OCR
RECOGNISING ACHIEVEMENT

GCE

Chemistry A

Advanced GCE

Unit **F325:** Equilibria, Energetics and Elements

Mark Scheme for January 2013

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All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

OCR will not enter into any discussion or correspondence in connection with this mark scheme.

Annotations available in scoris

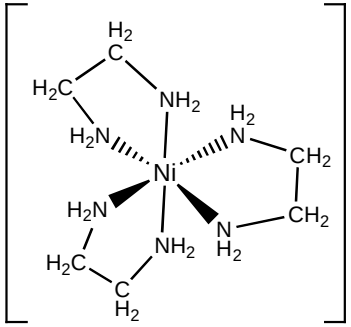
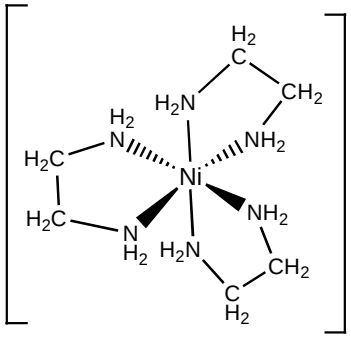
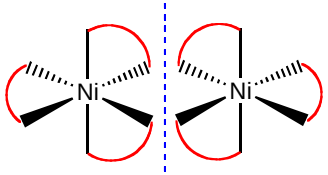
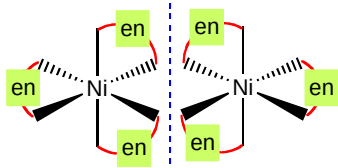
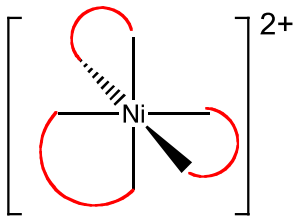
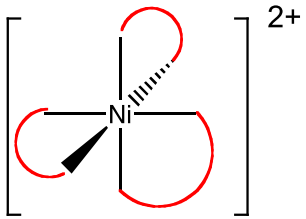
Annotation	Meaning
	Benefit of doubt given
	Contradiction
	Incorrect response
	Error carried forward
	Ignore
	Not answered question
	Benefit of doubt not given
	Power of 10 error
	Omission mark
	Rounding error
	Error in number of significant figures
	Correct response

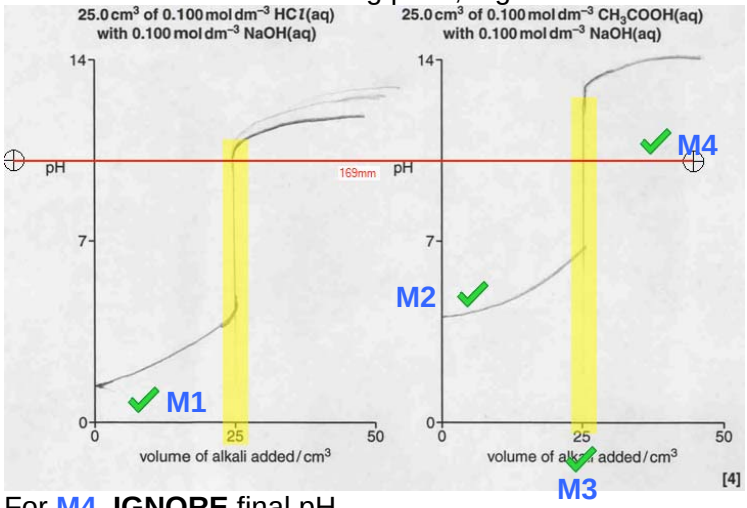
Annotation	Meaning
DO NOT ALLOW	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

Subject-specific Marking Instructions

The following questions should be fully annotated to show where marks have been awarded in the body of the text: **2(a)(i), 2(b)(ii), 3(b)(ii)**, **4(a), 5(a), 6(e)**, **7(c)(i) and 8(c)(ii)**.

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**	

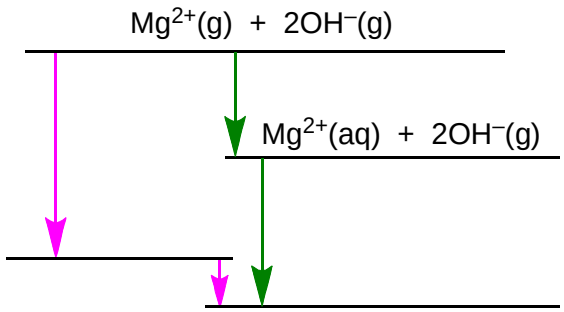
Question			Answer	Marks	Guidance
2	(a)	(i)	**M1 Shape** On **one** graph (can be either), shape: slight rise/flat, then vertical, then slight rise/flat ✓ **M2 pH at start for acid** Weak acid pH curve starts at higher pH and below pH 7 ✓ **M3 End point** On both graphs, vertical section approximately 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 ∝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 ∝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** $\frac{(3.02\times10^{-4})^2}{[HA]}$ ✓ $[HA] = \frac{(3.02\times10^{-4})^2}{1.51\times10^{-5}}$ ✓ $[HA] = 6.04 \times 10^{-3}$ (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**	

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