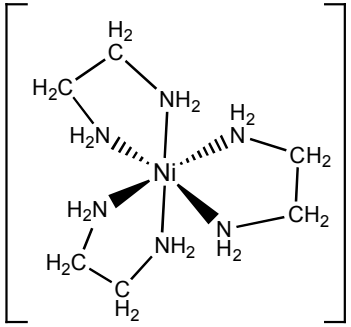
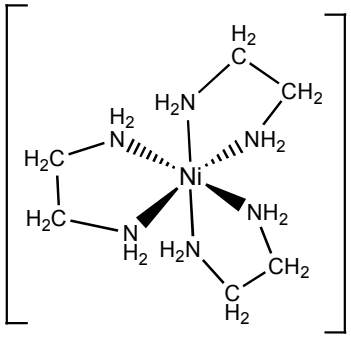
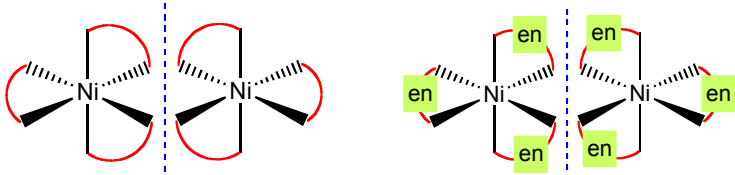
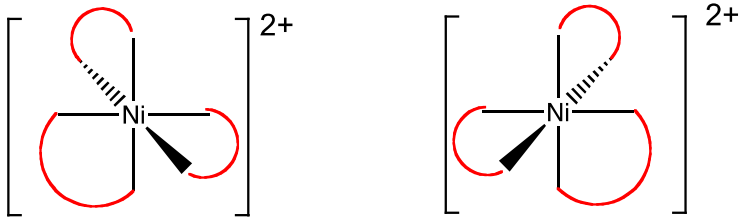
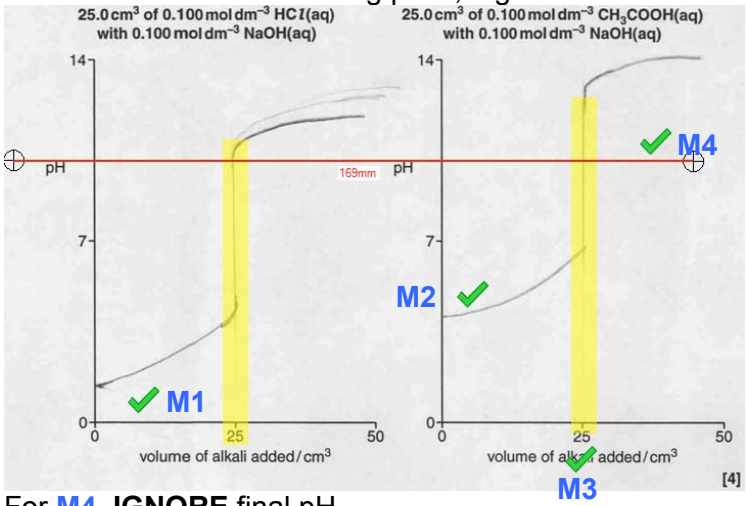
Question			Answer	Marks	Guidance
					Throughout Q1 **IGNORE** variations in caps and small letters
1	**(a)**	**(i)**	Fe ✓	1	**ALLOW** name: iron **DO NOT ALLOW** ions, e.g. Fe^{2+}
1	**(a)**	**(ii)**	Ti ✓ Ni ✓	2	**ALLOW** names: titanium and nickel **DO NOT ALLOW** ions
1	**(a)**	**(iii)**	Co ✓	1	**ALLOW** name: cobalt **ALLOW** Co^{2+}
1	**(a)**	**(iv)**	Mn ✓	1	**ALLOW** name: manganese **ALLOW** Mn_3O_4
1	**(a)**	**(v)**	Cr ✓	1	**ALLOW** name: chromium
1	**(b)**		deep-blue solution: $[Cu(NH_3)_4(H_2O)_2]^{2+}$ ✓ yellow solution: $CuCl_4^{2-}$ ✓ pale-blue precipitate: $Cu(OH)_2$ ✓	3	**DO NOT ALLOW** $[Cu(NH_3)_4]^{2+}$ **OR** $[Cu(NH_3)_6]^{2+}$ **[ ] not required** **ALLOW round brackets around any atom** **e.g. ALLOW** $[CuCl_4]^{2-}$**;** $Cu(Cl_4)^{2-}$ **DO NOT ALLOW** $[Cu(Cl^-)_4]^{2-}$ **OR** $[Cu^{2+}(Cl^-)_4]^{2-}$ **ALLOW** $Cu(OH)_2(H_2O)_4$ **OR** $[Cu(OH)_2(H_2O)_4]$
1	**(c)**	**(i)**	octahedral ✓	1	
1	**(c)**	**(ii)**	NiF_6^{4-} **OR** $[NiF_6]^{4-}$ ✓	1	**4–** charge **required** **ALLOW** $[Ni(F)_6]^{4-}$; **ALLOW** NiF_6^{-4} **ALLOW** round brackets **DO NOT ALLOW** F*l* for F **DO NOT ALLOW** $[Ni(F^-)_6]^{4-}$ **OR** $[Ni^{2+}(F^-)_6]^{4-}$

Question			Answer	Marks	Guidance
1	(c)	(iii)	 2+  2+ ✓ ✓ one mark for each structure *2nd structure must be correct mirror image of 1st structure*	2	1 mark for 3D diagram with ligands attached for ONE stereoisomer Must contain 2 out wedges, 2 in wedges or dotted lines and 2 lines in plane of paper **IGNORE** any charges shown **ALLOW** any attempt to show bidentate ligand. Bottom line shown in diagrams below. **IGNORE** connectivity: ——H_2N OK  **ALLOW**  **ALLOW** 2 x en seen in each bridge
			Total	**13**	

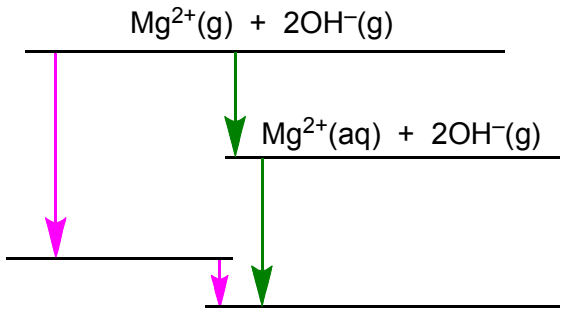
Question			Answer	Marks	Guidance
2	(a)	(i)	**M1 Shape** On **one** graph (can be either), shape: slight rise/flat, then vertical, then slight rise/flat ✓ **M2 pH at start for acid** Weak acid pH curve starts at higher pH and below pH 7 ✓ **M3 End point** On both graphs, vertical section approximately 25 cm^3 alkali have been added ✓ **M4 pH when alkaline** On both graphs, vertical section is **still vertical** through a ruler line aligned with the top of the pH axis label on left-hand axis ✓	4	**FULL ANNOTATIONS MUST BE USED** --- Use ruler tool for 4th marking point, e.g.  For **M4**, **IGNORE** final pH For **M1** and **M2**, **IGNORE** small gap before curve starts **Note**: If pH curves wrong way round (i.e. adding acid to alkali), **ONLY M3** (25 cm^3) can be awarded
2	(a)	(ii)	pH range (of the indicator) matches vertical section/**rapid** pH change **OR** end point/colour change matches vertical section/rapid pH change ✓	1	**ALLOW** pH range (of the indicator) matches equivalence point **ALLOW** end point/colour change matches equivalence point **IGNORE** colour change matches end point *Colour change is the same as end point*
2	(b)	(i)	(enthalpy change for) the formation of **1 mole H_2O** from reaction of an acid/H^+ with an alkali/base/OH^- ✓	1	**ALLOW** (enthalpy change for) the reaction of 1 mol H^+ with 1 mol of OH^- **DO NOT ALLOW** formation of 1 mol H_2O from *1 mole* of acid and/or *1 mole* of alkali **DO NOT ALLOW** formation of 1 mol H_2O from an acid and its *conjugate* base

Question			Answer	Marks	Guidance
2	(b)	(ii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = –57.5 (kJ mol^{-1}) award 3 marks** --- energy change = 70.0 x 4.18 x 16.5 = 4827.9 (J) **OR** 4.8279 (kJ) ✓ amount of H_2O formed = $2.4(0) \times \frac{35.0}{1000}$ = 0.084(0) mol ✓ $\Delta H_{neut} = -\frac{4.8279}{0.084(0)}$ = –57.475 **OR** –57.48 **OR** –57.5 (kJ mol^{-1}) ✓	3	**FULL ANNOTATIONS MUST BE USED** --- **IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below --- **IGNORE** any sign shown **ALLOW** 4830 **AND** 4828 (J) **ALLOW** amount of HC*l* **OR** amount of NaOH (same value) – sign **required** **ALLOW ECF** from $\frac{\text{calculated energy change}}{\text{calculated moles } H_2O}$ **ALLOW** 3 significant figures up to calculator value correctly rounded **Common errors** Use of 289.5 K can give up to 2 marks by **ECF:** = 70.0 x 4.18 x 289.5 = 84.71 **x** amount of H_2O formed = $2.4(0) \times \frac{35.0}{1000}$ = 0.084(0) mol ✓ $\Delta H_{neut} = -\frac{84.71}{0.084(0)}$ = –1008 **OR** –1010 (kJ mol^{-1}) ✓ Use of 35 can give up to 2 marks by **ECF:** = 35.0 x 4.18 x 16.5 = 2413.95 (J) **x** amount of H_2O formed = $2.4(0) \times \frac{35.0}{1000}$ = 0.084(0) mol ✓ $\Delta H_{neut} = -\frac{2.41395}{0.084(0)}$ = –28.7375 **OR** –28.7 (kJ mol^{-1}) ✓

Question			Answer	Marks	Guidance
2	**(b)**	**(iii)**	**Same** energy is spread over larger volume ✓ --- 11 ºC ✓	2	**ALLOW same** energy heats **greater** volume /mass **ALLOW** the following alternatives for '**energy'**: Heat, *q*, *mc*∆*T*, enthalpy **change**, ∆*H* **ALLOW** use to '105 cm^3/105 g' as evidence of 'greater volume/ mass' **ALLOW** use of same energy value as in **2(b)(ii)** as evidence for 'same energy' *May need to refer to previous part, 2(b)(ii)* **IGNORE** more energy heats a greater volume --- **ASSUME** units are ºC unless told otherwise
			Total	**11**	

Question			Answer	Marks	Guidance
3	(a)	(i)	**solution**: (enthalpy change for) 1 mole of a compound/substance/solid/solute dissolving ✓ **----------** **hydration**: (enthalpy change for) 1 mole of gaseous ions **OR** 1 mole of hydrated/aqueous ions ✓ gaseous ions forming aqueous/hydrated ions ✓	3	**IGNORE** 'energy released' **OR** 'energy required' For dissolving, **ALLOW** forms aqueous/hydrated ions **DO NOT ALLOW** dissolving elements **IGNORE** ionic **OR** covalent **DO NOT ALLOW** response that implies formation of **1 mole** of aqueous ions **----------** **IGNORE** 'energy released' **OR** 'energy required' For final mark **IGNORE** gaseous ions are hydrated **IGNORE** gaseous ions dissolve *Particles formed not stated*

Question			Answer	Marks	Guidance
3	(a)	(ii)	**For 1st two marking points (*Charge* and *Size*),** **IGNORE** 'atomic' and 'atoms' and assume that Mg or Na refer to ions, e.g. **ALLOW** Mg has a smaller (atomic) radius **----------** *Charge* Magnesium ion/Mg^{2+} has greater charge **OR** Mg^{2+} has greater charge density ✓ **----------** *Size* Magnesium ion **OR** Mg^{2+} is smaller ✓ **----------** *Attraction* **Note:** Correct particles required for this mark i.e. **DO NOT ALLOW** Mg; Mg atoms; Na; Na atoms Mg^{2+} has a stronger attraction/ force/ bonding to H_2O /$O^{\delta-}$ ✓	3	**Note:** Charge density can be used to credit the charge mark but **not** size mark **----------** **ORA** Sodium ion/Na^+ has smaller charge **OR** Na^+ has smaller charge density **----------** **ORA:** Sodium ion **OR** Na^+ is larger **IGNORE** smaller charge density (*'charge mark above')* **IGNORE** idea of close packing of ions **----------** **Note:** Response must refer to attraction/bonding with H_2O or this must be implied from the whole response **ALLOW** Mg^{2+} has a stronger ion–dipole attractions **ORA:** Na^+ has weaker attraction/bonding to H_2O **DO NOT ALLOW** a response implying that *ionic* bonds (between ions) **OR** *covalent* bonds **OR** *hydrogen* bonds are formed

Question			Answer	Marks	Guidance
3	(a)	(iii)	 ✓ ✓	2	Correct species **AND** state symbols required for both marks **Mark each marking point independently** **ALLOW** response on lower line: $Mg^{2+}(g)$ + $2OH^-(aq)$ (i.e. OH^- hydrated before Mg^{2+})
3	(a)	(iv)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = –2694 (kJ mol^{-1}) award 2 marks** --- Lattice enthalpy $(Mg(OH)_2)$ = [–1926 + (2 x – 460)] – (–152) **OR** – 2846 + 152 ✓ = –2694 ✓ (kJ mol^{-1})	2	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below. **See list below for marking of answers from common errors** --- **ALLOW** for 1 mark: –2234: *use of OH^- rather than 2 x OH^-* (+)2694: *signs all reversed* –2998: *sign wrong for 152* (+)1158: *sign wrong for 1926* –854: *sign wrong for 2 x 460* (+)2998: *sign wrong for 2846* **IF ALL 3 relevant values from the information at the start of Q3 have NOT been used, award zero marks unless one number has a transcription error, where 1 mark can be awarded ECF**

Question			Answer	Marks	Guidance
3	(b)	(i)	• ΔH **positive** (Intermolecular) bonds/forces are being broken ✓ • ΔS Increase in disorder/ randomness/ number of arrangements (of particles/molecules/energy) ✓ • **Comparison of ΔS (QWC)** In a gas, molecules/particles are **much** more disordered/ random (than in liquids and solids) ✓	3	**ALLOW** hydrogen bonds **DO NOT ALLOW** breaking of ionic **OR** covalent bonds **IGNORE** a response comparing bonds made and bonds broken (*boiling involves just breaking bonds*) **ALLOW** liquids are more disordered than solids **OR** gases are more disordered than liquids **ALLOW** in a gas, molecules are **much** further apart (than in liquids and solids) **IGNORE** ΔS is much greater (*in question*)
3	(b)	(ii)	$\Delta S = \Sigma S$(products) – ΣS(reactants) = 70.0 – 48.0 **OR** 22(.0) **OR** 0.022 (kJ K^{-1} mol^{-1}) ✓ $T = \frac{6.01}{0.022}$ = 273 (K) **OR** ΔG = 6.01 – 273 x 0.022 ✓ ΔG = 0 **OR** 0 = $\Delta H - T\Delta S$ stated anywhere ✓	3	**FULL ANNOTATIONS MUST BE USED** --- **NO UNITS** required **ALLOW** 273.18 (K) **OR** 273.2 (K) **ASSUME** units are K unless told otherwise **ALLOW** ΔG = 6.01 – 6.006 = +4 x 10^{-3} **ALLOW** 4 x 10^{-3} ~ 0 **ALLOW** 4 x 10^{-3} is very close to zero
			Total	**16**	

Question			Answer	Marks	Guidance
4	(a)		**Experimental:** ***2 marks*** vary $[S_2O_8^{2-}]$ while keeping $[I^-]$ constant ✓ vary $[I^-]$ while keeping $[S_2O_8^{2-}]$ constant ✓ **Obtaining rate from time** ***1 mark*** Rate $\propto 1/t$ **OR** rate = conc/time ✓ **Rate–concentration relationship – QWC** ***1 mark*** rate–concentration graph gives straight line through origin/0,0 **OR** when concentration doubles, rate doubles **OR** rate is proportional to concentration ✓	4	**FULL ANNOTATIONS MUST BE USED** --- **ALLOW** for 1 mark: 'keep one concentration constant whilst varying the other' **OR** vary the concentration of each reactant in turn, e.g. vary $[S_2O_8^{2-}]$ and then vary $[I^-]$ **ALLOW** rate = 1/*t* **OR** amount/time ***ALLOW*** *expressions communicating* rate $\propto 1/t$ **ALLOW** rate = gradient/tangent of a concentration–time graph **AND** measured at $t = 0$ **ALLOW** 'conc and rate increase by same factor/amount' **OR** 'change in concentration is same as change in rate **ALLOW** 'when concentration doubles, time halves' **IGNORE** constant half-life from conc–time graph *Half life is from continuous method, not in initial rates*
	(b)		$rate = k[I^-][S_2O_8^{2-}]$ **OR** $k = \frac{rate}{[I^-][S_2O_8^{2-}]}$ **OR** $\frac{1.2 \times 10^{-3}}{(8.0\times10^{-2})\times(4.0\times10^{-3})}$ ✓ = 3.75 **OR** 3.8 ✓ $dm^3\ mol^{-1}\ s^{-1}$ ✓	3	**Correct numerical answer subsumes previous marking point** **ALLOW** $mol^{-1}\ dm^3\ s^{-1}$ **NO ECF** from incorrect rate equation or *k* expression

Question			Answer	Marks	Guidance
	(c)	(i)	**Equation 1:** $S_2O_8^{2-} + 2Fe^{2+} \longrightarrow 2SO_4^{2-} + 2Fe^{3+}$ ✓ **Equation 2:** $2I^- + 2Fe^{3+} \longrightarrow I_2 + 2Fe^{2+}$ ✓	2	**ALLOW** correct multiples **IGNORE** state symbols **ALLOW** 1 mark for **2** correct equations in wrong order: i.e. $2I^- + 2Fe^{3+} \longrightarrow I_2 + 2Fe^{2+}$ $S_2O_8^{2-} + 2Fe^{2+} \longrightarrow 2SO_4^{2--} + 2Fe^{3+}$ **ALLOW** ⇌ sign shown instead of arrow as long as equation is shown the 'right way around'
		(ii)	Fe^{3+} could react with I^- ions first ✓	1	**ALLOW** equations in **(i)** could take place in the other order **IGNORE** responses that compare *E* values
			Total	**10**	

Question			Answer	Marks	Guidance
5	(a)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = 14.6 dm^6 mol^{-2} award 6 marks** **(5 for 14.6 and 1 for units)** **----------** equilibrium amount of CO = 0.114 – 0.052 = 0.062 (mol) ✓ equilibrium amount of H_2 = 0.152 – 2 x 0.052 = 0.048 (mol) ✓ [CO] = 5 x 0.062 = 0.31 (mol dm^{-3}) **AND** [H_2] = 5 x 0.048 = 0.24 (mol dm^{-3}) **AND** [CH_3OH] = 5 x 0.052 = 0.26 (mol dm^{-3}) ✓ (K_c =) $\frac{[CH_3OH]}{[CO]\,[H_2]^2}$ **OR** $\frac{0.26}{0.31 \times 0.24^2}$ ✓ = 14.6 ✓ dm^6 mol^{-2} ✓	6	**FULL ANNOTATIONS MUST BE USED** **----------** **IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below. **See list below for marking of answers from common errors** **----------** **ALLOW ECF** from equilibrium amounts Mark is for converting **ALL** 3 amounts into concentrations. For units, **ALLOW** mol^{-2} dm^6 **ALLOW ECF** from previous calculated values **OR** incorrect K_c expression **BUT** final answer **MUST** be to 3 SF (in question) **Common errors for K_c** 364: missing x 5 to calculate concentrations 4 marks + units mark (i.e. just one mark dropped) 3.35: H_2 = 0.100 by not using **2** H_2 4 marks + units mark (i.e. just one mark dropped) 0.79**0:** Use of initial amounts of CO and H_2) (3 marks + units mark) 0.79 Use of initial amounts of CO and H_2 **AND** answer not to 3 SF (2 marks + units mark)

Question	Answer	Marks	Guidance
(b)		4	**IGNORE** responses in terms of rate **Note**: **ALLOW** suitable alternatives for 'to right' e.g. towards CH_3OH **OR** towards products **OR** in forward direction **OR** increases yield of CH_3OH/products **ALLOW** 'favours the right', as alternative for 'shifts equilibrium to right' ----------
	Pressure: higher pressure shifts (equilibrium position) to the right **AND** right-hand side has fewer (gaseous) moles ✓		**ALLOW** equilibrium shifts to the right **AND** a statement that the concentrations on the top of K_c expression increases less than the bottom
	Temperature: higher temperature shifts (equilibrium position) to left **AND** (forward) reaction is exothermic / ΔH is –ve / gives out heat **OR** reverse reaction is endothermic / ΔH is +ve / takes in heat ✓		
	K_c decreases **AND** (forward) reaction is exothermic ✓		**ALLOW** K_c decreases **AND** reverse reaction is endothermic **Note:** exothermic/endothermic part of **AND** statement may be anywhere within the response
	Comparison Relative effect of pressure and temperature is not known ✓		Pressure and temperature send the equilibrium in opposite directions is **not** sufficient **IGNORE** 'temperature and pressure cancel each other out'
	Total	**10**	

Question			Answer	Marks	Guidance
6	(a)		**Circuit**: complete circuit with voltmeter and salt bridge linking two half-cells ✓ **Half cells**: Pt **AND** H^+/HCl (solution) **AND** H_2 gas (introduced via enclosed container around Pt) ✓ Fe **AND** Fe^{2+} (solution) ✓ **Conditions**: 1 mol dm^{-3} solutions **AND** 298 K / 25 ºC **AND** 1 atm/100 kPa/101 kPa/1 bar pressure ✓	4	Voltmeter must be shown **AND** salt bridge must be labelled **ALLOW** any correct circuit for a cell **ALL** labels required In H_2 half cell, **DO NOT ALLOW** just 'acid' **ALL** conditions required **ALLOW** if 1 mol dm^{-3}/1M mentioned for just one solution *Look also on diagram in addition to answer lines* **DO NOT ALLOW** 1 mol for concentration
	(b)	(i)	oxygen electrode: $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$ ✓ hydrogen electrode: $H_2(g) + 2OH^-(aq) \rightarrow 2H_2O(l) + 2e^-$ ✓	2	**ALLOW** multiples for each equation State symbols **NOT** required – **IGNORE** even if wrong If oxygen and hydrogen equations are written on the wrong lines **ALLOW** 1 mark if both correct **ALLOW** ⇌ sign shown instead of arrow as long as equation is shown the 'right way around' **ALLOW** one mark if both acid equations are given *i.e.* oxygen electrode: $O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$ **AND** hydrogen electrode: $H_2(g) \rightarrow 2H^+(aq) + 2e^-$
		(ii)	$2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$ ✓	1	**ALLOW** multiples, e.g. $H_2 + ½O_2 \rightarrow H_2O$ **IGNORE** state symbols **DO NOT ALLOW** if H_2O **OR** OH^- **OR** e^- are shown on both sides
		(iii)	1.23 (V) ✓	1	This is the **ONLY** correct answer

Question			Answer	Marks	Guidance
	(c)		A fuel cell reacts a fuel/H_2 with oxygen to produce a voltage/**electrical** energy ✓	1	**ALLOW** a fuel cell requires constant supply of a fuel/H_2 (and oxygen)/reactants **OR** operates continuously as long as a fuel/H_2 (and oxygen) are added **DO NOT ALLOW** storage cells can be recharged (Not all storage cells can be recharged)
	(d)		Fossil fuels used to make hydrogen **OR** fossil fuels required to make fuel cell ✓	1	Response requires link between **fossil fuels / carbon-containing compounds** and manufacture of the fuels cell or H_2 i.e. energy required to make H_2 is **not** sufficient
	(e)		Correctly calculates amount of Cr = 1.456/52.0 = **0.028(0)** ✓ **NOTE: The remaining marks are ONLY available if a 3:2 molar ratio has been used** **3** mol **X** reacts with **2** mol Cr^{3+} **OR 3** mol **X** ⟶ **2** mol Cr ✓ Correctly calculates amount of **X** = amount of Cr **x 1.5** = 0.028(0) x 1.5 = **0.042(0)** ✓ Correctly calculates Molar mass/A_r of **X** = 1.021/0.042(0) = **24.3** (g mol^{-1}) **AND** **X** identified as Mg ✓	4	**FULL ANNOTATIONS MUST BE USED** **ALLOW** equation: $2Cr^{3+} + 3X \longrightarrow 3X^{2+} + 2Cr$ **Note**: 3rd marking point subsumes the 2nd marking point **ALLOW** magnesium **OR** Mg^{2+} Mg with no evidence of how 24.3 had been calculated does **not** score this mark **ALLOW ECF** from incorrect amount of Cr for 2nd, 3rd and 4th marks --- **Common error** 3:2 ratio inverted between 2nd and 3rd marks: 3 marks: 3rd mark ECF: 0.028(0) ÷ 1.5 = 0.0187 (mol) ✓ Molar mass of **X** = 54.7 (g mol^{-1}) **AND X** = Mn ✓
			Total	**14**	

Question			Answer	Marks	Guidance
7	(a)		$CaCO_3 + 2SO_2 + H_2O \longrightarrow Ca(HSO_3)_2 + CO_2$ ✓	1	**ALLOW** multiples
	(b)	(i)	weak acid: partly dissociates ✓ $HSO_3^- \rightleftharpoons H^+ + SO_3^{2-}$ ✓	2	**ALLOW** ionisation for dissociation $\rightleftharpoons$ sign is required **ALLOW** multiples; state symbols **not** required **DO NOT ALLOW** equation with Ca^{2+} added to each side
		(ii)	$Mg + Ca(HSO_3)_2 \longrightarrow MgSO_3 + CaSO_3 + H_2$ ✓ $Mg + 2H^+ \longrightarrow Mg^{2+} + H_2$ ✓	2	**ALLOW** multiples State symbols **not** required **ALLOW** as products: $MgCa(SO_3)_2 + H_2$ **DO NOT ALLOW** $Mg + Ca(HSO_3)_2 \longrightarrow Mg^{2+} + Ca^{2+} + 2\,SO_3^{2-} + H_2$ **ALLOW** $Mg + 2HSO_3^- \longrightarrow Mg^{2+} + 2\,SO_3^{2-} + H_2$
		(iii)	HSO_3^- can accept a proton/H^+ and donate a proton/H^+ **OR** Base accepts a proton/H^+ **AND** Acid donates a proton/H^+ ✓ $HSO_3^- + OH^- \longrightarrow H_2O + SO_3^{2-}$ ✓ $HSO_3^- + H^+ \longrightarrow H_2O + SO_2$ ✓ **Two correct** equations linked to acid and base behaviour ✓ *This could simply be labels (Acid **AND** base) for each equation,* *i.e.* $HSO_3^- + OH^- \longrightarrow H_2O + SO_3^{2-}$ Acid $HSO_3^- + H^+ \longrightarrow H_2O + SO_2$ Base	4	**ASSUME** 'It' applied to HSO_3^- **ALLOW** equations with $\rightleftharpoons$ **ALLOW** $HSO_3^- + H^+ \longrightarrow H_2SO_3$ **Note**: Final mark can only be awarded if **both** equations are correct

Question			Answer	Marks	Guidance
	(c)	(i)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF M_r = 122 award first 5 marks** **6th mark is for formula** --- $[H^+] = 10^{-pH} = 10^{-3.52} = 3.02 \times 10^{-4}$ (mol dm^{-3}) ✓ $K_a = \frac{[H^+]\,[A^-]}{[HA]}$ **OR** $\frac{[H^+]^2}{[HA]}$ **OR** $\frac{(3.02\times10^{-4})^2}{[HA]}$ ✓ $[HA] = \frac{(3.02\times10^{-4})^2}{1.51\times10^{-5}}$ ✓ [HA] = 6.04 x 10^{-3} (mol dm^{-3}) ✓ $M = \frac{0.7369}{6.04\times10^{-3}}$ = 122(.0) (g mol^{-1}) ✓ Carboxylic acid is C_6H_5COOH **OR** $C_7H_6O_2$ ✓	6	**FULL ANNOTATIONS MUST BE USED** --- Throughout calculation, **ALLOW** 3 significant figures up to calculator value correctly rounded **ALLOW** 3 SF to calculator value of 3.01995172 x 10^{-4} **ALLOW** any correct equation that shows the relationship between K_a, [H$^+$], [A$^-$], [HA] Correct [HA] expression and calculation subsumes previous marks Using calculator [H$^+$] value, [HA] = 6.039806883 x 10^{-3} Using calculator [HA] value, M_r = 122.0072122 **ALLOW** any feasible formula with a molar mass of 122 containing C, H **AND** at least **two O** atoms e.g. $C_6H_2O_3$; $C_3H_6O_5$ **Note**: a structural formula must contain COOH/CO_2H **ALLOW ECF** for possible formula of HA from an incorrectly calculated molar mass of HA **Note**: the possible formula must be feasible and must contain C, H **AND** at least **two O** atoms **IF** '$[HA]_{eqm}$ = [HA] – [H$^+$]' has been used, M_r = 116 and formula is $C_5H_{11}COOH$ **OR** $C_6H_{12}O_2$ **ALL** marks are available for this answer Calculator unrounded M_r = 116.1972565

Question			Answer	Marks	Guidance
		(ii)	student is incorrect **AND** acid releases all H^+ ions **OR** more acid dissociates ✓	1	Statement **AND** reason required for the mark **ALLOW** incorrect **AND** equilibrium shifts to right **Note**: The key idea is that more H^+ ions are produced by more dissociation A comment that all the H^+ ions react is just repeating information in the question
			Total	**16**	

Question			Answer	Marks	Guidance
8	(a)		$(1s^2 2s^2 2p^6)\ 3s^2 3p^6 3d^2$ ✓	1	**ALLOW** $4s^0$: $(1s^2 2s^2 2p^6)\ 3s^2 3p^6 3d^2 4s^0$ **ALLOW** subscripts for superscripts **ALLOW** S, P, D (i.e. upper case)
8	(b)		(Only) 5 electrons in 4s and 3d sub-shells/orbitals ✓	1	**ALLOW** 3d sub-shell is empty **OR** no d electrons left **ALLOW** 6th electron in a 3p sub-shell/orbital **ALLOW** too much attraction on 3p electrons **OR** a lot of energy required to remove 3p electrons **IGNORE** only 5 electrons in outer shell **IGNORE** full outer shell/noble gas electron configuration **IGNORE** no 3d sub-shell **Note**: Key comment about 3d sub-shell being empty **OR** non-removal/greater attraction of 3p electrons
8	(c)	(i)	$KMnO_4$ is purple/pink **AND** V^{n+}/V^{2+} is violet ✓	1	**ALLOW** $KMnO_4$ **AND** V^{n+}/V^{2+} have similar colours **ALLOW** $KMnO_4$ is purple and 'the solution' is violet *Assumption is that 'the solution'* is $V^{2+}(aq)$ **ALLOW** any reasonable description of purple/mauve/violet colours **DO NOT ALLOW** just '$KMnO_4$ is purple/pink' **IGNORE** reference to Mn^{2+} being (pale) pink

Question			Answer	Marks	Guidance
8	(c)	(ii)	**Marks are for correctly calculated values. Working shows how values have been derived.** $n(KMnO_4) = \frac{2.25\times10^{-2}\times13.2}{1000}$ = **2.97×10^{-4}** (mol) ✓ $n(V) = \frac{0.126}{50.9}$ = **2.48×10^{-3}** (mol) ✓ *Factor of 5:* $\frac{2.48\times10^{-3}}{5}$ = **4.96×10^{-4}** (mol) **OR** 5 x 2.97×10^{-4} = **1.485×10^{-3}** (mol) ✓ ratio $\frac{n(V^{n+})}{n(MnO_4^-)} = \frac{4.96\times10^{-4}}{2.97\times10^{-4}} = \frac{1.67}{1}$ **OR** 1.67 **OR** $\frac{5}{3}$ **OR** 1 mol MnO_4 reacts with 1.67 mol V^{n+} ✓ 5 : 3 ratio seen **AND** n = 2 ✓ Correct equation with all species on both sides cancelled: $5V^{2+}(aq) + 3MnO_4^-(aq) + 3H_2O(l) \longrightarrow 5VO_3^-(aq) + 3Mn^{2+}(aq) + 6H^+(aq)$ $5V^{2+} + 3MnO_4^-$ on left **AND** $5VO_3^- + 3Mn^{2+}$ on right ✓ Complete equation correct ✓	7	**FULL ANNOTATIONS MUST BE USED** --- **ALLOW 2.48 x 10^{-3}** up to calculator value of 2.475442043 x 10^{-3}, correctly rounded **ALLOW 4.95 × 10^{-4}** (mol) from 2.475442043 x 10^{-3} **ALLOW** ratio $\frac{n(V^{n+})}{n(MnO_4^-)} = \frac{2.48\times10^{-3}}{1.485\times10^{-3}} = \frac{1.67}{1}$ **OR** 1.67 **OR** $\frac{5}{3}$ **ALLOW** inverse ratio **DO NOT ALLOW** n = 2 without some justification e.g.: 3 mol MnO_4^- reacts with 5 mol V^{2+}; V changes oxidation number by 3 **OR** 3 electrons transferred to V **IGNORE** state symbols --- ***ALLOW any attempted equation using n = 2, 3 OR 4.*** ***See correct eqn for n=2 and equations on next page*** ---

Question			Answer	Marks	Guidance
8	(c)	(ii)	*Cont.*		**From V^{4+} :** $5V^{4+}(aq) + MnO_4^-(aq) + 11H_2O(l) \rightarrow 5VO_3^-(aq) + Mn^{2+}(aq) + 22H^+(aq)$ $5V^{4+}$ + MnO_4^-on left **AND** $5VO_3^-$ + Mn^{2+} on right ✓ Complete equation correct ✓ **----------** **From V^{3+} :** $5V^{3+}(aq) + 2MnO_4^-(aq) + 7H_2O(l) \rightarrow 5VO_3^-(aq) + 2Mn^{2+}(aq) + 14H^+(aq)$ ✓✓ $5V^{3+}$ + $2MnO_4^-$on left **AND** $5VO_3^-$ + $2Mn^{2+}$ on right ✓ Complete equation correct ✓
			Total	**10**	