 mol $NaHCO_3$ reacts with 1 mol citric acid ✓

amount of citric acid = 5.95 x 10^{-3}/3 = 1.98 x 10^{-3} mol ✓

mass of citric acid required = 1.98 x 10^{-3} x 192 = 0.380 g ✓
(allow 0.4 g)

Answer of 0.127g / 0.12698 g from dividing by 3 twice ⟶ ✓✓✓✓✗

[5]
[Total: 16]

Question			Expected Answers	Marks	Additional Guidance
2	(a)	(i)	energy = $mc\Delta T$ (1) = 400 x 4.18 x 13.6 = 22.7 (kJ) (1)	2	need not be actually stated – can be awarded if numbers used correctly if m = 200, allow first mark ignore extra sig figs
		(ii)	number of moles = 0.4 (1) ΔH neut = 56.8 (kJ mol^{-1}) sign ie negative (1)	3	ecf possible from (i) and number of moles in (ii) watch – if 1 used in (i) gives 56.8 stand alone mark
	(b)		$H^+ + OH^- \rightarrow H_2O$ (1)	1	
	(c)		result same for experiments 1 and 2 because the ionic equation/reaction is the same/ both acids are completely dissociated (1) the result for experiment 3 (is less because) ethanoic acid is weak/ not completely dissociated (1) energy is needed to break the bond (and release the H^+) (1)	3	both acids strong is insufficient idea of another ΔH as part of overall reaction must be included
			Total	**9**	

Abbreviations, annotations and conventions used in the Mark Scheme	/	= alternative and acceptable answers for the same marking point
	,	= separates marking points
	NOT	= answers which are not worthy of credit
	( )	= words which are not essential to gain credit
	___	= (underlining) key words which **must** be used to gain credit
	ecf	= error carried forward
	AW	= alternative wording
	ora	= or reverse argument

Question		Expected Answers	Marks
1	(a)	both atomisation steps	1
		1^{st} and 2^{nd} ionisation enthalpies	1
		electron affinity step	1
		lattice enthalpy	1
		enthalpy of formation	1
		all to be chemically correct and correctly labelled; penalise state symbols once only	
	(b)	$\Delta H_f = (+148) + (2\times122) + (738) + (1451) + (2\times -349) + (-2526)$	1
		$\Delta H_f = -643$ kJ mol^{-1} *(with units, correct answer = 2 marks)*	1
		allow ecf from (a)	
	(c)	$MgCl_2$	1
		Cl^- is the smallest anion *(reject chlor__ine__ ion)*	1
		strongest attraction / bonding	1

[Total: 10]

Question			Expected Answers	Marks
2	(a)		$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5$	1
	(b)	(i)	energy of the d electrons approximately the same / transfer energy easily / adsorb well / hold reactants in place / variable oxidation state / easily transfer electrons / good bonding potential *not "cheap"*	1
	(b)	(ii)	in the Haber process / $FeCl_3$ in Friedel Crafts	1
	(c)		from <u>yellow</u> to (blood) <u>red</u>	2
			$[Fe(H_2O)_6]^{3+}$ + SCN^- → $[Fe(H_2O)_5SCN]^{2+}$ + H_2O *2 marks for correct equation* *allow one mark for correct formula and charge on complex ion*	2
	(d)	(i)	from <u>colourless / pale green</u> (*NOT 'green'*) to <u>pink/purple</u>	1
	(d)	(ii)	no mol Fe^{2+} = 25/1000 × 0.05 (= 0.00125 mol)	1
			no mol MnO_4^- = 0.00125 / 5 (= 0.00025 mol)	1
			concn MnO_4^- = 0.00025 / (12.3 × 10^{-3}) = 0.02(03) mol dm^{-3} *allow ecf from line 2, correct answer with units = 3 marks*	1

[Total: 11]

Question		Expected Answers	Marks
4	(a)	[redacted]	
	(b)	*complex ion* metal atom or ion surrounded by ligands	1
		ligand a species able to donate a pair of electrons / form a dative/co-ordinate bond	1
		ligand substitution exchange of ligands	1
		example + colour change + equation	3×2

e g $[Cu(H_2O)_6]^{2+}$ + $4NH_3$ ⇌ $[Cu(H_2O)_2(NH_3)_4]^{2+}$ + $4H_2O$
blue — dark blue

$[Cu(H_2O)_6]^{2+}$ + $4Cl^-$ ⇌ $[CuCl_4]^{2-}$ + $6H_2O$
blue — yellow/green

octahedral + example $[Cu(H_2O)_2(NH_3)_4]^{2+}$

tetrahedral + example $[CuCl_4]^{2-}$

square planar + example $[PtCl_4]^{2-}$

linear + example $[Ag(NH_3)_2]^+$ 2
2

Max 12

QWC, organisation of response 1

[Total: 15]

Abbreviations, annotations and conventions used in the Mark Scheme	/	= alternative and acceptable answers for the same marking point
	,	= separates marking points
	NOT	= answers which are not worthy of credit
	( )	= words which are not essential to gain credit
	___	= (underlining) key words which **must** be used to gain credit
	ecf	= error carried forward
	AW	= alternative wording
	ora	= or reverse argument

Question	Expected Answers		Marks
1 (a) (i)	has at least one ion with a partially filled d-orbital		1
(ii)	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 4s^2$		1
(b) (i)	$Fe(OH)_2$	green	2
	$Fe(OH)_3$ / $Fe_2O_3.xH_2O$	brown/red-brown/rust coloured/orange-brown	2
	both solid		1
(ii)	$[Cu(H_2O)_6]^{2+} + 2OH^- \rightarrow Cu(OH)_2 + 6H_2O$ / $Cu^{2+} + 2OH^- \rightarrow Cu(OH)_2$		1
	$Cu(OH)_2$ obtains 1 mark if not part of balanced equation		1
	$[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4H_2O$		1
	$[Cu(NH_3)_4(H_2O)_2]^{2+}$ / $[Cu(NH_3)_4]^{2+}$ =1mark if not part of balanced equation		1
	N.B. Correctly balanced equations obtain both marks		
		[Total:	11]

Question	Expected Answers	Marks
2 (a)	absorbs violet/blue / 400 nm - 450 nm No other absorbance below 650 nm	1
(b)	absorbs the complementary colour it transmits	1
(c)	K : Cr : F = 0.818 : 0.410 : 2.46 (correct ratios obtain this mark)	1
	2K 1Cr 6F / K_2CrF_6	1
(d)	F^- / fluoride	1
	Don't accept fluorine or F	
	[Total:	5]

Question	Expected Answers	Marks
3 (a)	*correctly labelled* atomisation of chlorine + atomisation of caesium	1
	1st ionisation energy + 1st electron affinity	1
	formation of CsCl + LE	1
(b)	-443 = + 76 + (+122) + (+376) + (-349) + LE	1
	LE = -668 kJ mol^{-1} (allow ecf here if 1 mistake only in step 1)	1
(c)	Na^+ smaller than Cs^+ (don't accept sodium smaller first time)	1
	Na^+ has a larger charge density	1
	attracts the anion/Cl^- more strongly/ sodium chloride has the stronger bonding	1
(d)	dissolves / no reaction *do not accept "nothing"*	1
	colourless / neutral / pH 7	1
(e)	add aqueous $AgNO_3$	1
	chloride gives a white ppt	1
	iodide gives a yellow ppt	1
	Alternative answer	
	Pass chlorine/use NaOCl & HCl	
	No change with CsCl	
	Iodine displaced/brown solution with CsI	
	[Total:	13]

Question	Expected Answers	Marks
4 (a)	$2MnO_4^- + 16H^+ + 5C_2O_4^{2-} \rightarrow 2Mn^{2+} + 8H_2O + 10CO_2$	2
	1 mark for correct species, 1 mark for correct balancing including electrons if present	
(b)	amount of $C_2O_4^{2-}$ = (25.0/1000) × 0 0400 = 0 001 mol	1
	amount of MnO_4^- required = 0 001 × (2/5) = 0.0004 mol	1
	vol of MnO_4^- required = 0 0004/0.0200 × 1000 = 20 cm^3 / 0.02 dm^3	1
	(Allow ecf on parts 2 & 3)	
	[Total	5]

Question			Expected answers	Marks	Additional guidance
3	(a)		$1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$ (1), (Iron is a transition element since this ion has an) incomplete set of 3d electrons / aw (1)	2	Allow second mark even if first marking point is incorrect providing it has an incomplete set of 3d electrons Allow partially filled d orbital
	(b)		Iron in the Haber process / Iron to catalyse reaction of nitrogen and hydrogen / iron in the synthesis of ammonia (1)	1	Allow $FeCl_3$ for Friedel-Crafts alkylation or acylation of benzene
	(c)	(i)	Calculation of moles / mole ratio (1) Na = 1.21, Fe = 0 603 and O = 2.41; Divide by smallest to give correct molar ratio (1) OR Calculation of relative formula mass (1); Working out to get the same percentage compositions (1)	2	Be careful not to award marks for the empirical formula – marks are for the working out
		(ii)	+6 (1)	1	Allow 6 / 6+ / VI / Fe^{6+}
	(d)	(i)	$2I^- \rightarrow I_2 + 2e^-$ (1)	1	Allow $2I^- - 2e^- \rightarrow I_2$ Allow multiples of this equation
		(ii)	$FeO_4^{2-} + 8H^+ + 4I^- \rightarrow Fe^{2+} + 4H_2O + 2I_2$ Correct reactants and products (1); Balancing (1)	2	Ignore state symbols Allow multiples of this equation Allow $4e^-$ on both sides of equation No ecf from (i)
		(iii)	Colour after is orange / yellow / brown (solution) (1)	1	Ignore the colour to start with
				Total = 10	

Question	Expected answers	Marks	Additional guidance
4	**Any eleven from** **Bonding and shape** Dative / coordinate bonding – this must be stated in words (1); Water is an electron pair donor / ligand is an electron pair donor / lone pair on oxygen (1); Metal ion accepts electron pair (1), Octahedral / drawing of octahedral complex (1) **Water** In both cases central oxygen is surrounded by four electron pairs (1), In gaseous water (2 bond pairs and) 2 lone-pairs (1); In gaseous water lone pair-lone pair repulsion is greater than other electron pair repulsions (1); Bond angle is $104^\circ - 105^\circ$ (1), In complex one dative bond is more like a bond pair / water has only one lone pair (1), So less repulsion from the lone pairs (1); bond angle in complex is $106^\circ - 108^\circ$ / bond angle is slightly bigger than 104° (1)	12	Allow by a diagram that clearly shows the oxygen lone pairs being donated to the central metal ion Allow shape by a diagram that clearly shows 3D shape either by wedges, construction lines or bond angles Allow marks by a diagram .
		Total = 12	

Question	Expected answers	Marks	Additional guidance
4	**Distinguishing** Reagent (1) e g aqueous sodium hydroxide / add aqueous ammonium thiocyanate / aqueous ammonia, Result of test with Fe^{2+} (1) e.g. green ppt with Fe^{2+} and NH_3 or NaOH and no reaction with SCN^-, Result with Fe^{3+} (1) e.g orange ppt with Fe^{3+} and NH_3 or NaOH and blood red with SCN-; Suitable equations (2) e.g. $Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$ or $[Fe(H_2O)_6]^{3+} + SCN^- \rightarrow [Fe(SCN)(H_2O)_5]^{2+} + H_2O$ **And** QWC – award one mark for answers using the correct scientific terminology (1)	12	**Allow** OH^- / $NH_3(aq)$ / SCN^- **Allow** acidified MnO_4^- **Allow** other suitable reagents if they are simple chemical tests **Not** colorimetry State symbols **not** needed but may be used to indicate a ppt QWC – candidates must attempt all three parts of the question and must use at least three of the following terms (spelt correctly) octahedral, ligand, dative, coordinate / coordination, lone pair, substitution or precipitate
		Total = 12	

Question	Expected answers	Marks
1 (a)	Correct oxidation states for **each** atom i.e. Ca = +2, C = +4 and O = -2 (1); Oxidation numbers do not change during the reaction / no electron transfer during reaction (1)	2
(b)	$MgCO_3$ decomposition easier than $CaCO_3$ / higher decomposition temperature with $CaCO_3$ / ora (1); ~~Mg^{2+} higher charge density than Ca^{2+} / both have the same charge but Mg^{2+} has a smaller ionic radius (1);~~ So Mg^{2+} will polarise CO_3^{2-} more than Ca^{2+} can / more distortion of the CO_3^{2-} electron cloud by Mg^{2+} (1)	3
(c)	ΔH = +1207 +(-635) + (-393) / correct energy cycle drawn / ΔH_fproduct – ΔH_f reactants (1); ΔH = +179 (kJ mol^{-1})(1)	2
(d)	Mg^{2+} + O^{2-} → MgO (1); (3916 kJ of) energy is released (1); when one mole of **solid** magnesium oxide is made from its constituent **gaseous** ions (1)	3
(e) (i)	Enthalpy change of atomisation (of oxygen) (1)	1
(ii)	**Any two from** Mg^+ has one more proton than electrons / same number of protons but one fewer electron (1); Electron is lost from a particle that carries an overall positive charge (rather than being neutral) (1); So (outer) electron more firmly attracted to the nucleus (1)	2
(iii)	Correct energy level diagram labelled with correct formulae / correct cycle labelled with correct formulae (1); **Any two from** Correct state symbols (1); Correct energy values shown in the Born-Haber cycle (1) Correct labels for the enthalpy changes (1) **And** Lattice enthalpy = -735 +(-1445) + (-150) + (-878) + 141 + (-247) + (-602) (1)	4
(f)	Furnace lining / aw (1)	1
		Total = 18

Question			Expected answers	Marks
2	(a)		Have variable oxidation states / aw (1); (Elements or compounds are) often catalysts (1)	2
	(b)	(i)	$Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)$ / $[Cu(H_2O)_6]^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s) + 6H_2O(l)$ / $[Cu(H_2O)_6]^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(H_2O)_4(s) + 2H_2O(l)$	1
	(b)	(ii)	Colorimeter needs a clear solution / precipitate will interfere with [redacted] the concentration of just the complex ion (1)	1
	(c)		Points plotted correctly (1); Two **straight** lines of best fit that intersect (1)	2
	(d)	(i)	0.0025 (1)	1
		(ii)	10 (cm^3)	1
		(iii)	Answer to part (ii) x 10^{-3} / 0.010 (1)	1
		(iv)	x = 4 and y = 2 (1)	1
	(e)	(i)	Has a lone pair / it is an electron pair donor (1)	1
		(ii)	Lone pair in the ammonia ligand is more like a bond (pair) / ammonia ligand has four bond (pairs) (1); So equal repulsion between all four electron pairs or bonds with the ligand / extra repulsion due to presence of lone-pair in ammonia / aw (1)	2
	(f)	(i)	$[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CuCl_4]^{2-} + 6H_2O$ / $[Cu(H_2O)_6]^{2+} + 4HCl \rightarrow [CuCl_4]^{2-} + 6H_2O + 4H^+$ / $Cu^{2+} + 4HCl \rightarrow CuCl_4^{2-} + 4H^+$	1
		(ii)	Tetrahedral shape with either wedges or correct bond angles / square planar shape (1)	1
				Total = 15

2815/01 Trends and Patterns

Mark Scheme Page 1 of 5	Unit Code 2815/01	Session January	Year 2008	Version Final

Question	Expected answers	Marks	Additional guidance
1 (a)	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$ and iron has an incompletely filled d-orbital (1)	1	Allow [Kr]$3d^6$ incomplete 3d sub-shell / Incomplete d sub-shell
(b) (i)	$[Fe(H_2O)_6]^{2+}$ (1)	1	Allow other correct complex ions If answer blank credit can be obtained from (ii)
(ii)	Octahedral shape with indication of three dimensions (1); 90° (1)	2	Must have at least two wedges, dotted lines or construction lines Allow three dimensions if at least two bond angles of 90° are shown that clearly demonstrate 3D If two different bond angles do not award bond angle mark unless correct 90° and 180° Allow ecf from other complex ions even if they do not contain iron. This may include tetrahedral or square planar arrangements
(iii)	Ligand donates an electron pair / ligand donates a lone pair / iron accepts a lone pair / iron accepts electron pair (1); Dative (covalent) / coordinate (1)	2	Allow ecf from wrong complex
(c)	$[Fe(H_2O)_6]^{3+} + SCN^- \rightarrow [Fe(H_2O)_5SCN]^{2+} + H_2O$ (1); Yellow / orange to (blood) red (1)	2	

Mark Scheme Page 2 of 5	Unit Code 2815/01	Session January	Year 2008	Version Final

Question	Expected answers	Marks	Additional guidance
1 (d)	$FeCl_2$ gives green (grey) ppt and $FeCl_3$ gives foxy red or orange red or brown-red ppt (1); $Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$ / $Fe^{3+}(aq) + 3OH^-(aq) \rightarrow Fe(OH)_3(s)$ (1)	2	Allow solid instead of ppt / use state symbol from equation if ppt not written If give two equations both must be correct Allow equations which give $Fe(OH)_2(H_2O)_4$ or $Fe(OH)_3(H_2O)_3$
(e)	Cr goes from +3 to +6 which is oxidation (1); Fe goes from +6 to +3 which is reduction (1)	2	Allow one mark for correct identification of all oxidation numbers if other marks not scored
(f)	$2FeO_4^{2-} + 10H^+ \rightarrow 2Fe^{3+} + 3/2O_2 + 5H_2O$ Correct reactants and products (1); Balanced (1)	2	Allow correct multiples
		Total = 14	

Mark Scheme	Unit Code	Session	Year	Version
Page 3 of 5	2815/01	January	2008	Final

Question	Expected answers	Marks	Additional guidance
2 (a)	$2Na^+(g) + O^{2-}(g) \rightarrow Na_2O(s)$ (1); Enthalpy change when one mole of solid Na_2O is made from its gaseous ions (1)	2	**Allow** energy released **Not** energy required **Allow** ionic compound / ionic solid / salt / ionic lattice State symbols from equation can be used if states missing from definition
(b)	Correct formulae (1); Correct state symbols (1); Labelled energy changes • Lattice enthalpy • Enthalpy change of formation • Atomisation of magnesium • Atomisation of oxygen • First and second ionisation energy of magnesium (can be labelled together) • First and second electron affinity of oxygen (can be labelled together) Six correct (3); Four or five correct (2); Two or three correct (1)	5	**Allow** use of acceptable symbols for each enthalpy change eg ΔH_f If arrows missing from cycle penalise once only
(c)	(MgO more exothermic because) Oxide ion smaller than carbonate ion / oxide ion has a higher charge density than carbonate ion (1); So oxide ion has a stronger attraction to magnesium ion / carbonate ion has a weaker attraction (1)	2	**Allow** ora **Penalise** use of incorrect particle only once in this question
(d) (i)	$CaCO_3 \rightarrow CaO + CO_2$ (1)	1	**Ignore** state symbols
(ii)	Magnesium ion smaller than calcium ion / magnesium ion has a higher charge density / ora (1); Magnesium ion distorts the carbonate ion more than calcium ion / magnesium ion causes more polarization of the carbonate ion (1)	2	**Allow** ora **Penalise** use of incorrect particle only once in this question
		Total = 12	

Mark Scheme Page 4 of 5	Unit Code 2815/01	Session January	Year 2008	Version Final

Question	**Expected answers**	**Marks**	**Additional guidance**
3 (a)	**Colourless to purple or (pale) pink (1)**	1	**allow** it goes pink / it goes purple **not** just pink / just purple
(b)	Moles of MnO_4^- = 3.81 × 10^{-4} (1); Moles of ethanedioic acid = 9.525 × 10^{-4} (1) / 2.5 × moles of MnO_4^-; Relative formula mass = 126 (1) / 0.120 ÷ moles of ethanedioic acid; x = 2 / (M_r – 90) ÷ 18 (1)	4	**Allow** ecf throughout
(c)	$(COO)_2Mg$ / $Mg(OOC)_2$ (1)	1	**Allow** $(COO^-)_2Mg^{2+}$ / $Mg^{2+}(^-OOC)_2$
		Total = 6	
4	**Structure and Bonding** Correct 'dot and cross' diagram for $SiCl_4$ (1); Correct 'dot and cross' diagram for $MgCl_2$ (1): Correct charges – Mg^{2+} and Cl^- (1); $SiCl_4$ – simple molecular / simple covalent (1); $MgCl_2$ – giant ionic (1)	5	Charges on ions are independent of 'dot and cross' diagram
	Melting Points $MgCl_2$ – (strong electrostatic) attraction between ions (1); $SiCl_4$ – (weak) Van der Waals forces / temporary dipole-temporary dipole interaction / induced dipole-induced dipole interaction (1) Correct use of strong and weak – must be linked to the correct force / bond (1)	3	**Allow** ionic bonds / ionic lattice / 'is ionic' (1) **Allow** intermolecular forces / description of an intermolecular (1)
	Action of water $PCl_5 + 4H_2O \rightarrow 5HCl + H_3PO_4$ (1) Steamy fumes produced / acidic solution produced / vigorous reaction / exothermic (1) $MgCl_2$ + aq → $Mg^{2+}(aq) + 2Cl^-(aq)$ / dissolves / magnesium ions polarises water molecules (1) Makes a colourless solution / neutral solution (1)	4	**Allow** any pH between 6 and 7

2815/01 Trends and Patterns

Mark Scheme Page 1 of 5	Unit Code 2815/01	Session June	Year 2008	Version Final Mark Scheme

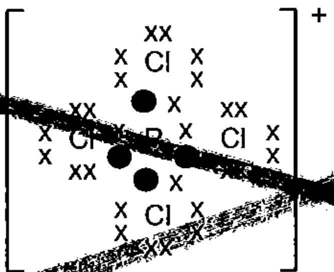
Question	Expected Answers	Marks	Additional Guidance
1 (a)	**Any three from** Strontium ion smaller than barium ion / strontium ion has a higher charge density / ora (1); Strontium ion is more polarising / ora (1); Strontium ion distorts the carbonate ion more than barium ion / ora (1); So carbon–oxygen or covalent bond (in carbonate) is weaker (1)	3	**No** mark for just writing decomposition temp is higher for $BaCO_3$ If $SrCO_3$ with higher temp award 0 marks **Must** use correct particle but only penalise once in part (a) **Allow** Sr^{2+} is more polarising and distorts the carbonate ion (2) / Sr^{2+} polarises the carbonate ion causing more distortion (2) Allow marks from a labeled diagram
(b) (i)	$2Mg(NO_3)_2 \rightarrow 2MgO + 4NO_2 + O_2$ (1)	1	**Allow** any correct multiple **Ignore** state symbols
(ii)	Oxide (ion) smaller than nitrate (ion) / oxide (ion) has a higher charge density than nitrate (ion) / oxide (ion) has a higher charge than nitrate (ion) (1); So oxide (ion) has a stronger attraction to magnesium ion / nitrate (ion) has a weaker attraction to positive ion / MgO has stronger ionic bond / MgO has stronger attraction between ions (1)	2	**Allow** ora **Must** use correct particle but only penalise once 'It' refers to oxide (ion) or MgO **Allow** MgO has stronger bond between charged particles

Mark Scheme Page 2 of 5	Unit Code 2815/01	Session June	Year 2008	Version Final Mark Scheme

Question	Expected Answers	Marks	Additional Guidance
1 (c) (i)	Fe goes from +2 to +3 which is oxidation (1); S goes from +6 to +4 which is reduction (1)	2	If no other marks awarded **allow** one mark for correct identification of all oxidation numbers or ecf from wrong oxidation numbers if both oxidation and reduction identified
(c) (ii)	Idea of use of (2 ×) +929 –826 – 297 – 396 / correct use of molar ratios (1); = (+)339 (1)	2	**Allow** full marks for correct answer with no working out **Allow** one mark for –590 / –339 / 3377 / –3377 Unit **not** needed
(iii)	(Moles of SO_2 = 0.00385 so) moles of $FeSO_4.7H_2O$ = 0.00771 (1); M_r of $FeSO_4.7H_2O$ = 277.9 (1); (So mass = 2.14) and % = 76.9 / 77.0 (1) Or M_r of $FeSO_4.7H_2O$ = 277.9 (1); (Moles of $FeSO_4.7H_2O$ = 0.01 so) moles of SO_2 = 0.005 (1); (So volume = 120) and % = 76.9 / 77.0 (1)	3	**Allow** (Moles of SO_2 = 0.004 so) moles of $FeSO_4.7H_2O$ = 0.008 (1) **Allow** ecf from wrong moles and/or M_r of $FeSO_4.7H_2O$ **Allow** ecf from wrong M_r **Allow** ecf from wrong moles of SO_2 **Percentage** must be quoted to 3 sig figs
		Total = 13	

Mark Scheme	Unit Code	Session	Year	Version
Page 3 of 5	2815/01	June	2008	Final Mark Scheme

Question	Expected Answers	Marks	Additional Guidance
2 (a)	$MoO_3 + 2Al \rightarrow Al_2O_3 + Mo$ (1)	1	**Ignore** state symbols **Allow** correct multiples
(b)	[Kr] $4d^3$ **and** (Mo^{3+}) has an incomplete filled d-subshell (1)	1	**Allow** has incomplete 4d sub-shell / incomplete d orbital **Ignore** errors in [Kr]
(c)	Correct molar ratio of Mo and Cr species $3MoO_2 + Cr_2O_7^{2-} \rightarrow 2Cr^{3+} + 3MoO_4^{2-}$ (1); **But** $3MoO_2 + Cr_2O_7^{2-} + 2H^+ \rightarrow 2Cr^{3+} + H_2O + 3MoO_4^{2-}$ (2)	2	Ignore H^+, H_2O and e^- in equation For the second mark the H^+ and H_2O must be cancelled down to 2 and 1
(d) (i)	K_2FeO_4 (1)	1	
(ii)	Moles of Fe_2O_3 = 0.00627 (1); Moles of OH^- = 0.0400 (1); Fe_2O_3 in excess since there needs to be 0.0627 moles of OH^- / evidence of working out the reagent in excess (1)	3	**Allow** reverse argument e.g. 0.0400 moles of OH^- can only react with 0.004 moles of Fe_2O_3 **Allow** ecf from wrong moles
		Total = 8	

Mark Scheme Page 4 of 5	Unit Code 2815/01	Session June	Year 2008	Version Final Mark Scheme	
Question	**Expected Answers**			**Marks**	**Additional Guidance**
3 (a)	$Ca^{+}(g) \rightarrow Ca^{2+}(g) + e^{-}$ (1); atomisation (of oxygen) / ΔH_{at} (1); Second electron affinity (of oxygen) / ΔH_{ea2} (1); $Ca(s) \rightarrow Ca(g)$ (1)			4	State symbols needed
(b)	Al_2O_3 – intermediate bonding / electrostatic attraction between ions (1); $AlCl_3/Al_2Cl_6$ – van der Waals / temporary dipole – temporary dipole / induced dipole – induced dipole interactions / intermolecular forces (1); Correct comparison of strength of forces e.g. intermediate bonds stronger than van der Waals (1)			3	**Allow** giant ionic / giant intermediate **Allow** simple molecular Comparison of forces **dependent** on forces being correct
(c)	Al_2O_3 does not dissolve / does not react (1); $AlCl_3$ reacts / $AlCl_3$ is hydrolysed / polarisation of water molecules by aluminium ion (1); $AlCl_3$ – gives a colourless solution / misty fumes / steamy fumes / pH 1 to 6 (1)			3	**Allow** mark from an appropriate equation **Allow** acidic solution / gets hot / exothermic
(d) (i)	Correct dot and cross diagram (1) 			1	**Ignore** lack of charge **Ignore** inner shells
(ii)	Tetrahedral / correct drawing of tetrahedral (1); Has four bond pairs / repulsion between four bond pairs / four bonds repelling (1)			2	**Allow** ecf from wrong dot and cross diagram for a PCl_4^+ species
				Total 13	

Mark Scheme Page 5 of 5	Unit Code 2815/01	Session June	Year 2008	Version Final Mark Scheme	
Question	**Expected Answers**			**Marks**	**Additional Guidance**
4	Bonding in complex ion Ligand donates an electron pair / copper accepts electron pair (1); Dative (covalent) / coordinate (1)			2	**Allow** even if not a copper complex **Allow** marks from a diagram
	Shape of complex ion Correct name or formula of copper complex ion (1); Correct shape of a copper complex either by name or clear drawing with indication of three dimensions (1); Correct bond angle (1) • *e.g.* $[Cu(H_2O)_6]^{2+}$ is octahedral and 90° • *e.g.* $[CuCl_4]^{2-}$ is (flattened) tetrahedral and bond angle between 90° and 110°			3	**Allow** last two marking points if not a copper complex
	Ligand substitution Correct example of ligand substitution reaction involving a copper complex (1); Correct equation (1); Idea of one ligand being swapped with another one (1)			3	**Allow** all marks from an equation **Allow** last two marking points if not a copper complex
	Colour Correct colour of two copper complex ions one mark for each correct colour			2	If one colour given is wrong max 1 If two colours wrong score 0
	Quality of Written Communication. Answer must address the question set and include at least three of the following terms in the correct context • Electron / lone pair • Covalent • Dative • Coordinate • Octahedral • Tetrahedral • Square planar • Molecule			1	
				Total = 11	

2815/01 Trends and Patterns

Question	Expected Answers	Marks	Additional Guidance
1 (a)	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^9$ (1)	1	
(b) (i)	Correct formula of a copper(II) complex ion e.g. $CuCl_4^{2-}$ / $[Cu(NH_3)_4(H_2O)_2]^{2+}$ / $[Cu(H_2O)_6]^{2+}$ (1)	1	
(ii)	Correct colour (1) e.g. $CuCl_4^{2-}$ green/yellow, $[Cu(NH_3)_4(H_2O)_2]^{2+}$ dark blue and $[Cu(H_2O)_6]^{2+}$ blue	1	**Allow** ecf from a known copper compound
(iii)	Coordinate bond / dative bond (1) Lone pair donated by ligand / lone pair accepted by copper (1)	2	
(c) (i)	Blue precipitate / blue solid	1	Can get credit for ppt from state symbol of correct product in part (ii)
(ii)	$Cu^{2+} + 2OH^- \rightarrow Cu(OH)_2$ / $[Cu(H_2O)_6]^{2+} + 2OH^- \rightarrow Cu(OH)_2 + 6H_2O$ / $[Cu(H_2O)_6]^{2+} + 2OH^- \rightarrow Cu(H_2O)_4(OH)_2 + 2H_2O$ (1)	1	**Allow** correct multiples **Ignore** state symbol
(d) (i)	Mole ratio C:Cu:K:N = 0.0320:0.00800:0.0240:0.0320 (1) $K_3CuC_4N_4$ (1)	2	**Allow** the four masses ÷ appropriate A_r if mole ratio not calculated **Allow** any order of atoms Can award formula mark if given in part (ii) **Allow** ecf from wrong mole ratio
(ii)	$[Cu(CN)_4]^{3-}$ / $CuC_4N_4^{3-}$ (1)	1	**Allow** any order of atoms with or without brackets **Allow** ecf from wrong formula
	Total	10	

Question	Expected Answers	Marks	Additional Guidance
3 (a)	$2Cr^{3+} + 3H_2O_2 + 10OH^- \rightarrow 2CrO_4^{2-} + 8H_2O$ Correct reactants and products (allow e^- and OH^- on **both** left and right) and correct molar ratio of Cr^{3+} and H_2O_2 (1); Balanced (1)	2	For the second mark the OH^- and e^- must be cancelled down
(b)	Moles MnO_4^- = 0.000463 (1) Moles Fe^{2+} = 5 × moles MnO_4^- / 0.002315 (1) M_r = 392 / 391.8 (1) x = 6 (1) **dependent** on M_r given	4	**Allow** ecf within the question ecf is 0.907 ÷ moles of Fe^{2+} **Allow** three marks for 392 / 391.8 with no working ecf is (M_r – 283.8) ÷ 18 **Allow** one mark for 6 with no working
	Total	**6**	

Question	Expected Answers	Marks	Additional Guidance
4 (b)	Definitions $2Na^+ + O^{2-} \rightarrow Na_2O$ (1) $2Na + \frac{1}{2}O_2 \rightarrow Na_2O$ (1) Lattice enthalpy is the enthalpy change when one mole (of ionic solid) is made from its constituent gaseous ions but formation from its constituent elements (1)	3	If given state symbols must be **correct** **Allow** energy released **Not** energy absorbed **Allow** states from equations
	Born-Haber cycle Correct state symbols for the formulae given (1); Correct formula (1); Labelling of enthalpy changes Three correct labels (1) but five correct labels (2) but all labels correct (3) Expression or statement in words or symbols to show how lattice enthalpy is calculated (1)	6	Formula must have correct state symbol at least once in the cycle Formulae given must be correct but there can be a formula missing **Allow** ecf from the cycle drawn **Allow** conventional symbols e.g. ΔH_f **Allow** ecf from cycle drawn

Question	Expected Answers	Marks	Additional Guidance
4	**Lattice enthalpy** magnesium oxide, sodium chloride and potassium bromide (1) **Any two from** Comparison of charge density or ionic radius of cation (1) e.g. ionic radius decreases from K^+, Na^+ to Mg^{2+} / charge density increases from K^+, Na^+ to Mg^{2+} (1) Comparison of charge density or ionic radius of anion (1) e.g. e.g. ionic radius decreases from Br^-, Cl^- to O^{2-} / charge density increases from Br^-, Cl^- to O^{2-} (1) Comparison of charge on ions (1) Na^+ but Mg^{2+} / O^{2-} but Cl^-	3	**Allow** Mg^{2+} but Na^+ (1) and Na^+ is smaller than K^+ (1) **Allow** O^{2-} but Cl^- (1) and Cl^- is smaller than Br^- (1)
	Quality of Written Communication (1) At least two complete sentences with correct spelling, punctuation and grammar that address the question set	1	
	Total	**17**	

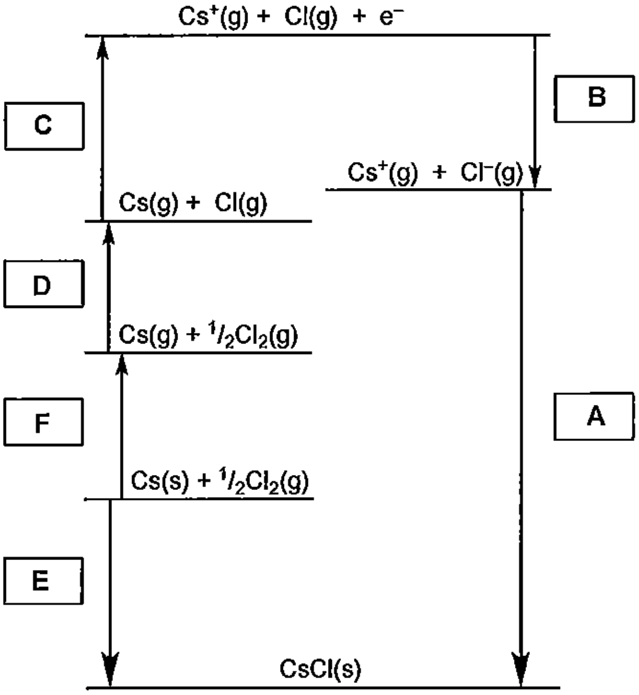
2815/01 Trends and Patterns

Qu.		Expected Answers	Marks	Additional Guidance
1	(a)	(Enthalpy change of/energy change of) atomisation (1) $Ba(g) \rightarrow Ba^{+}(g) + e^{-}$ (1) <u>Second</u> electron affinity (1) $Ba(s) + ½O_2(g) \rightarrow BaO(s)$ (1)	4	Ss must be correct throughout No multiples
	(b)	Impossible/difficult to get gaseous ions (without them reacting)/difficult to vapourise ions and measure the enthalpy change at the same time/AW (1)	1	
	(c)	Oxide ion is smaller than carbonate ion/oxide ion has a higher charge/electron density/ora (1) (So) stronger attraction between ions in barium oxide/ora (1)	2	**Must** use correct particle but only penalise once
	(d)	**Rb^{+}, Na^{+}, Mg^{2+}, Al^{3+} (1)** and Any two from Idea that polarising power depends on ionic radius and ionic charge/idea that polarising power depends on charge density of ion (1) Rb^{+} is larger than Na^{+}/Na^{+} is larger than Mg^{2+}/Mg^{2+} is larger than Al^{3+}/Al^{3+} smallest radius/Rb^{+} largest radius ora (1) Rb^{+} is less charged than Mg^{2+}/Na^{+} is less charged than Mg^{2+}/Mg^{2+} is less charged than Al^{3+}/Al^{3+} highest charge ora (1)	3	
			10	

Qu.		Expected Answers	Marks	Additional Guidance
3 (a)		moles of MnO_4^- = 0.000571 (1) moles of H_2O_2 = 0.00143 (1) concentration (of diluted H_2O_2 is 0.143 and of) undiluted is 1.43 mol dm^{-3} (1) Concentration = 48.5 g dm^{-3} (1) (accept range 48.45–48.63 g dm^{-3})	4	**Allow** ecf within the question **Allow** 2 or more sig figs for first three marking points **Allow** 3 or 4 for the last marking point
(b)		$Fe^{2+} \rightarrow Fe^{3+} + e^-$ / Unbalanced full equation with all correct species (1) but $H_2O_2 + 2H^+ + 2Fe^{2+} \rightarrow 2H_2O + 2Fe^{3+}$ (2)	2	**Allow** full marks for the correct ionic equation between H_2O_2 and Fe^{2+} **Allow** correct multiples of equation **Ignore** state symbols
(c)		There is no longer a green precipitate/green solid (1) $Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$ (1) **or** There is now a red-brown precipitate/orangey brown/brown/rusty solid (1) $Fe^{3+} + 3OH^- \rightarrow Fe(OH)_3$ (1)	2	**Allow** precipitate mark if state symbol given in equation **Ignore** state symbols
(d)	(i)	-1/1-/- (1)	1	**Allow** O_2^-
	(ii)	Oxygen from -1 to -2/0 to -2 which is reduction (1) Oxygen from -1 to 0/-2 to 0 which is oxidation (1)	2	**Allow** 1 mark for either 2 correct ON changes (1 ox and 1 red) OR correct reference to oxidation and reduction from their ON changes
	(iii)	Moles of KO_2 = 14.1 (1) Moles of CO_2 = 7.05 (1) Volume of CO_2 = 168.8 dm^3 (1) Allow range 168 to 169.2	3	**Allow** ecf within question **Allow** 2 or more sig figs for first two marking points **Allow** 3 or 4 sig figs for answer
			14	

Qu.	Expected Answers	Marks	Additional Guidance
4	Properties 3 from Coloured (ions)/coloured (compounds) (1) Catalysts (1) **Several oxidation states (1)** **Paramagnetic (1)**	3	
	Complex ion **Octahedral/clear three dimensional drawing (1)** **Ligand donates a pair of electrons/central atom or ion accepts a pair of electrons (1)** **Coordinate bond/dative bond (1)** **Bond angles (1)**	4	**Allow** tetrahedral or square planar and correct bond angles from a correct example **Allow** bonding marks (2 and 3) from an incorrect complex ion
	Ligand substitution Involves swapping of one ligand for another/exchange of ligands/displacement of ligands (1) Example (1) eg reaction of aqueous iron(III) ions with thiocyanate ions Equation (1) eg $[Fe(H_2O)_6]^{3+}$ + SCN^- → $[Fe(H_2O)_5(SCN)]^{2+}$ + H_2O Observation (1) eg red coloration	4	Correct equation also scores the description of ligand substitution Wrong metal in complex ions can score the description and equation mark
	Quality of Written Communication (1) Use of at least three of the following technical words in the correct context • Catalyst/catalytic • Dative/coordinate • Lone pair/electron pair • Oxidation state/oxidation number • Octahedral/tetrahedral/square planar	1	
		12	

2815/01 Trends and Patterns

Qu.	Expected answers	Marks	Additional guidance
1 (a)	 6 correct labels: 3 marks 4 correct labels: 2 marks 3 correct labels: 1 mark	3	Allow values (except A)
(b)	= –443 =+76 + 376 + 122 + –349 + Lattice enthalpy ✓ Lattice enthalpy = –668 (kJ mol^{-1}) ✓	2	Allow ECF from (a) 668 = 1 mark
(c)	Lattice enthalpy of NaCl would be more exothermic than that of CsCl / lattice enthalpy is greater in magnitude / ORA ✓ Na^+ is smaller than Cs^+ / Na^+ has a larger charge density than Cs^+ / ORA ✓ NaCl has stronger ionic bonding / stronger attraction between the positive and negative ion ✓	3	Not bigger or smaller lattice enthalpy NOT larger charge Correct particles must be used e.g. not Na has a smaller radius All comparative
		8	

Qu.	Expected answers	Marks	Additional guidance
3 (a)	Oxidation: oxidation number of O changes from –1 to 0 ✓ Reduction: oxidation number of O changes from –1 to –2 ✓	2	Allow 1 mark for either 2 correct ON changes (1 ox I red) OR correct ref to ox and red from their ON changes
(b) (i)	$2MnO_4^- + 6H^+ + 5H_2O_2 \longrightarrow 2Mn^{2+} + 8H_2O + 5O_2$ Correct reactants and products and balanced (but can include e^- on both sides and H^+ on both sides. ✓ Correct balanced equation with no electrons shown and H^+ only on left hand side ✓	2	**Allow** correct multiples of equation **Ignore** state symbols
(ii)	Moles of MnO_4^- = $\frac{23.35 \times 0.0150}{1000}$ / 3.5025×10^{-4} / 3.50×10^{-4} / 3.5×10^{-4} ✓ Moles of H_2O_2 = 2.5 × moles of MnO_4^- / 8.75×10^{-4} / 8.76×10^{-4} ✓ Concentration of H_2O_2 = $\frac{8.75 \times 10^{-4} \times 1000}{25.0}$ = 0.035(0) (mol dm^{-3}) ✓ correct answer = 3 marks	3	**Allow** ECF within the question
(c)	sodium hydroxide / potassium hydroxide / hydroxide ions / potassium thiocyanate / ammonium thiocyanate / thiocyanate ions ✓ observation: orange-red / brown / brown-red / foxy-red ppt with NaOH(aq) or (blood) red with KSCN / NH_4SCN / SCN^- ✓	2	**Allow** formulae Colour AND ppt needed (not red or orange) Not ppt
		9	

Qu.		Expected answers	Marks	Additional guidance
4	(a)	$1s^22s^2(2)p^63s^2(3)p^6(3)d^9$ ✓ (Cu is a transition element since Cu^{2+} has an) incomplete d sub-shell / AW ✓	2	
	(b)	complex ion: metal/TE atom / ion surrounded by ligands ✓ ligand: a species able to donate a pair of electrons ✓ to form a dative covalent / co-ordinate bond ✓ ligand substitution: 2 examples with colour change and equation , eg $[Cu(H_2O)_6]^{2+}$ and NH_3 ✓ $[Cu(H_2O)_6]^{2+} + 4NH_3 \longrightarrow [Cu(H_2O)_2(NH_3)_4]^{2+} + 4H_2O$ ✓ blue dark blue ✓ $Cu(H_2O)_6]^{2+}$ and Cl^- ✓ $[Cu(H_2O)_6]^{2+} + 4Cl^- \longrightarrow [CuCl_4]^{2-} + 6H_2O$ ✓ blue yellow/green ✓ octahedral ✓ with shape drawn out, eg $[Cu(H_2O)_6]^{2+}$ ✓ Must have 2 bonds in plane of paper, 2 out of paper and 2 into paper Or 4 in plane of paper, one out of paper and one into paper. tetrahedral ✓ with shape drawn out, eg $[CuCl_4]^{2-}$ ✓ Must have at least 1 bond in plane of paper, 1 out of paper and 1 into paper with last bond one of three types above.	3 5 from 6 4	**Allow** 2 marks for a corectly balanced equation **Allow** other correct examples If incorrect metal mark equations only **Allow** other correct examples Ignore bond angles
		Quality of Written Communication (1) At least 2 complete sentences in which the meaning is clear. ✓	1	
			15	

Question	Expected Answers	Marks	Additional Guidance
1 a(i)	(Enthalpy change of) formation (of barium oxide) ✓ (Enthalpy change of) atomisation (of barium) ✓ First ionisation energy (of barium) ✓	3	
a(ii)	$Ba^{2+}(g)$ and $O^{2-}(g)$ ✓	1	State symbols essential
b(i)	Lattice enthalpy = –180 – 503 – 965 – 248 – 650 – 554 ✓ = –3,100 (kJ mol^{-1}) ✓	2	
b(ii)	Lattice enthalpy of BaO is less exothermic than that of MgO / lattice enthalpy is smaller in magnitude / ORA ✓ Mg^{2+} (has a) smaller (ionic radius) than Ba^{2+} / Mg^{2+} has a higher charge density than Ba^{2+}/ORA ✓ So stronger attraction between the positive and negative ion / ORA ✓	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
1c	High melting point / (very) large lattice enthalpy / AW ✓	1	
1d(i)	$BaCO_3 \longrightarrow BaO + CO_2$ ✓	1	State symbols not essential
1d(ii)	Decomposition temperature higher for $BaCO_3$ / ORA ✓ Polarising ability of cation decreases from Mg^{2+} to Ba^{2+} ✓ Distortion of the charge cloud around the carbonate ion / weakens the covalent bonds within the carbonate ion ✓	3	Particles used must be correct e.g. not Mg is more polarising **ALLOW** marks via a diagram
	Total	14	

Question	Expected Answers	Marks	Additional Guidance
2 a(i)	A clear 3D drawing of an octahedral ion ✓ Bond angle of 90°✓	2	2 bonds in plane, 2 bonds out and 2 bonds into plane 4 in plane, 1 into and 1 out charge not required
a(ii)	**A**: $CuCl_4^{2-}$ ✓ **B**: $[Cu(NH_3)_4(H_2O)_2]^{2+}$ ✓	2	
b(i)	a species that bonds by a dative covalent bond/donates an electron or lone pair to a metal ion/cation ✓	1	
b(ii)	Suitable equation: e.g. $[Cu(H_2O)_6]^{2+} + 4Cl^- \longrightarrow [CuCl_4]^{2-} + 6H_2O$ Or $[Cu(H_2O)_6]^{2+} + 4NH_3 \longrightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4H_2O$ ✓ Reaction in which a ligand is swapped or replaced or displaced by another ligand / AW ✓	2	
	Total	**7**	

Question	Expected Answers	Marks	Additional Guidance
3 a	$(1s^2 2s^2 2p^6) 3s^2 3p^6 3d^5$ ✓ Fe is a transition element since Fe^{3+} ion has an incomplete d sub-shell/ AW ✓	2	
b	Haber process / production of ammonia ✓	1	
c(i)	From colourless/pale green to pink/purple ✓	1	
c(ii)	moles Fe^{2+} = 25.0 / 1000 x 0.0500 (= 0.00125 mol) ✓ moles MnO_4^- = 0.00125 / 5 (= 0.00025 mol) ✓ conc MnO_4^- = 1000 x 0.00025 / 12.3 = 0.0203 mol dm^{-3} ✓	3	ecf through correct answer with units = 3 marks 3 sf
d(i)	(+)6 ✓	1	ALLOW 6+
d(ii)	$2I^-(aq) \longrightarrow I_2(aq) + 2e^-$ ✓	1	**IGNORE** state symbols
d(iii)	$8H^+(aq) + FeO_4^{2-}(aq) + 4I^-(aq) \longrightarrow 2I_2(aq) + Fe^{2+}(aq) + 4H_2O(l)$ Correct reactants and products ✓ Balancing ✓	2	**IGNORE** state symbols **IGNORE** electrons here no electrons **ALLOW** multiples
e(i)	From yellow to blood-red ✓	1	[redacted]e yellow
[redacted]	$[Fe(H_2O)_6]$[redacted]$(SCN)]^{2+}$ + [redacted]	1	
	Total	13	