OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE

CHEMISTRY A **F325/01**

Equilibria, Energetics and Elements

FINAL MARK SCHEME

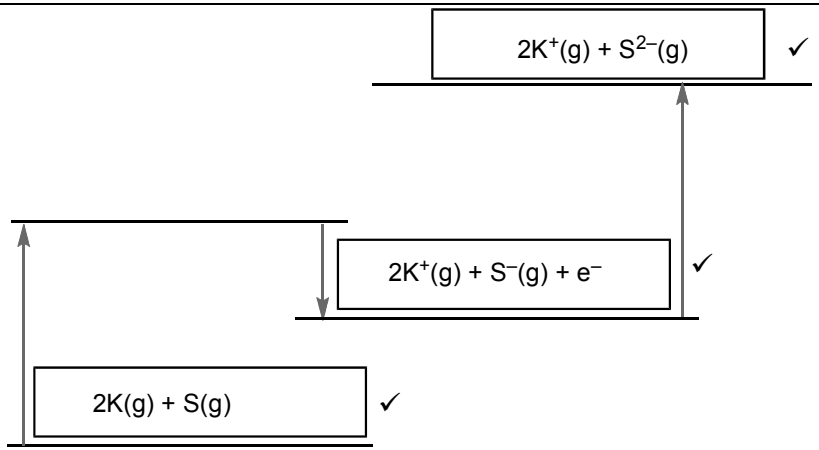
Afternoon

Duration: 2 hours

MAXIMUM MARK **100 (keep this alignment and spacing)**

This document consists of 24 pages

F325 V2 – 29/06/14

Question			Answer	Marks	Guidance
1	(a)	(i)		3	Mark each marking point independently Correct species **AND** state symbols required for each mark For S^{2-}, **DO NOT ALLOW** S^{-2} For e^-, **ALLOW** e For e^- **only**, **IGNORE** any state symbols added **ALLOW** k and s *It can be very difficult distinguishing K from k; S from s*

1	**(a)**	**(ii)**	(The enthalpy change that accompanies) the **formation** of **one mole** of a(n ionic) compound from its **gaseous ions** (under standard conditions) ✓✓ Award marks as follows. **1st mark:** **formation** of **compound** from **gaseous ions** **2nd mark:** **one mole** for compound **only** **DO NOT ALLOW** 2nd mark without 1st mark Note: A definition for enthalpy change of **formation** will receive **no** marks	**2**	**IGNORE** 'Energy needed' **OR** 'energy required' **ALLOW one mole** of compound is **formed/made** from its **gaseous ions** **ALLOW** as alternative for compound: lattice, crystal, substance, solid **IGNORE**: $2K^+(g) + S^{2-}(g) \longrightarrow K_2S(s)$ (question asks for words) **ALLOW** 1 mark (special case) for absence of 'gaseous' only, i.e. the **formation** of **one mole** of a(n ionic) compound from its **ions** (under standard conditions) ✓

1	**(a)**	**(iii)**	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = –2116 (kJ mol^{-1}) award 2 marks** --- –381 – (2 × +89 + 279 + 2 × +419 –200 + 640) ✓ –381 – 1735 = – 2116 ✓ (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 **ONE** mistake with sign **OR** use of 2: –2027 (**2** × 89 not used for K) –1697 (**2** × 419 not used for K) –2516 (+200 rather than –200 for S 1st electron affinity) (+)2116 (wrong sign) –1354 (+381 instead of –381) (+)1354 (+1735 instead of –1735) –836 (–640 instead of +640) –1558 (–279 instead of +279) –1760 (–2 × 89 instead of +2 x 89) –439 (–2 × 419 instead of +2 x 419) –2120 (rounded to 3SF) **For other answers**, check for a **single** transcription error or calculator error which could merit 1 mark **DO NOT ALLOW** any other answers, e.g. –1608 (2 errors: **2** × 89 and **2 x** 419 not used for K) –846 (3 errors:)

1	(b)		Lowest melting point **KI** **RbC*l*** Highest melting point **NaBr** Correct order ✓ **Mark 2nd and 3rd marking points independently** **Attraction and ionic size linked:** Greater attraction from smaller ions/closer ions/larger charge density ✓ *Comparison needed* **Energy AND attraction/breaking bonds linked:** More **energy**/**heat** to overcome attraction (between ions) **OR** More **energy**/**heat** to break (ionic) bonds ✓	**3**	***FULL ANNOTATIONS MUST BE USED*** **----------** **ORA** throughout Response must clearly refer to **ions** for explanation marks **2nd and 3rd marking point must be comparative** **DO NOT ALLOW incorrect named particles, e.g.** 'atoms', 'molecules', Na, Cl, Cl_2, 'atomic', etc **DO NOT ALLOW** responses using nuclear size or attraction **DO NOT ALLOW** responses linked with **loss** of electrons **IGNORE** larger **electron** density **ALLOW** smaller **sum** of radii gives a greater ionic attraction **IGNORE** NaBr has greater ionic attraction **IGNORE** NaBr has smallest ionic radius (*not focussing on size of **each** ion*) **ASSUME** bonds broken are ionic unless otherwise stated **DO NOT ALLOW incorrect named particles, e.g.** 'atoms', 'molecules', Na, Cl, Cl_2, 'atomic', etc **Note**: Comparison for energy **only** *(i.e. link between more energy and breaking bonds/overcoming attraction)*
			Total	**10**	

Question			Answer	Marks	Guidance
2	(a)	(i)	(entropy) decreases **AND** (solid/ice has) less disorder/ more order/ fewer ways of arranging energy/ less freedom/ less random molecules ✓	1	**ORA** **decreases and reason required for mark** **ASSUME change is for freezing of water unless otherwise stated** **DO NOT ALLOW** atoms are more ordered
2	(a)	(ii)	(entropy) increases **AND** (CO_2) **gas** is **formed** ✓ *Could be from equation with $CO_2(g)$*	1	**increases and reason required for mark** **ASSUME** gas is CO_2 unless otherwise stated **BUT DO NOT ALLOW** an incorrect gas (e.g. H_2) **ALLOW** more gas
2	(a)	(iii)	entropy decreases **AND** 3 mol O_2 form 2 mol O_3 **OR** $3O_2 \rightarrow 2O_3$ **OR** 3 mol gas form 2 mol gas ✓	1	**decreases and reason required for mark** For mol, **ALLOW** molecules **ALLOW** multiples, e.g. $1½O_2 \rightarrow O_3$; $O_2 + ½O_2 \rightarrow O_3$ **ALLOW** $O_2 + O \rightarrow O_3$ **Note: DO NOT ALLOW** 2 mol gas forms 1 mol gas unless linked to $O_2 + O \rightarrow O_3$ **IGNORE** reaction forms fewer moles/molecules

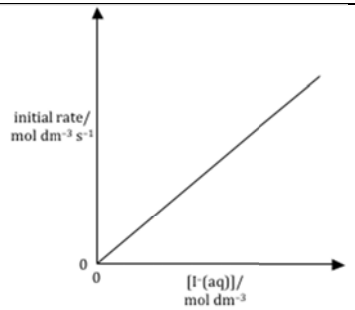
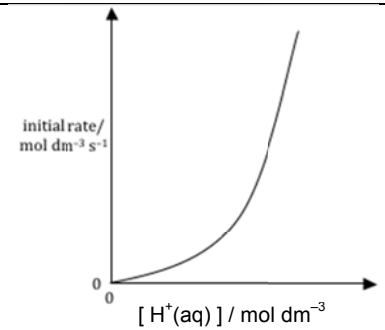
2	**(b)**		**CARE: responses involve changes of negative values** --- **Feasibility AND ΔG** Reaction becomes/is less feasible/not feasible **AND** ΔG increases **OR** ΔG becomes/is less negative/more positive **OR** $\Delta G > 0$ **OR** $\Delta H - T\Delta S > 0$ **OR** $\Delta H - T\Delta S$ becomes/is less negative/more positive **OR** $\Delta H > T\Delta S$ ✓ **OR** $T\Delta S$ becomes/is more negative than ΔH ✓ --- **Effect on $T\Delta S$** $T\Delta S$ becomes more negative **OR** $T\Delta S$ decreases **OR** $-T\Delta S$ becomes more positive **OR** $-T\Delta S$ increases **OR magnitude** of $T\Delta S$ increases **OR** $\lvert T\Delta S \rvert$ increases ✓ ---	**2**	***FULL ANNOTATIONS MUST BE USED*** --- As alternative for 'less feasible' **ALLOW 'less** spontaneous' **OR** a comment that implies 'reaction no longer take place' **ALLOW for ΔG increases** $\Delta G < 0$ **only** at low T **DO NOT ALLOW** $T\Delta S > \Delta H$ (*comparison wrong way round*) **NOTE: Last statement automatically scores 2nd mark ALSO** **IGNORE** significance **IGNORE** magnitude for 1st marking point --- **DO NOT ALLOW** $T\Delta S$ increases **IGNORE** significance --- ***APPROACH BASED ON TOTAL ENTROPY:*** **Feasibility with increasing temperature** Reaction becomes less feasible/not feasible **AND** $\Delta S - \Delta H/T$ **OR** ΔS_{total} decreases/ less positive ✓ **Effect on $\Delta H/T$** $\Delta H/T$ is less negative **OR** $\Delta H/T$ increases **OR** $-\Delta H/T$ decreases **OR** magnitude of $\Delta H/T$ decreases ✓

2	**(c)**	**(i)**	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 75.962 **OR** 75.96 **OR** 76.0 **OR** 76, award **2 marks** --- ΔS = (33 + 3 × 189) – (76 + 3 × 131) = (+)131 (J K^{-1} mol^{-1}) ✓ ΔG = 115 – (298 × 0.131) = (+) 75.962 **OR** 75.96 **OR** 76.0 **OR** 76 (kJ K^{-1} mol^{-1}) ✓	**2**	**DO NOT ALLOW** –131 **ALLOW ECF** from incorrect calculated value of ΔS
2	**(c)**	**(ii)**	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 878 **OR** 877.9 **OR** 877.86, award **2 marks** --- (Minimum temperature when) $\Delta G = 0$ **OR** $\Delta H - T\Delta S = 0$ **OR** (For feasibility) $\Delta G = 0$ **OR** $\Delta G < 0$ **OR** $\Delta H - T\Delta S < 0$ **OR** $T = \frac{\Delta H}{\Delta S}$ ✓ $T = \frac{115}{0.131}$ = 878 K ✓	**2**	**ALLOW** total entropy statement: ΔS(total) = 0 **OR** ΔS(total) >0 **ALLOW ECF** from incorrect calculated value of ΔS from **2(c)(i)** **ALLOW** 878 up to calculator value of 877.862595 correctly rounded
			Total	**9**	

Question			Answer	Marks	Guidance
3	(a)		$(K_c =)\ \frac{[C_2H_2]\,[H_2]^3}{[CH_4]^2}$ ✓	1	Square brackets are **essential** State symbols **not** required. **IGNORE** incorrect state symbols
3	(b)	(i)	amount of $H_2 = 3 \times 0.168$ $= 0.504$ (mol) ✓	1	

3	**(b)**	**(ii)**	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 0.153 $mol^2\ dm^{-6}$, award **3 marks** **IF** answer = 0.153 with incorrect units, award **2 marks** --- **IF answer from 3(b)(i) for $n(H_2) \neq 0.504$, mark by ECF.** **Equilibrium concentrations** (from $n(H_2) = 0.504$ mol dm^{-3}) $[CH_4] = 2.34 \times 10^{-2}$ (mol dm^{-3}) **AND** $[C_2H_2] = 4.20 \times 10^{-2}$ (mol dm^{-3}) **AND** $[H_2] = 0.126$ (mol dm^{-3}) ✓ **Calculation of K_c and units** $K_c = \frac{4.20 \times 10^{-2} \times (0.126)^3}{(2.34 \times 10^{-2})^2} = 0.153$ ✓ $mol^2\ dm^{-6}$ ✓ **3 significant figures** are required	**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 --- **ALLOW** ÷ by 4 of equilibrium amounts in all expressions, i.e. **ALLOW** $[CH_4] = \frac{9.36 \times 10^{-2}}{4}$ mol dm^{-3} **AND** $[C_2H_2] = \frac{0.168}{4}$ mol dm^{-3} **AND** $[H_2] = \frac{0.504}{4}$ mol dm^{-3} ✓ **ALLOW ECF** from incorrect concentrations or from moles From moles: 9.36×10^{-2}, 0.168 and 0.504, $K_c = 2.45$ by **ECF** **ALLOW** $dm^{-6}\ mol^2$ **DO NOT ALLOW** mol^2/dm^6 **ALLOW ECF** from incorrect K_c expression for both calculation and units --- **COMMON ECF** From **3(b)(i)** answer of 0.1404, $K_c = 3.32 \times 10^{-3}$ 2 marks + units $K_c = 0.0531$ No ÷ 4 throughout 1 mark + units
3	**(b)**	**(iii)**	**Initial amount of CH_4** amount of $CH_4 = 9.36 \times 10^{-2} + 2 \times 0.168$ = 0.4296 **OR** 0.43(0) (mol) ✓	**1**	**NO ECF** possible (all data given in question)

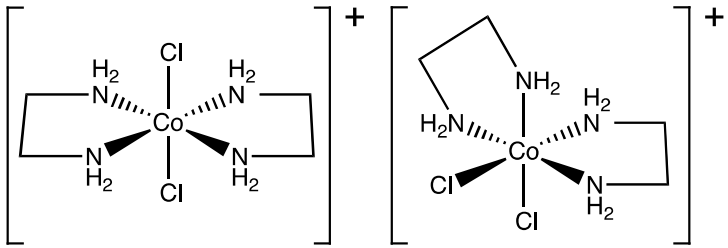
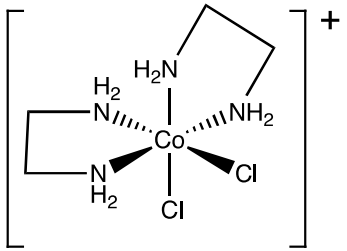
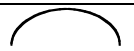
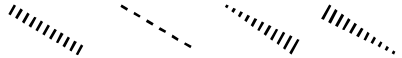
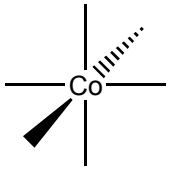
3 **(c)**	<table><tr><th>**Change**</th><th>K_c</th><th>**Equilibrium amount of C_2H_2 / mol**</th><th>**Initial rate**</th></tr><tr><td>temperature increased</td><td>greater</td><td>greater</td><td>greater</td></tr><tr><td>smaller container</td><td>same</td><td>smaller</td><td>greater</td></tr><tr><td>catalyst added</td><td>same</td><td>same</td><td>greater</td></tr><tr><td></td><td>✓</td><td>✓</td><td>✓</td></tr></table>	**3**	Mark by **COLUMN** **ALLOW** obvious alternatives for greater/smaller/same, e.g. increases/decreases; more/less
3 **(d)**	**ONE** mark only **USE ONE TICK ONLY** ✓ from **TWO** uses: **1.** fuel cells **2.** manufacture of margarine **OR** hydrogenation of alkenes/unsaturated fats/unsaturated oils/unsaturated molecules **3.** making of ammonia **OR** Haber process **4.** making of HCl/hydrochloric acid **5.** making of methanol	**1**	**IGNORE** just 'fuel' **IGNORE** hydrogenation of margarine **ALLOW** hydrogenation of fats/oils **DO NOT ALLOW** explosives **OR** fertilisers
	Total	**10**	

Question			Answer	Marks	Guidance
4	(a)	(i)	5 **OR** 5th (order) ✓	1	
4	(a)	(ii)	(stoichiometry in) rate equation does not match (stoichiometry) in **overall** equation ✓ Collision unlikely with more than 2 ions/species/particles ✓	2	**ALLOW** moles/ions/species/particles/molecules/atoms throughout (*i.e. emphasis on particles)* **IGNORE** more reactants in overall equation **If number of species is stated, ALLOW 3–5 only** *(rate equation contains 5 ions)* **DO NOT ALLOW** negative ions would repel (*there is a mixture of positive and negative ions*) **IGNORE** more than two **reactants** collide (*not related to rate equation*)
4	(b)		 Straight upward line **AND** starting at 0,0 ✓  Curve with increasing gradient, **AND** starting at 0,0 ✓	2	**ALLOW** lines starting close to 0,0 **ALLOW** 2nd order line with 'straight' section early or late as long as an upward curve is seen between.
4	(c)	(i)	5.4(0) ✓ 614.4(0) ✓	2	**IGNORE** sign **ALLOW** 614 **OR** 610

4	**(c)**	**(ii)**	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 6.7×10^8 **OR** 670000000 dm^{12} mol^{-4} s^{-1}, award **3 marks** **IF** answer = 6.7×10^8 **OR** 670000000 with incorrect units, award **2 marks** *k* to >2 SF: 666666666.7 ✓ **OR** *k* to 2 SF: 6.7×10^8 **OR** 670000000 ✓✓ units: dm^{12} mol^{-4} s^{-1} ✓	**3**	**ALLOW ECF** from incorrect initial rates if 1st experimental results have **not** been used. **(Look to 4(c)(i) to check)** *i.e.* **IF** other rows have been used, then calculate the rate constant from data chosen. For *k*, **ALLOW** 1 mark for the following: 6.6×10^8 recurring 6.6×10^8 2 SF answer for *k* **BUT** one power of 10 out i.e. 6.7×10^9 **OR** 6.7×10^7 **ALLOW** units in any order, e.g. mol^{-4} dm^{12} s^{-1}
4	**(c)**	**(iii)**	(K_a =) $10^{-3.75}$ **OR** 1.78×10^{-4} ($mol\ dm^{-3}$) ✓ $[H^+]$ **=** $\sqrt{1.78 \times 10^{-4} \times 0.0200}$ = 1.89×10^{-3} ($mol\ dm^{-3}$) ✓ initial rate = 6.7×10^8 x 0.01 x 0.015^2 x $(1.89 \times 10^{-3})^2$ = 5.33×10^{-3} to 5.38×10^{-3} ($mol\ dm^{-3}\ s^{-1}$) **OR** 5.3×10^{-3} to 5.4×10^{-3} ($mol\ dm^{-3}\ s^{-1}$) ✓ Actual value will depend on amount of acceptable rounding in steps and whether figures kept in calculator even if rounding is written down. **ALLOW** any value in range given above.	**3**	***FULL ANNOTATIONS MUST BE USED*** **----------** **For ALL marks, ALLOW 2 SF** up to calculator value correctly rounded $1.77827941 \times 10^{-4}$ **ALLOW** $\sqrt{10^{-3.75} \times 0.0200}$ for first marking point **ALLOW** 1.88×10^{-3} ($mol\ dm^{-3}$) **ALLOW ECF** from calculated $[H^+(aq)]$ and calculated answer for *k* from **4(c)(ii)** e.g. If no square root taken, $[H^+] = 3.56 \times 10^{-6}$ $mol\ dm^{-3}$ and *rate* = 1.91×10^{-8} **OR** 1.9×10^{-8} by **ECF**
			Total	**13**	

Question			Answer	Marks	Guidance
5	(a)		(Transition element) has **an ion** with an incomplete/partially-filled d **sub-shell/d-orbital** ✓ Scandium/Sc and zinc/Zn are not transition elements ✓ *Electron configurations of ions* Sc^{3+} **AND** $1s^2 2s^2 2p^6 3s^2 3p^6$ ✓ Zn^{2+} **AND** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$ ✓ Sc^{3+} **AND** d **sub-shell** empty **/ d orbital(s) empty** ✓ ***Note**: Sc^{3+} must be the **ONLY** scandium ion shown for this mark* Zn^{2+} **AND** d **sub-shell** full **/ALL d-orbitals** full ✓ ***Note**: Zn^{2+} must be the **ONLY** zinc ion shown for this mark*	**6**	***FULL ANNOTATIONS MUST BE USED*** **----------** **ALLOW** capital **'**D' within definition **DO NOT ALLOW** d shell **ALLOW** if **ONLY** Sc and Zn are used to illustrate d block elements that are **NOT** transition elements This can be from anywhere in the overall response in terms of Sc, Sc^{3+}, Zn, Zn^{2+} **OR** incorrect charges, i.e. only Sc^{+}, Sc^{2+}, Zn^{+} In electron configurations, **IF** subscripts **OR** caps used, **DO NOT ALLOW** when first seen but credit subsequently **ALLOW** $4s^0$ in electron configurations **IGNORE** [Ar] **IGNORE** electron configurations for other Sc and Zn ions **ALLOW** for Sc^{3+}: Sc forms a 3+ ion; **ALLOW** Sc^{+3} **ALLOW** for Zn^{2+}: Zn forms a 2+ ion; **ALLOW** Zn^{+2} **ALLOW** Sc^{3+} has no d sub-shell **DO NOT ALLOW** 'd sub-shell is incomplete' *(in definition)* **DO NOT ALLOW** 'd sub-shell is incomplete' *(in definition)*

5	**(b)**	**(i)**	Donates **two** electron/lone pairs to a metal ion **OR** Co^{3+} ✓ ***DO NOT ALLOW*** *metal (complex contains Co^{3+})* Electron/lone pair on N **OR** NH_2 (groups) ✓	 **2**	**ALLOW** 'forms **two** coordinate bonds/dative covalent/dative bonds' as an alternative for 'donates **two** electron/lone pairs' *Two is required for 1st marking point* *Two can be implied using words such as 'both' or 'each'* For metal ion, **ALLOW** transition (metal) ion Second mark is for the atom that donates the electron/lone pairs **ALLOW** both marks for a response that communicates the same using N as the focus: e.g. The two N atoms each donate an electron pair to metal ion
5	**(b)**	**(ii)**	$[Co(H_2NCH_2CH_2NH_2)_2Cl_2]^+$ ✓	**1**	Square brackets **AND** + charge required **DO NOT ALLOW** any charges included within square brackets **ALLOW** $[Co(C_2H_8N_2)_2Cl_2]^+$ **OR** $[CoC_4H_{16}N_4Cl_2]^+$ **ALLOW** structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **IGNORE** $[Co(en)_2Cl_2]^+$ *simplifies question* Within formula, **ALLOW** ….$(Cl)_2$, (Cl_2) **ALLOW** CO Within the context of the question, CO is Co
5	**(b)**	**(iii)**	6 ✓	**1**	

5	**(b)**	**(iv)**	 ✓ ✓  ✓ Note: For each structure, **ALL** NH_2 groups must be shown **AND** bonding between Co **AND** N of NH_2. For $H_2NCH_2CH_2NH_2$, **ALLOW** C–C without Hs and  --- **IF** NH_2 shown without Hs, e.g.  , penalise first time **ONLY** --- **IF ALL** 3 isomers are 'correct', but 2 x Cl **AND** no Ns, e.g.  **AWARD** 1 mark	**3**	***FULL ANNOTATIONS MUST BE USED*** --- **IGNORE** charges (**anywhere**) and labels (even if wrong) Square brackets **NOT** required Must contain 2 'out wedges', 2 'in wedges' and 2 lines in plane of paper **OR** 4 lines, 1 'out wedge' and 1 'in wedge': For bond into paper, **ALLOW**:  **ALLOW** following geometry throughout:  **TAKE CARE**: structures may be in different orientations. For $H_2NCH_2CH_2NH_2$, **ALLOW**  *(connectivity within 'loop' only)* **If Cl_2s are shown instead of Cl, penalise 1st time only**

5	**(c)**	**(i)**	O_2/oxygen **bonds** to Fe^{2+}/Fe(II) ✓ *Fe^{2+}/Fe(II) essential for 1st marking point* (When required,) O_2 substituted **OR** O_2 released ✓ *Fe^{2+} not required for 2nd marking point (e.g. **IGNORE** Fe)*	**2**	**ASSUME that 'it' refers to oxygen** **ALLOW** O_2 **binds** to Fe^{2+} **OR** O_2 donates electron pair to Fe^{2+} **OR** O_2 is a ligand with Fe^{2+} **IGNORE** O_2 reacts with Fe^{2+} **OR** O_2 is around Fe^{2+} **ALLOW** bond to O_2 breaks when O_2 required **OR** H_2O replaces O_2 **OR** vice versa **ALLOW** CO_2 replaces O_2 **OR** vice versa **ALLOW** O_2 bonds/binds reversibly
5	**(c)**	**(ii)**	$(K_{stab} =) \frac{[HbO_2(aq)]}{[Hb(aq)]\,[O_2(aq)]}$ ✓ **ALL Square brackets essential**	**1**	**ALLOW** expression without state symbols (*given in question*)
5	**(c)**	**(iii)**	**Both marks require a comparison** Stability constant/K_{stab} value with CO is **greater** (than with complex in O_2) ✓ (Coordinate) bond with CO is **stronger** (than O_2) **OR** CO binds more strongly ✓	**2**	**IGNORE** (complex with) CO is more stable **ALLOW** bond with CO is less likely to break (than O_2) **OR** CO is a stronger ligand (than O_2) **OR** CO has greater affinity for ion/metal/haemoglobin (than O_2) **ALLOW** CO bond formation is irreversible **OR** CO is not able to break away **IGNORE** CO bonds more easily **OR** CO complex forms more easily
			Total	**18**	

Question			Answer	Marks	Guidance
6	(a)		CH_3COOH + H_2O ⇌ H_3O^+ + CH_3COO^- ✓ Acid 1 Base 2 Acid 2 Base 1 ✓	2	**IGNORE** state symbols (even if incorrect) **ALLOW** 1 **AND** 2 labels the other way around. **ALLOW** 'just acid' and 'base' labels if linked by lines so that it is clear what the acid–base pairs are **ALLOW** A and B for 'acid' and 'base' **IF** proton transfer is wrong way around **ALLOW** 2nd mark for idea of acid–base pairs, *i.e.* CH_3COOH + H_2O ⇌ $CH_3COOH_2^+$ + OH^- × Base 2 Acid 1 Acid 2 Base 1 ✓ **NOTE** For the 2nd marking point (acid–base pairs), this is the **ONLY** acceptable **ECF** *i.e., **NO ECF** from impossible chemistry*
6	(b)	(i)	Water dissociates/ionises **OR** $H_2O \rightleftharpoons H^+ + OH^-$ **OR** $2H_2O \rightleftharpoons H_3O^+ + OH^-$ ✓	1	**ALLOW** $K_w = [H^+]\,[OH^-]$ **OR** $[H^+]\,[OH^-] = 10^{-14}$ ($mol^2\ dm^{-6}$) **IGNORE** breaking for dissociation **IGNORE** water contains H^+ and OH^- **IGNORE** $H_2O \rightarrow H^+ + OH^-$ *i.e. no equilibrium sign* **IGNORE** $2H_2O \rightarrow H_3O^+ + OH^-$ *i.e. no equilibrium sign*

6	**(b)**	**(ii)**	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = 1.15 × 10^{-11}, award 2 marks** --- $[H^+] = 10^{-3.06} = 8.71 \times 10^{-4}$ (mol dm^{-3}) ✓ $[OH^-] = \frac{1.00 \times 10^{-14}}{8.71 \times 10^{-4}} = 1.15 \times 10^{-11}$ (mol dm^{-3}) ✓ **ALLOW** answer to two or more significant figures 2SF: 1.1×10^{-11}; 4SF: 1.148×10^{-11}; calculator $1.148153621 \times 10^{-11}$	**2**	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below. --- **ALLOW 2 SF:** 8.7×10^{-4} up to calculator value of 8.7096359×10^{-4} correctly rounded **ALLOW** alternative approach using pOH: pOH = 14 – 3.06 = 10.94 ✓ $[OH^-] = 10^{-10.94} = 1.15 \times 10^{-11}$ (mol dm^{-3}) ✓
6	**(c)**	**(i)**	$2CH_3COOH + CaCO_3 \rightarrow (CH_3COO)_2Ca + CO_2 + H_2O$ ✓	**1**	**IGNORE** state symbols **ALLOW** ⇌ provided that reactants on LHS For $CO_2 + H_2O$, **ALLOW** H_2CO_3 **ALLOW** $Ca(CH_3COO)_2$ **ALLOW** $(CH_3COO^-)_2Ca^{2+}$ **BUT DO NOT ALLOW** if either charge is missing or incorrect

6	**(c)**	**(ii)**	solution contains CH_3COOH **AND** CH_3COO^- ✓	**1**	**ALLOW** names: ethanoic acid for CH_3COOH ethanoate for CH_3COO^- **ALLOW** calcium ethanoate **OR** $(CH_3COO)_2Ca$ for CH_3COO^- **IGNORE** 'acid, salt, conjugate base; responses must identify the acid and conjugate base as ethanoic acid and ethanoate **IGNORE** ethanoic acid is in excess (*in question*) **BUT DO ALLOW** some ethanoic acid is left over/present/some ethanoic acid has reacted **IGNORE** equilibrium: $CH_3COOH \rightleftharpoons H^+ + CH_3COO^-$ *Dissociation of ethanoic acid only*

6	**(c)**	**(iii)**	**Quality of written communication, QWC** 2 marks are available for explaining how the equilibrium system allows the buffer solution to control the pH on addition of H^+ and OH^- (see below) --- $CH_3COOH \rightleftharpoons H^+ + CH_3COO^-$ ✓ --- CH_3COOH reacts with added alkali **OR** $CH_3COOH + OH^- \rightarrow$ **OR** added alkali reacts with H^+ **OR** $H^+ + OH^- \rightarrow$ ✓ Equilibrium → right **OR** Equilibrium → CH_3COO^- ✓ (**QWC**) CH_3COO^- reacts with added acid ✓ Equilibrium → left **OR** Equilibrium → CH_3COOH ✓ (**QWC**)	**5**	***FULL ANNOTATIONS MUST BE USED*** --- **Note: If there is no equilibrium equation then the two subsequent equilibrium marks are not available: max 2** **DO NOT ALLOW** $HA \rightleftharpoons H^+ + A^-$ **DO NOT ALLOW** more than one equilibrium equation. --- **ALLOW** response in terms of H^+, A^- and HA **IF** more than one equilibrium shown, it **must** be clear which one is being referred to by labeling the equilibria. **ALLOW** weak acid reacts with added alkali **DO NOT ALLOW** acid reacts with added alkali **ALLOW** conjugate base reacts with added acid **DO NOT ALLOW** salt/base reacts with added acid

6	**(d)**		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = 11.48 OR 11.5 (g), award 5 marks** --- $[H^+] = 10^{-5}$ (mol dm^{-3}) ✓ --- **[CH_3COO^-]** = $\frac{1.75 \times 10^{-5}}{10^{-5}}$ ✓ × 0.200 = 0.350 mol dm^{-3} ✓ n(**CH_3COONa/CH_3COO^-**) in 400 cm^3 = 0.350 × $\frac{400}{1000}$ = 0.14(0) (mol) ✓ --- mass **CH_3COONa** = 0.140 × 82.0 = 11.48 **OR** 11.5 (g) ✓ For **ECF**, ***n*(CH_3COONa/CH_3COO^-) must** have been calculated in step before	**5**	***FULL ANNOTATIONS MUST BE USED*** --- **IF** there is an alternative answer, check to see if there is any **ECF** credit possible. **Incorrect use of [H^+] = √([CH_3COOH] × K_a) scores zero** **BUT IGNORE** if an alternative successful method is present **Incorrect use of K_w, 1 max for [H^+] = 10^{-5} (mol dm^{-3})** **BUT IGNORE** if an alternative successful method is present --- **ALLOW** n(**CH_3COONa/CH_3COO^-**) = $\frac{1.75 \times 10^{-5}}{10^{-5}}$ ✓ × 0.08 = 0.14(0) (mol) ✓✓ **Note: There is no mark just for** n(**CH_3COOH**) in 400 cm^3 = 0.200 × $\frac{400}{1000}$ = 0.08 (mol) --- As alternative for the 4th and 5th marks, **ALLOW**: mass of CH_3COONa in 1 dm^3 = 0.350 × 82.0 = 28.7 g ✓ mass of CH_3COONa in 400 cm^3 = 28.7 × $\frac{400}{1000}$ = 11.48 g ✓ --- **COMMON ECF** 4.592 **OR** 4.6 g **AWARD** 4 marks *use of 400/1000 twice*

					ALLOW variants of Henderson–Hasselbalch equation. $pK_a = -\log(1.75 \times 10^{-5}) = 4.757$ ✓ *Calc: 4.75696…..* $\log \frac{[CH_3COO^-]}{[CH_3COOH]} = pH - pK_a = 5 - 4.757 = 0.243$ $\frac{[CH_3COO^-]}{[CH_3COOH]} = 10^{0.243} = 1.75$ ✓ $[CH_3COO^-] = 1.75 \times 0.200 = 0.350$ mol dm^{-3} ✓ n(**CH_3COONa/CH_3COO^-**) in 400 cm^3 $= 0.350 \times \frac{400}{1000} = 0.14(0)$ (mol) ✓ --- mass **CH_3COONa** = $0.140 \times 82.0 = 11.48$ **OR** 11.5 (g) ✓
			Total	**17**	

Question			Answer	Marks	Guidance
7	(a)		**Definition** The e.m.f. (of a half-cell) compared with/connected to a (standard**)** hydrogen half-cell/(standard**)** hydrogen electrode ✓ **Standard conditions** *Units essential* Temperature of 298 K / 25ºC **AND** (solution) concentrations of 1 mol dm^{-3} **AND** pressure of 100 kPa **OR** 10^5 Pa **OR** 1 bar ✓	**2**	As alternative for e.m.f., **ALLOW** voltage **OR** potential difference **OR** p.d. **OR** electrode potential **OR** reduction potential **OR** redox potential **ALLOW** /(standard) hydrogen cell **IGNORE** S.H.E. (as abbreviation for standard hydrogen electrode) **ALLOW** 1M **DO NOT ALLOW** 1 mol **ALLOW** 1 atmosphere/1 atm **OR** 101 kPa **OR** 101325 Pa
7	(b)	(i)	$2Ag^+(aq) + Cu(s) \rightarrow 2Ag(s) + Cu^{2+}(aq)$ ✓	**1**	State symbols **not** required **ALLOW** ⇌ provided that reactants on LHS
7	(b)	(ii)	**Assume Cu^{2+}|Cu OR Cu half cell unless otherwise stated.** $[Cu^{2+}]$ decreases **OR** < 1 mol dm^{-3} **AND** Equilibrium (shown in table) shifts to left ✓ more electrons are released by Cu ✓ The cell has a bigger **difference** in *E* ✓	**3**	***FULL ANNOTATIONS MUST BE USED*** --- **ALLOW** $[Cu^{2+}]$ less than standard concentration/1 mol dm^{-3} **DO NOT ALLOW** water reacts with Cu^{2+} **OR** Cu **ALLOW** *E* (for Cu^{2+}|Cu) is less positive / more negative /decreases **IGNORE standard** electrode potential (*Cell no longer standard*) **IGNORE** $E^{\ominus}$ decreases **CARE** **DO NOT ALLOW** statements about silver *E* changing (**CON**) **IGNORE** just 'cell potential increases' (in the question) *The final mark is more subtle and is a consequence of the less positive E value of the copper half cell*

7	**(c)**	**(i)**	no/less CO_2 **OR** H_2O is **only** product **OR** greater efficiency ✓	**1**	**IGNORE** less pollution **IGNORE** less carbon emissions **IGNORE** less fossil fuels used **IGNORE** no/less greenhouse gas **OR** no global warming (*H_2O vapour is a greenhouse gas)*
7	**(c)**	**(ii)**	liquefied/as a liquid **AND** under pressure/pressurised ✓	**1**	**IGNORE** adsorption or absorption **IGNORE** low temperature **DO NOT ALLOW** liquidise *processes are described in the question*
7	**(d)**	**(i)**	E = –2.31 (V) ✓	**1**	– sign **AND** 2.31 **required** for the mark
7	**(d)**	**(ii)**	$4Al(s) + 4OH^-(aq) + 3O_2(g) + 6H_2O(l) \rightarrow 4Al(OH)_4^-(aq)$ species ✓ balance ✓	**2**	**IGNORE** state symbols **ALLOW** multiples **ALLOW** 1 mark for an equation in which OH^- are balanced but have not been cancelled, e.g. $4Al(s) + 16OH^-(aq) + 3O_2(g) + 6H_2O(l) \rightarrow 4Al(OH)_4^-(aq) + 12OH^-(aq)$ **ALLOW** 1 mark if charge on $Al(OH)_4$ is omitted, i.e $4Al(s) + 4OH^-(aq) + 3O_2(g) + 6H_2O(l) \rightarrow 4Al(OH)_4(aq)$ **ALLOW** 1 mark for an 'correct equation' reversed, i.e. $4Al(OH)_4^-(aq) \rightarrow 4Al(s) + 4OH^-(aq) + 3O_2(g) + 6H_2O(l)$
			Total	**11**	

Question			Answer	Marks	Guidance
8	(a)		$Fe_2O_3 + 3Cl_2 + 10OH^- \rightarrow 2FeO_4^{2-} + 6Cl^- + 5H_2O$ ✓✓ First mark for all 6 species Second mark for balancing	2	**ALLOW** multiples **ALLOW** oxidation half equation for two marks $Fe_2O_3 + 10OH^- \rightarrow 2FeO_4^{2-} + 5H_2O + 6e^-$ Correct species would obtain 1 mark *– question: equation for oxidation* **ALLOW variants forming H^+ for 1 mark, e.g:** $Fe_2O_3 + 3Cl_2 + 5OH^- \rightarrow 2FeO_4^{2-} + 6Cl^- + 5H^+$ $Fe_2O_3 + 3Cl_2 + 5OH^- \rightarrow 2FeO_4^{2-} + 5HCl + Cl^-$
8	(b)		$Ba^{2+}(aq) + FeO_4^{2-}(aq) \rightarrow BaFeO_4(s)$ ✓	1	Balanced **ionic** equation **AND** state symbols required **DO NOT ALLOW** +2 or –2 for ionic charges
8	(c)		**Reason can ONLY be correct from correct reducing agent** **----------** ***reducing agent***: I^- **OR** KI ✓ I^- adds/donates/loses electrons **AND** to FeO_4^{2-} **OR** to $BaFeO_4$ **OR** to Fe(VI) or to Fe(+6) ✓ ***ALLOW** Fe(6+) **OR** Fe^{6+}*	2	**IGNORE** H^+ **OR** acidified **ALLOW** iodide/potassium iodide but **DO NOT ALLOW** iodine **ALLOW** I^- loses electrons **AND** to form I_2 **ALLOW** Fe(6+) **OR** Fe^{6+}

8	**(d)**		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 51.8%, award **4 marks.** --- $n(S_2O_3^{2-})$ used = $0.1000 \times \frac{26.4}{1000} = 2.64 \times 10^{-3}$ (mol) ✓ $n(FeO_4^{2-}) = ½ \times 2/3 \times 2.64 \times 10^{-3} = 8.8(0) \times 10^{-4}$ (mol) ✓ Mass $BaFeO_4$ in sample $= 8.8 \times 10^{-4} \times 257.1$ g = 0.226248 g ✓ % purity = $\frac{0.226248}{0.437} \times 100$ = 51.8% ✓ **MUST** be to **one** decimal place (in the question) --- As an alternative for the final two marks, **ALLOW**: Theoretical amount of $BaFeO_4$ = $\frac{0.437}{257.1}$ = 0.00170 (mol) ✓ % purity = $\frac{8.8 \times 10^{-4}}{1.70 \times 10^{-3}} \times 100$ = 51.8% ✓	**4**	***FULL ANNOTATIONS MUST BE USED*** **----------** For alternative answers, look first at common **ECFs** below. Then check for **ECF** credit possible using working below **IF** a step is omitted but subsequent step subsumes previous, then award mark for any missed step --- **Working must be to at least 3 SF throughout until final % mark** **BUT** ignore trailing zeroes, ie for 0.880 allow 0.88 **ECF** answer above × ½ × 2/3 This mark may be seen in 2 steps via I_2 but the mark is for both steps combined **ECF** 257.1 × answer above **ECF** $\frac{\text{answer above}}{0.437} \times 100$ **ALLOW** 51.7% FROM 0.226 g $BaFeO_4$ (earlier rounding) --- **Common ECFs:** No × 2/3 for $n(FeO_4^{2-})$: % purity = 77.7%/77.6% 3 marks No ÷ 2 for $n(FeO_4^{2-})$: % purity = 25.9% 3 marks 24.6 used instead of 26.4: % purity = 48.2% 3 marks

8	**(e)**		**gas**: O_2 ✓ **precipitate**: $Fe(OH)_3$ ✓ **equation**: $2FeO_4^{2-} + 5H_2O \rightarrow 1½O_2 + 2Fe(OH)_3 + 4OH^-$ **OR** $2FeO_4^{2-} + H_2O + 4H^+ \rightarrow 1½O_2 + 2Fe(OH)_3$ ✓	**3**	**DO NOT ALLOW** names **IGNORE** a balancing number shown before a formula **ALLOW** $Fe(OH)_3(H_2O)_3$ **ALLOW** multiples **ALLOW** $2FeO_4^{2-} + 11H_2O \rightarrow 1½O_2 + 2Fe(OH)_3(H_2O)_3 + 4OH^-$
			Total	**12**	

OCR
Oxford Cambridge and RSA

GCE

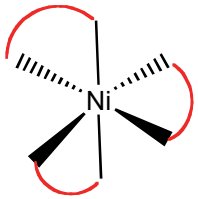
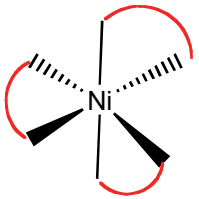
Chemistry A

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

Advanced GCE

Mark Scheme for June 2015

Question			Answer	Marks	Guidance
1	(a)		(+)5 ✓	1	**ALLOW** 5+ **OR** V **OR** Cr^{5+}
1	(b)		For equations, **IGNORE** any state symbols; **ALLOW** multiples --- Any correct equation for a reaction catalysed by a transition element, compound or ion **AND** transition element, compound or ion (by formula or name) ✓	1	**EXAMPLES** $N_2 + 3H_2 \rightleftharpoons 2NH_3$ (allow →) **AND** Fe/iron oxide $2SO_2 + O_2 \rightleftharpoons 2SO_3$ (allow →) **AND** V_2O_5/Pt $2CO + 2NO \rightarrow 2CO_2 + N_2$ **AND** Pt/Pd/Rh/Au Equation for any alkene + H_2 → alkane **AND** Ni/Pt/Pd $C_6H_6 + Cl_2 \rightarrow C_6H_5Cl + HCl$ **AND** Fe/$FeCl_3$/Fe^{3+} $C_6H_6 + Br_2 \rightarrow C_6H_5Br + HBr$ **AND** Fe/$FeBr_3$/Fe^{3+} $2H_2O_2 \rightarrow 2H_2O + O_2$ **AND** MnO_2 For other examples, **CHECK** with TL
1	(c)	(i)	**Donates two** electron **pairs** (to a metal ion) **AND** forms **two** coordinate **bonds** (to a metal ion) ✓ ***NOTE:*** *Metal ion not required as* Ni^{3+} *is in the question*	1	**ALLOW** lone pairs for electron pairs **ALLOW** dative (covalent) bonds for coordinate bonds **TWO** is only needed once, e.g. **Donates two** electron **pairs** to form coordinate **bonds** **Donates** electron **pairs** to form **two** coordinate **bonds**
1	(c)	(ii)	$C_3H_{10}N_2$ ✓	1	**ALLOW** in any order **IGNORE** structure
1	(c)	(iii)	**MARK INDEPENDENTLY** --- $H_2NCH_2CH_2CH_2NH_2$ ✓ Each N **OR** each NH_2 **OR** amine group has a lone pair/electron pair **OR** lone pairs shown on N atoms in structure ✓	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **ALLOW** $H_2NCH_2CH(CH_3)NH_2$ **OR** $H_2NCH(CH_2CH_3)NH_2$ **ALLOW** secondary or tertiary diamines or mixture **IGNORE** complex ion For other examples, **CHECK** with TL

Question			Answer	Marks	Guidance
1	(c)	(iv)	6 ✓	1	
1	(c)	(v)	3–D diagrams of **BOTH** optical isomers required for the mark  **AND**  ✓	1	In this part, Charge **AND** Square brackets **NOT** required **IGNORE** N or attempts to draw structure of bidentate ligand Other orientations possible but all follow same principle with 2nd structure being a mirror image of the first

Question			Answer	Marks	Guidance
1	(d)		*Quality of written communication* Observation must be linked to the correct **reaction** ***REACTIONS OF AQUEOUS Cu^{2+}*** --- **REACTION OF Cu^{2+} with NaOH(aq)** **Correct balanced equation** $Cu^{2+}(aq) + 2OH^-(aq) \longrightarrow Cu(OH)_2(s)$ ✓ state symbols **not** required **Observation** blue precipitate/solid ✓	**2**	***FULL ANNOTATIONS MUST BE USED THROUGHOUT*** **ALLOW some reactions for Cu^{2+} and some for Co^{2+}** **ALLOW equilibrium signs in all equations** **IGNORE any incorrect initial colours** **IGNORE state symbols** **IGNORE an incorrect formula for an observation** --- **ALLOW** $[Cu(H_2O)_6]^{2+} + 2OH^- \rightarrow Cu(OH)_2(H_2O)_4 + 2H_2O$ **ALLOW** full or 'hybrid' equations, e.g. $Cu^{2+} + 2NaOH \rightarrow Cu(OH)_2 + 2Na^+$ $[Cu(H_2O)_6]^{2+} + 2OH^- \rightarrow Cu(OH)_2 + 6H_2O$ $_4 + 2NaOH \rightarrow Cu(OH)_2 + Na_2SO_4$ **ALLOW** any shade of blue CuSO
1	(d)		**REACTION OF Cu^{2+} WITH excess NH_3(aq)** **Correct balanced equation** $[Cu(H_2O)_6]^{2+} + 4NH_3 \longrightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4H_2O$ ✓ **Observation** deep/dark blue (solution) ✓	**2**	**IGNORE initial precipitation of $Cu(OH)_2$** **IGNORE** $[Cu(NH_3)_4]^{2+}$ **ALLOW** royal blue, ultramarine blue or any blue colour that is clearly darker than for $[Cu(H_2O)_6]^{2+}$ **DO NOT ALLOW** deep blue precipitate for observation
1	(d)		**REACTION OF Cu^{2+} WITH HCl(aq)** **Correct balanced equation** $[Cu(H_2O)_6]^{2+} + 4Cl^- \longrightarrow [CuCl_4]^{2-} + 6H_2O$ ✓ **Observation** yellow (solution) ✓	**2**	**IGNORE** mention of different concentrations of HCl **ALLOW** $CuCl_4^{2-}$ i.e. no brackets **OR** $Cu(Cl)_4^{2-}$ **ALLOW** $[Cu(H_2O)_6]^{2+} + 4HCl \longrightarrow [CuCl_4]^{2-} + 6H_2O + 4H^+$ **IGNORE** $Cu^{2+} + 4Cl^- \longrightarrow CuCl_4^{2-}$ **ALLOW** green–yellow **OR** yellow–green **DO NOT ALLOW** yellow precipitate for observation

Question			Answer	Marks	Guidance
1	(d)		*Quality of written communication* Observation must be linked to the correct **reaction** ***REACTIONS OF AQUEOUS Co^{2+}*** --- **REACTION OF Co^{2+} with NaOH(aq)** **Correct balanced equation** $Co^{2+}(aq) + 2OH^-(aq) \longrightarrow Co(OH)_2(s)$ ✓ state symbols **not** required **Observation** blue precipitate/solid ✓	2	***FULL ANNOTATIONS MUST BE USED THROUGHOUT*** **ALLOW some reactions for Cu^{2+} and some for Co^{2+}** **ALLOW equilibrium signs in all equations** **IGNORE any incorrect initial colours** **IGNORE state symbols** **IGNORE an incorrect formula for an observation** --- **ALLOW** $[Co(H_2O)_6]^{2+} + 2OH^- \rightarrow Co(OH)_2(H_2O)_4 + 2H_2O$ **ALLOW** full or 'hybrid' equations, e.g. $Co^{2+} + 2NaOH \rightarrow Co(OH)_2 + 2Na^+$ $[Co(H_2O)_6]^{2+} + 2OH^- \rightarrow Co(OH)_2 + 6H_2O$ $_4 + 2NaOH \rightarrow Co(OH)_2 + Na_2SO_4$ **ALLOW** any shade of blue CoSO **IGNORE** changes in colour over time
1	(d)		**REACTION OF Co^{2+} WITH excess $NH_3(aq)$** **Correct balanced equation** $[Co(H_2O)_6]^{2+} + 6NH_3 \longrightarrow [Co(NH_3)_6]^{2+} + 6H_2O$ ✓ **Observation** brown/yellow (solution) ✓	2	**IGNORE initial precipitation of $Co(OH)_2$** **ALLOW** any shade of brown or yellow **DO NOT ALLOW** brown/yellow precipitate for observation
1	(d)		**REACTION OF Co^{2+} WITH HCl(aq)** **Correct balanced equation** $[Co(H_2O)_6]^{2+} + 4Cl^- \longrightarrow [CoCl_4]^{2-} + 6H_2O$ ✓ **Observation** blue (solution) ✓	2	**IGNORE** mention of different concentrations of HCl **ALLOW** $CoCl_4^{2-}$ i.e. no brackets **OR** $Co(Cl)_4^{2-}$ **ALLOW** $[Co(H_2O)_6]^{2+} + 4HCl \longrightarrow [CoCl_4]^{2-} + 6H_2O + 4H^+$ **IGNORE** $Co^{2+} + 4Cl^- \longrightarrow CoCl_4^{2-}$ **ALLOW** any shades of blue **DO NOT ALLOW** blue precipitate for observation
			Total	14	

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>2</td><td>(a)</td><td></td><td>
NOTE: First 3 marks are ONLY available from an expression using [NO]^2
Units are marked independently

Using values ON THE CURVE in CORRECT expression 1 mark
Use of any two correct values for rate and [NO] from graph
e.g. for 5.0×10^{-4} and 4.2×10^{-4},
$k = \dfrac{4.2 \times 10^{-4}}{(2.0 \times 10^{-2}) \times (5.0 \times 10^{-4})^2}$

OR $4.2 \times 10^{-4} = k\,(2.0 \times 10^{-2}) \times (5.0 \times 10^{-4})^2$ ✓

Calculation of k 2 marks

FOR 1 MARK
k calculated correctly from values obtained from graph
BUT NOT in standard form AND/OR more than 2 SF
e.g. $k = \dfrac{6.0 \times 10^{-4}}{(2.0 \times 10^{-2}) \times (6.0 \times 10^{-4})^2} = 83333.33$ ✓

OR FOR 2 MARKS
k calculated correctly from values obtained from graph
AND in standard form AND TO 2 SF
e.g. k = 83333.33 gives 8.3×10^4 ✓

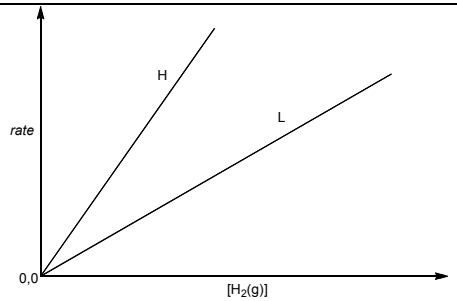
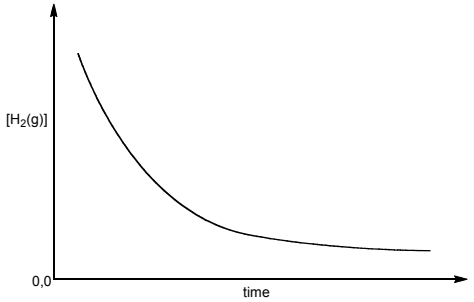
UNITS FOR 1 MARK:
$dm^6\ mol^{-2}\ s^{-1}$ ✓
</td><td>4</td><td>
Note: rate and [NO] are any correct pair of readings from the graph,
The [NO] below are the most commonly seen.
For these [NO] values, these are the ONLY rates allowed

<table>
<tr><th>[NO]</th><th>rate</th><th>k</th><th>k</th></tr>
<tr><td>1.0×10^{-4}</td><td>0.1×10^{-4} to 0.2×10^{-4}</td><td>50000
100000</td><td>5.0×10^4
1.0×10^5</td></tr>
<tr><td>2.0×10^{-4}</td><td>0.6×10^{-4} to 0.7×10^{-4}</td><td>75000
87500</td><td>7.5×10^4
8.8×10^4</td></tr>
<tr><td>3.0×10^{-4}</td><td>1.5×10^{-4}</td><td>83333</td><td>8.3×10^4</td></tr>
<tr><td>4.0×10^{-4}</td><td>2.7×10^{-4}</td><td>84375</td><td>8.4×10^4</td></tr>
<tr><td>5.0×10^{-4}</td><td>4.2×10^{-4}</td><td>84000</td><td>8.4×10^4</td></tr>
<tr><td>6.0×10^{-4}</td><td>6.0×10^{-4}</td><td>83333</td><td>8.3×10^4</td></tr>
<tr><td>7.0×10^{-4}</td><td>8.2×10^{-4}</td><td>83673</td><td>8.4×10^4</td></tr>
</table>
IF OTHER values are given, mark using the same principle. If any doubt, contact TL.

NOTE: IGNORE any numbers used from tangents

SPECIAL CASES that ALLOW ECF for calculation of k from ONLY ONE of the following (2 marks)
1. Powers of 10 incorrect or absent in initial k expression
2. $[H_2]^2[NO]$ used instead of $[H_2][NO]^2$
3. Any value within ±0.2 of actual values from graph

ALLOW units in any order, e.g. $mol^{-2}\ dm^6\ s^{-1}$
</td></tr>
</table>

Question			Answer	Marks	Guidance
2	(b)	(i)	 One straight upward line **AND** starting at 0,0 ✓ 2nd straight upward line starting at 0,0 and steeper **AND** Steeper line labelled H **OR** less steep line labelled L ✓	2	**ALLOW** 1 mark for two upward sloping curves starting at origin **AND** upper curve labelled H and lower curve labelled L **NOTE: ALLOW** some leeway for lines starting from origin **ALLOW** straight line not drawn with ruler, i.e. is a straight line rather than a curve **ALLOW** similar labelling as long as it is clear which line is which
2	(b)	(ii)	increases ✓	1	
2	(c)		**MARK INDEPENDENTLY** **----------**  Downward curve ✓ Half life is constant ✓	2	**ALLOW** curve touching y axis **ALLOW** curve touching x axis **ALLOW** Two half lives are the same **IGNORE** 'regular' half life (not necessarily the same)

Question			Answer	Marks	Guidance
2	(d)	(i)	$H_2 + N_2O \rightarrow N_2 + H_2O$ ✓	1	**ONLY** correct answer **DO NOT ALLOW** multiples
2	(d)	(ii)	Steps 1 **AND** Step 2 together give $2NO + H_2$ ✓	1	**ALLOW** Step 1 **AND** Step 2 together give species in same ratio as in rate equation **ALLOW** rate-determining step/slow step for Step 2 **ALLOW** H_2 reacts with N_2O_2 which is formed from 2NO **NOTE**: The response must link Step 1 with Step 2 Steps can be referenced from the species in each step
			Total	11	

Question			Answer	Marks	Guidance
3	(a)	(i)	5 mol/molecules (of gas) forms 3 mol/molecules (of gas) ✓	1	**ALLOW** reaction forms fewer moles/molecules **IF** stated, numbers of molecules **MUST** be correct **IGNORE** comments related to ΔG **OR** disorder (even if wrong)
3	(a)	(ii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer =(+)131 (J K^{-1} mol^{-1}) , award 2 marks** **----------** $-164 = (186 + 2 \times 206) - (4 \times S + 238)$ **OR** $4S = 164 + (186 + 2 \times 206) - 238$ ✓ S = (+)131 (J K^{-1} mol^{-1}) ✓	2	**NOTE:** IF any values are omitted, **DO NOT AWARD** any marks. e.g. –164 may be missing **ALLOW FOR 1 mark** –131 wrong final sign 49 wrong sign for 164 79.5 no use of 2 524 no division by 4 38 wrong sign for 186 –75 wrong sign for 206 250 wrong sign for 238 Any other number: **CHECK** for **ECF** from 1st marking point for expressions using **ALL** values with **ONE** error only e.g. one transcription error:, e.g.146 for 164

Question			Answer	Marks	Guidance
3	(a)	(iii)	**NOTE: DO NOT ALLOW answer to 3(a)(ii) for ΔG calculation** --- **ΔG calculation: 2 marks** $\Delta G = -234 - 298 \times -0.164$ ✓ $= -185$ (kJ mol^{-1}) ✓ **IGNORE** units (even if wrong) –185 subsumes 1st mark) **Feasibility comment for negative ΔG answer: 1 mark** (Forward) reaction is feasible / spontaneous **AND** $\Delta G < 0$ / $\Delta H - T\Delta S < 0$ ✓	**2** **1**	**ALLOW** ΔG correctly calculated from 3 SF up to calculator value of –185.128 **ALLOW** working in J, *ie*: $\Delta G = -234000 - 298 \times -164$ ✓ $= -185000$ (J mol^{-1}) ✓ **ALLOW** 1 mark for use of 25 **OR** mixture of kJ and J, e.g. $\Delta G = -234 - 25 \times -0.164 = -229.9$ $\Delta G = -234 - 298 \times -164 = +48638$ **ALLOW ECF** if calculated value for ΔG is +ve Then 'correct' response for 3rd mark would be **not** feasible/not spontaneous **AND** $\Delta G > 0$ / $\Delta H - T\Delta S > 0$
3	(a)	(iv)	**(**ΔG =) $-234 - 1427 \times \frac{-164}{1000} = 0$ (calculator 0.028(kJ) OR 28 (J)) ✓ **2nd mark only available if 1st mark has been awarded** (Above 1427K/1154ºC), reaction is **not** feasible/**not** spontaneous✓ **OR** 1427 K is maximum temperature that reaction happens	**2**	**ALLOW** (When $\Delta G = 0$) $T = \frac{-234}{-0.164} = 1427$ K **OR** $\frac{-234000}{-164} = 1427$ K For 2nd mark, **IF** ΔG is +ve from **(a)(iii)** **ALLOW ECF** for: Above 1427 K, reaction is feasible / spontaneous **OR** 1427 K is minimum temperature that reaction happens **IGNORE LESS feasible** **IGNORE** comparisons of the signs of $T\Delta S$ and ΔH, *e.g IGNORE $T\Delta S$ is more negative than ΔH*

Question			Answer	Marks	Guidance
3	(b)	(i)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 57.6 dm^3 mol^{-1}, award **6 marks** **IF** answer = 57.6 with incorrect units, award **5 mark** --- **Equilibrium amounts in mol 2 MARKS** $n(SO_2)$ = 0.180 (mol) **ALL 3** correct: ✓✓ $n(O_2)$ = 0.090 (mol) **ANY 2** correct: ✓ $n(SO_3)$ = 0.820 (mol) **Equilibrium concentrations (moles × 4) 1 MARK** SO_2 = 0.720 (mol dm^{-3}) **AND** O_2 = 0.360 (mol dm^{-3}) **AND** SO_3 = 3.28 (mol dm^{-3}) ✓ **Calculation of K_c and units 3 MARKS** $K_c = \frac{[SO_3]^2}{[SO_2]^2\,[O_2]}$ **OR** $\frac{3.28^2}{(0.720)^2 \times (0.360)}$ ✓ = 57.6 ✓ dm^3 mol^{-1} ✓ *At least 3SF is required*	**6**	**FULL ANNOTATIONS NEEDED** **IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below --- **ALLOW ECF** from incorrect moles of SO_2, O_2 **AND** SO_2 **ALL three** concentrations required for this mark **ALLOW ECF** from incorrect concentrations **NO ECF** for numerical value with a square missing For K_c, **ALLOW** 3 significant figures up to calculator value of 57.64746228 correctly rounded For units, **ALLOW** mol^{-1} dm^3 **DO NOT ALLOW** dm^3/mol **ALLOW ECF** from incorrect K_c expression for both calculation and units **COMMON ERRORS** 0.0294 ***3 marks + units mark*** from SO_2 = 0.820, O_2 = 0.410, SO_3 = 0.180 (mol)
3	(b)	(ii)	(Pressure) decreases **AND** fewer molecules/moles ✓	**1**	For fewer moles, **ALLOW** 3 mol → 2 mol **ALLOW** more moles **of reactants**

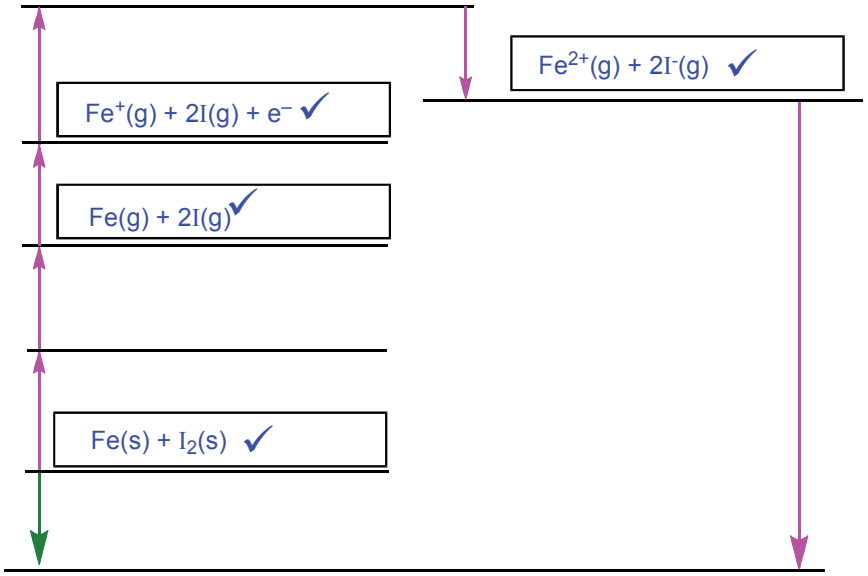
Question			Answer	Marks	Guidance
3	(b)	(iii)	ΔH is negative / '– ' / –ve **AND** yield of SO_3 decreases ✓	1	**IGNORE** exothermic and endothermic
3	(b)	(iv)	**IGNORE** le Chatelier responses **----------** ***Each marking point is independent*** ***K_c*** K_c does not change (with pressure/ concentration) ✓ ***Comparison of conc terms with more O_2*** $[O_2]$/concentration of oxygen is greater **OR** denominator/bottom of K_c expression is greater ✓ ***QWC: yield of SO_3 linked to K_c*** (Yield of) SO_3 is greater/increases **AND** numerator/top of K_c expression is greater/increases ✓	3	**FULL ANNOTATIONS NEEDED** **ALLOW** K_c **only** changes with temperature **IF** 1st marking point has been awarded, **IGNORE** comments about 'K_c decreasing' or 'K_c increasing' and assume that this refers to how the ratio subsequently changes. i.e **DO NOT CON** 1st marking point. **IGNORE** O_2 is greater/increases **ALLOW** **(Yield of) SO_3 is greater/increases** **AND** to reach/restore K_c value ✓
			Total	**19**	

Question			Answer	Marks	Guidance
4	(a)		Proton/H^+ donor **AND** Partially dissociates/ionises ✓	1	
4	(b)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 13.7(0), award **2 marks** --- $[H^+] = \frac{1.00 \times 10^{-14}}{0.5(00)}$ **OR** $2(.00) \times 10^{-14}$ (mol dm^{-3}) ✓ pH = $-\log 2(.00) \times 10^{-14}$ = **13.7(0)** ✓	2	For pOH method:, **ALLOW** pOH = $-\log[OH^-]$ = 0.3(0) ✓ (calculator 0.301029995) **ALLOW** pH = 14 – 0.3 = 13.7 ✓ **ALLOW** 13.7 up to calculator value of 13.69897 correctly rounded. **ALLOW ECF** from incorrect $[H^+(aq)]$ provided that pH >7
4	(c)	(i)	(K_a =) $\frac{[H^+]\,[C_2H_5COO^-]}{[C_2H_5COOH]}$ ✓	1	**IGNORE** $\frac{[H^+]^2}{[C_2H_5COOH]}$ **OR** $\frac{[H^+]\,[A^-]}{[HA]}$ **ALLOW** $[H_3O^+]$ for $[H^+]$ **IGNORE** state symbols

Question			Answer	Marks	Guidance
4	(c)	(ii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = **2.9(0)**, award **3 marks** --- [C_2H_5COOH] = 0.12(0) mol dm^{-3} ✓ $[H^+] = \sqrt{K_a \times [C_2H_5COOH]} = \sqrt{1.35\times10^{-5}\times0.12(0)}$ **OR** 1.27×10^{-3} (mol dm^{-3}) ✓ pH = –log 1.27×10^{-3} = **2.9(0)** ✓ **NOTE**: The final two marks are **ONLY** available from attempted use of K_a **AND** [C_2H_5COOH]	**3**	**ALLOW** HA for C_2H_5COOH and A^- for $C_2H_5COO^-$ **ALLOW ECF** from incorrectly calculated [C_2H_5COOH] **ALLOW** 1.27×10^{-3} to calculator value of $1.272792206 \times 10^{-3}$ correctly rounded **ALLOW** $2.9(0) \times 10^{-3}$ to calculator value of 2.895242493 correctly rounded **ALLOW** use of quadratic equation which gives same answer of 2.90 from 0.120 mol dm^{-3} --- **COMMON ERRORS (MUST be to AT LEAST 2 DP unless 2nd decimal place is 0)** **pH = 2.59 2 marks** –log√ (1.35 x $10^{-5} \times 0.480$) *Original conc* **pH = 5.79 2 marks** –log(1.35 x $10^{-5} \times 0.120$) *No √* **pH = 5.19 1 mark** –log (1.35 x $10^{-5} \times 0.480$) *Original conc, no √* **pH = 4.87 0 marks** –log(1.35 x 10^{-5}) = 4.87 *–log K_a*

Question			Answer	Marks	Guidance
4	(d)	(i)	$2C_2H_5COOH + Na_2CO_3 \rightarrow 2C_2H_5COONa + CO_2 + H_2O$ ✓	1	**IGNORE** state symbols and use of equilibrium sign **FOR** $CO_2 + H_2O$ **ALLOW** H_2CO_3 **ALLOW** $C_2H_5COO^-Na^+$ **OR** $C_2H_5COO^- + Na^+$ **BUT BOTH** + and – charges **must** be shown **ALLOW** NaC_2H_5COO
4	(d)	(ii)	$H^+ + OH^- \rightarrow H_2O$ ✓	1	**ALLOW** $C_2H_5COOH + OH^- \rightarrow C_2H_5COO^- + H_2O$ **IGNORE** state symbols
4	(e)	(i)	pH = –log 1.35×10^{-5} = **4.87** ✓	1	**ONLY** correct answer **DO NOT ALLOW** 4.9 (*Question asks for 2 DP)*
4	(e)	(ii)	**Added ammonia** C_2H_5COOH removes added NH_3/alkali/base **OR** $C_2H_5COOH + NH_3 / OH^- \rightarrow$ **OR** NH_3/alkali reacts with/accepts H^+ **OR** $H^+ + NH_3 \rightarrow$ **OR** $H^+ + OH^- \rightarrow$ ✓ Equlibrium → $C_2H_5COO^-$ **OR** Equilibrium → right ✓	 2	**ALLOW** use of HA/weak acid/acid for C_2H_5COOH; **ALLOW** use of NH_4OH for NH_3 **ALLOW** A^- for $C_2H_5COO^-$ **ASSUME** that equilibrium applies to that supplied in the question, i.e. **IGNORE** any other equilibria

Question			Answer	Marks	Guidance
4	(e)	(iii)	***CHECK WORKING CAREFULLY AS CORRECT NUMERICAL ANSWER IS POSSIBLE FROM WRONG VALUES*** ========== **ALLOW** HA and A^- throughout **Amount of Mg (1 mark)** $n(Mg) = \frac{6.075}{24.3} = 0.25(0)$ mol ✓ --- **Moles/concentrations(2 marks)** $n(C_2H_5COOH) = 1.00 - (2 \times 0.25) = 0.50$ (mol) ✓ $(C_2H_5COO^-) = 1.00 + (2 \times 0.25) = 1.50$ (mol) ✓ ~~n~~--- **$[H^+]$ and pH (1 mark)** $[H^+] = 1.35 \times 10^{-5} \times \frac{0.50}{1.50}$ **OR** 4.5×10^{-6} (mol dm^{-3}) pH = –log 4.5×10^{-6} = **5.35 2 dp required** ✓ **NOTE: IF there is no prior working,** **ALLOW 4 MARKS for** $[H^+] = 1.35 \times 10^{-5} \times \frac{0.50}{1.50}$ **AND** pH = **5.35** **IF the ONLY response is pH = 5.35, award 1 mark ONLY**	**4**	***FULL ANNOTATIONS MUST BE USED*** --- **For *n*(Mg), 1 mark** **ALLOW ECF f**or **ALL** marks below from incorrect *n*(Mg) **ECF ONLY** available from concentrations that have • subtracted 0.50 **OR** 0.25 from 1 for $[C_2H_5COOH]$ • added 0.50 **OR** 0.25 to 1 for $[C_2H_5COO^-]$ ***i.e.*** **For moles/concentration 1 mark (1 mark lost)** **1.** *n* $(C_2H_5COOH) = 0.75$ **AND** $n(C_2H_5COO^-) = 1.25$ ***2.*** $n(C_2H_5COOH) = 0.50$ **AND** $n(C_2H_5COO^-) = 1.25$ ***3.*** $n(C_2H_5COOH) = 0.75$ **AND** $n(C_2H_5COO^-) = 1.50$ --- **ALLOW ECF ONLY** for the following giving 1 additional mark and a total of **3 marks** **1.** $[H^+] = 1.35 \times 10^{-5} \times \frac{0.75}{1.25}$ pH = –log 8.1×10^{-6} = **5.09** **2.** $[H^+] = 1.35 \times 10^{-5} \times \frac{0.50}{1.25}$ pH = –log 5.4×10^{-6} = **5.27** **3.** $[H^+] = 1.35 \times 10^{-5} \times \frac{0.75}{1.50}$ pH = –log 6.75×10^{-6} = **5.17**
			Award a maximum of 1 mark (for *n*(Mg) = 0.25 mol) for: pH value from K_a square root approach (weak acid pH) pH value from $K_w / 10^{-14}$ approach (strong base pH) --- **ALLOW** alternative approach based on Henderson–Hasselbalch equation for final 1 mark $pH = pK_a + \log \frac{1.5}{0.5}$ **OR** $pK_a - \log \frac{0.5}{1.5}$ pH = 4.87 + 0.48 = 5.35 ✓ **ALLOW** $-\log K_a$ for pK_a		
			Total	**16**	

Question			Answer	Marks	Guidance
5	(a)	(i)	 **Mark each marking point independently**	4	Correct species **AND** state symbols required for each marks **ALLOW** e for e^{-} **TAKE CARE**: In top left box, e^{-} may be in centre of response and more difficult to see than at end. There is only **ONE** correct response for each line *From the gaps in the cycle, there is **NO** possibility of any **ECF***

Question			Answer	Marks	Guidance
5	(a)	(ii)	(The enthalpy change that accompanies) the **formation** of **one mole** of a(n ionic) compound from its **gaseous ions** (under standard conditions) ✓✓ Award marks as follows. **1st mark: formation** of **compound** from **gaseous ions** **2nd mark: one mole** for compound **only** **DO NOT ALLOW** 2nd mark without 1st mark **DO NOT ALLOW** any marks for a definition for enthalpy change of **formation BUT** note the two concessions in guidance	**2**	**IGNORE** 'Energy needed' **OR** 'energy required' **ALLOW one mole** of compound is **formed/made** from its **gaseous ions** **ALLOW** as alternative for compound: lattice, crystal, substance, solid **IGNORE**: $Fe^{2+}(g) + 2I^{-}(g) \longrightarrow FeI_2(s)$ (Part of cycle) **ALLOW** 1 mark for absence of 'gaseous' only, i.e. the **formation** of **one mole** of a(n ionic) compound from its **ions** (under standard conditions) ✓ **ALLOW** 1 mark for ΔH_f definition with 'gaseous': the **formation** of **one mole** of a(n ionic) compound from its **gaseous** elements (under standard conditions) ✓

Question			Answer	Marks	Guidance
5	(a)	(iii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = –2473 (kJ mol^{-1}) award 2 marks** --- (–113) = 416 + (2 × +107) + 759 + 1561 + (2 × –295) + $\Delta H_{LE}(FeI_2)$ **OR** $\Delta H_{LE}(FeI_2)$ = –113 – (416 + (2 × +107) + 759 + 1561 + (2 × –295)) **OR** –113 – 2360 ✓ = – 2473 ✓ (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: +2473 wrong sign –2661 107 and –295 used instead of **2 ×** 107 and **2 ×** –295 –2366 +107 used instead of **2 ×** 107 –2768 –295 used instead of **2 ×** –295 –3653 wrong sign for 295 –2247 wrong sign for 113 –1641 wrong sign for 416 –2045 wrong sign for 2 **×** 107 –955 wrong sign for 750 +649 wrong sign for 1561 –3653 wrong sign for **2 ×** –295 Any other number: **CHECK** for **ECF** from 1st marking point for expressions with **ONE** error only e.g. one transcription error: e.g. +461 instead of +416
5	(b)	(i)	Fe^{2+}: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$ ✓ Br^-: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6$ ✓	**2**	**ALLOW** 4s before 3d, ie $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6$ **ALLOW** $1s^2$ written after answer prompt (*ie* $1s^2$ twice) **ALLOW** upper case D, etc and subscripts, e.g. ……$4S_2 3D_1$ **ALLOW** for Fe^{2+} **……..**$4s^0$ **DO NOT ALLOW** [Ar] as shorthand for $1s^2 2s^2 2p^6 3s^2 3p^6$ Look carefully at $1s^2 2s^2 2p^6 3s^2 3p^6$ – there may be a mistake

Question			Answer	Marks	Guidance
5	(b)	(ii)	With Cl_2 **AND** Br_2 **AND** I_2 products are Fe^{2+} (AND halide ion) $FeCl_2$ **AND** $FeBr_2$ **AND** FeI_2 ✓ **OR** Evidence that **two** electrode potentials have been compared for at least **ONE** reaction, ✓ e.g. Fe –0.44 **AND** Cl_2 +1.36 e.g. Iron has more/most negative electrode potential With Cl_2 **AND** Br_2, products are Fe^{3+} (AND halide ion) $FeCl_3$ **AND** $FeBr_3$ ✓	3	**FULL ANNOTATIONS NEEDED** **ALLOW** products within equations (even if equations are not balanced) **IF stated, IGNORE reactants** **ALLOW** response in terms of positive 'cell reactions', e.g $Fe + Cl_2 \rightarrow Fe^{2+} + 2Cl^-$ E = (+)1.80 V **IGNORE** comments about reducing and oxidising agents and electrons
5	(c)		**BOTH EQUATIONS REQUIRE IONS PROVIDED IN QUESTION** **OR** **Reaction 1: 2 marks** **1st mark** for **ALL CORRECT species** e.g.: $Fe^{2+} + NO_3^- + H^+ \rightarrow Fe^{3+} + NO + H_2O$ **2nd mark** for **CORRECT balanced equation** $3Fe^{2+} + NO_3^- + 4H^+ \rightarrow 3Fe^{3+} + NO + 2H_2O$ ✓✓ --- **Reaction 2: 1 mark** $_2O)_6]^{2+} + NO \rightarrow [Fe(H_2O)_5NO]^{2+} + H_2O$ ✓	3	**ALLOW** correct multiples throughout **ALLOW equilibrium signs in all equations** **For 1st mark, IGNORE** e^- present **Check** carefully for correct **charges**
			[Fe(H **Total**	16	

Question			Answer	Marks	
6	(a)		E^{o} / redox system Most negative: **E** **C** Least negative: **D** ✓	1	**ALL** 3 correct for 1 mark
6	(b)	(i)	pH = 0 ✓	1	**Guidance**
6	(b)	(ii)	H redox system is more negative (e.g. has a more –ve *E* **OR** less +ve *E* **OR** is –ve electrode) **OR** H redox system releases electrons (May be in equation, e.g. $H_2 \rightarrow 2H^+ + 2e^-$) ✓ Equilibrium **shifts** to increase $[H^+]$ **OR** H^+ **OR** standard hydrogen equation **shifts** to increase $[H^+]$ **OR** H^+ ✓	2	**ALLOW ORA**, *ie* Ag redox system (D) has more positive *E* / less negative *E* **ALLOW** equilibrium sign **IGNORE** H is more reactive **ORA** **IGNORE** direction of equilibrium shift
6	(b)	(iii)	$H_2 + 2Ag^+ \rightarrow 2Ag + 2H^+$ ✓	1	**ALLOW** multiples e.g. $\frac{1}{2}H_2 + Ag^+ \rightarrow Ag + H^+$ State symbols **NOT** required **ALLOW** equilibrium sign
6	(c)	(i)	CN^- H_2O ⇌ **HCN** OH^- **AND** Base 2 Acid 1 Acid 2 Base 1 ✓ CN	1	State symbols **NOT** required **ALLOW** CNH and HO^- (i.e. any order) **ALLOW** 1 **and** 2 labels the other way around. **ALLOW** 'just acid' and 'base' labels throughout if linked by lines so that it is clear what the acid-base pairs are.

Question			Answer	Marks	Guidance
6	(c)	(ii)	H^+ reacts with CN^- **OR** HCN forms **OR** equation: $H^+ + CN^- \rightarrow HCN$ (**ALLOW** $\rightleftharpoons$) **OR** CN^- accepts a proton/H^+ **OR** equilibrium shifts right **AND** CN^- is removed ✓	1	**ALLOW** Acid reacts with/removes OH^- ions (to form HCN) **ALLOW** CNH (i.e. any order) **IGNORE** other equilibrium comments
6	(d)	(i)	Fuel reacts with oxygen/oxidant to give **electrical** energy/voltage✓	1	**ALLOW** named fuel. e.g. hydrogen/H_2; ethanol; methanol, etc **ALLOW** fuel cell requires constant supply of fuel **AND** oxygen/an oxidant **OR** fuel cell operates continuously as long as a fuel **AND** oxygen/an oxidant are added **IGNORE** 'reactants' 'products' and comments about pollution and efficiency
6	(d)	(ii)	ethanol is a **liquid OR** is **less** volatile **OR** ethanol is easier to store/transport/stored more safely **OR** hydrogen is explosive/more flammable **OR** ethanol has more public/political acceptance ✓	1	Assume that '**it**' refers to ethanol **ALLOW** ORA throughout **IGNORE** ethanol has a higher boiling point **IGNORE** H_2 is a gas **IGNORE** 'produces no CO_2' **OR** less pollution **IGNORE** comments about efficiency **IGNORE** comments about biomass and renewable
6	(d)	(iii)	$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$ ✓	1	Correct species **AND** balancing needed **ALLOW** multiples **ALLOW** C_2H_6O for formula of ethanol **IGNORE** state symbols
6	(d)	(iv)	$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$ ✓	1	Correct species **AND** balancing needed **ALLOW** multiples, e.g. $3O_2 + 12H^+ + 12e^- \rightarrow 6H_2O$ $_2 + 2H^+ + 2e^- \rightarrow H_2O$ **ALLOW** e (*ie* no + sign) ~~½~~O_2 **ALLOW** $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$ **OR** $3O_2 + 6H_2O + 12e^- \rightarrow 12OH^-$ **IGNORE** state symbols

Question			Answer	Marks	Guidance
6	(d)	(v)	oxidation: C from –2 to +4 '+' sign **not** required ✓ reduction: O from 0 to –2 ✓	2	**ALLOW** 2– and 4+ **ALLOW** $C^{2-} \rightarrow C^{4+}$ **ALLOW** 0 and 2– **ALLOW** $O^{0} \rightarrow O^{2-}$ **ALLOW** 1 mark if correct oxidation numbers shown for **BOTH** C and O but wrong way around (*ie* C on reduction line and O on oxidation line) **IGNORE** O_2 reduced **IGNORE** any reference to electron transfer (*not in question*)
			Total	13	

Question			Answer	Marks	Guidance
7	(a)		**Equations can be in either order**		**ALLOW** multiples throughout **IGNORE** state symbols
			$Na_2O + H_2O \rightarrow 2NaOH$ ✓		**ALLOW** $Na_2O + H_2O \rightarrow 2Na^+ + 2OH^-$ **DO NOT ALLOW** equations with uncancelled species. e.g. $Na_2O + 2H_2O \rightarrow 2NaOH + H_2O$
			$NaFeO_2 + 2H_2O \rightarrow Fe(OH)_3 + NaOH$ ✓	**2**	**ALLOW** $2NaFeO_2 + H_2O \rightarrow Fe_2O_3 + 2NaOH$ **OR** $_2 + H_2O \rightarrow Fe_2O_3 + 2Na^+ + 2OH^-$ ✓ 2NaFeO

Question			Answer	Marks	Guidance
7	(b)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 33.7%, award **6 marks.** **IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below --- amount $S_2O_3^{2-}$ used = $0.1000 \times \frac{25.50}{1000}$ = **2.550×10^{-3}** (mol) ✓ amount I_2 = 2.550×10^{-3} **÷ 2** **1.275×10^{-3}** (mol) ✓ amount CrO_4^{2-} **2/3 ×** 1.275×10^{-3} **OR** 1.275×10^{-3} **÷ 1.5** = **$8.5(00) \times 10^{-4}$** (mol) ✓ amount CrO_4^{2-} in original 1000 cm^3 = **40 ×** $8.5(00) \times 10^{-4}$ = **$3.4(00) \times 10^{-2}$** mol ✓ Mass of Cr/Cr^{3+} in ore = **52.0** × $3.4(00) \times 10^{-2}$ g **1.768 g** ✓ percentage Cr in ore = $\frac{1.768}{5.25} \times 100$ = **33.7%** ✓ **MUST** be to **one** decimal place (in the question)	**6**	***FULL ANNOTATIONS MUST BE USED*** **IF** a step is omitted but subsequent step subsumes previous, then award mark for any missed step **Working: at least 3 SF throughout until final % mark** BUT ignore trailing zeroes, ie for 0.490 allow 0.49 --- **ECF** answer above **÷ 2** **ECF** answer above **÷ 1.5** **ECF** answer above **×** 40 **ECF** answer above × 52.0 **IMPORTANT**: The last two marks are **ONLY** available by using 52.0 for Cr --- **Common ECFs:** **0.8%** x 40 missing 5 marks (scaling error) **0.84%** x 40 missing 4 marks (scaling error and 2 DP) **33.68%** 5 marks (2 DP) **16.8%** 5 marks (divide Cr somewhere by 2) **144.9%; 72.5%** 4 marks (**Final 2 marks unavailable**) Use of $M(Fe(CrO_2)_2)$ = 223.8 instead of $M(Cr)$.

Question	Answer	Marks	Guidance
(c)	*Overall*: $_4^{2-}$ + $3I^-$ + $4H_2O \rightarrow Cr^{3+}$ + $1½\ I_2$ + $8OH^-$ ✓ CrO *Half equations*: $_4^{2-}$ + $4H_2O$ + $3e^-$ → Cr^{3+} + $8OH^-$ ✓ CrO $2I^- \rightarrow I_2 + 2e^-$ ✓	3	**ALLOW multiples and equilibrium signs throughout** **IGNORE** state symbols throughout e.g. $2CrO_4^{2-}$ + $6I^-$ + $8H_2O \rightarrow 2Cr^{3+}$ + $3I_2$ + $16OH^-$ **ALLOW** equation using H^+. i.e. CrO_4^{2-} + $3I^-$ + $8H^+ \rightarrow Cr^{3+}$ + $1½\ I_2$ + $4H_2O$ **OR** $2CrO_4^{2-}$ + $6I^-$ + $16H^+ \rightarrow 2Cr^{3+}$ + $3I_2$ + $8H_2O$ **ALLOW** CrO_4^{2-} half equation using H^+. i.e. $_4^{2-}$ + $8H^+$ + $3e^-$ → Cr^{3+} + $4H_2O$ CrO
	Total	**11**	

OCR
Oxford Cambridge and RSA

GCE

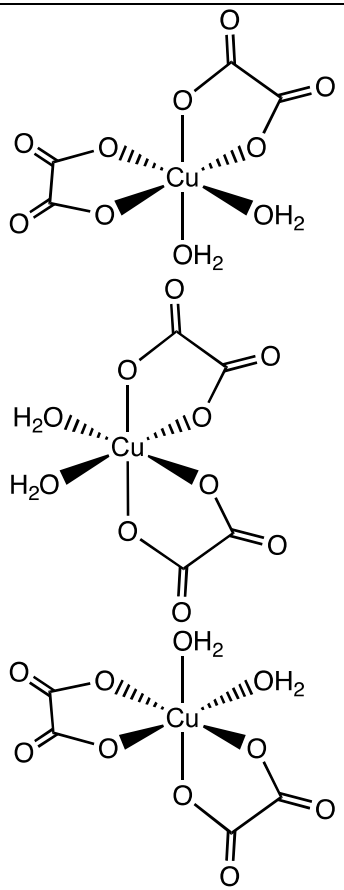
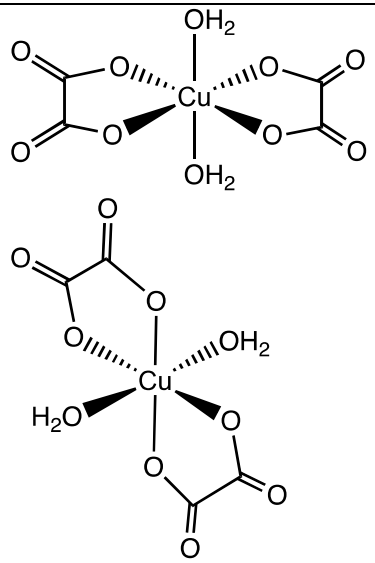
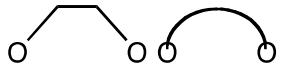
Chemistry A

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

Advanced GCE

Mark Scheme for June 2016

Question			Answer	Marks	Guidance
1	(a)		**IGNORE** any charges shown within complexes (treat as rough working) **Formulae** **2 marks** $[Cu(NH_3)_4(H_2O)_2]^{2+}$ ✓ $[CuCl_4]^{2-}$ ✓ **Colours** **1 mark** blue **AND** yellow ✓ *Mark independently of formulae*	**3**	For charges, **ALLOW** +2 and –2 Square brackets **required**, i.e. **DO NOT ALLOW** $Cu(NH_3)_4(H_2O)_2^{2+}$ **ALLOW** Ligands in any order **ALLOW** $CuCl_4^{2-}$ i.e. no brackets **OR** $Cu(Cl)_4^{2-}$ For $CuCl_4^{2-}$, **ALLOW** green–yellow **OR** yellow–green **DO NOT ALLOW** green For $[Cu(NH_3)_4(H_2O)_2]^{2+}$ **DO NOT ALLOW** pale blue, light blue **DO NOT ALLOW** precipitate with blue **OR** yellow
1	(b)	(i)	**Donates two** electron **pairs** to a metal ion/metal/Cu^{2+} **AND** forms **two** coordinate **bonds** to a metal ion/metal/Cu^{2+} ✓	**1**	**ALLOW** lone pairs for electron pairs **ALLOW** molecule/atom/ion/substance for 'ligand' **ALLOW** dative (covalent) bonds for coordinate bonds **ALLOW** transition element for metal **Two is needed once only** e.g. **Donates two** electron **pairs** to form coordinate **bonds** to a metal ion/metal/Cu^{2+} **Donates** electron **pairs** to form **two** coordinate **bonds** to a metal ion/metal/Cu^{2+} **DO NOT ALLOW** donates **two** electron pairs to form **one/a** coordinate bond

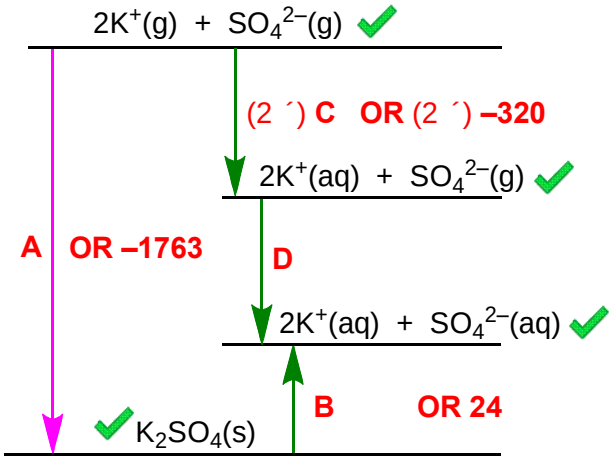
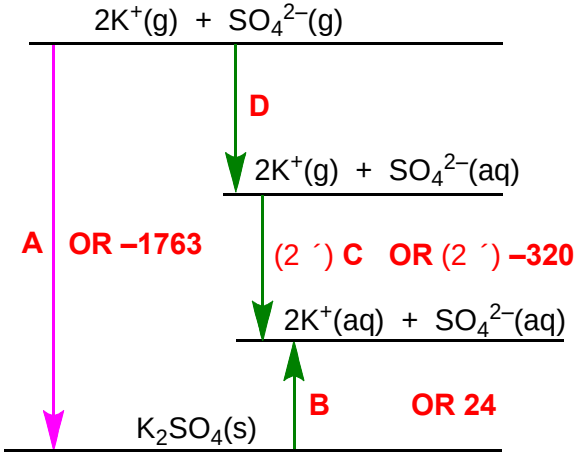
Question			Answer		Marks	Guidance
1	(b)	(ii)			3	***FULL ANNOTATIONS MUST BE USED*** ---------- **2 marks**: one for each correct isomer ✓✓ **TAKE CARE**: structures may be in different orientations and in different order **IF BOTH** isomers are 'correct', but O connectivity wrong, **AWARD** 1 mark for both structures **Check** H_2O ligands carefully for connectivity **ALLOW** H_2O reversed shown as $–O_2H$ **IGNORE** charges (**anywhere)** ---------- **NOTE**: For each structure, **ALL** O atoms must be shown **AND** For $(COO^–)_2$, **ALLOW** skeletal, structural or displayed formula **DO NOT ALLOW** structures such as those shown below 
			cis ✓ *trans* optical ✓	*cis* *trans* ✓ optical		**1 mark**: for whole of 2nd row for whole of 'Type' row i.e. (cis **AND** optical) **AND** trans only

Question			Answer	Marks	Guidance
1	(b)	(iii)	$CuC_4H_4O_{10}^{2-}$ Formula ✓ 2– charge ✓ **MARK formula and charge INDEPENDENTLY**	2	**Empirical** formula essential, e.g. **DO NOT ALLOW** $Cu(COO)_2(H_2O)_2$ for formula mark **ALLOW** any order of elements in formula **ALLOW** –2 for charge
			Total	9	

Question			Answer	Marks	Guidance
2	(a)		***initial rates data (3 marks)*** **NOTE**: Each comparison **MUST** relate to the **actual** change in concentration/rate in the experiments **EXPTS** **H_2O_2**: $[H_2O_2] \times 2$ rate $\times 2$ (1 & 2) **AND** 1st order ✓ **H^+**: $[H^+] \times 2$ rate does not change (2 & 3) **AND** Zero order ✓ **I^-**: $[I^-] \times 2$ **AND** $[H_2O_2] \times 2$ rate $\times 4$ (2 & 4) **OR** $[I^-] \times 2$ **AND** $[H_2O_2] \times 4$ rate $\times 8$ (1 & 4) **OR** $[I^-] \times 2$ **AND** $[H_2O_2] \times 2$ rate $\times 4$ (3 & 4) **AND** 1st order ✓	**3**	***FULL ANNOTATIONS MUST BE USED*** **----------** **THROUGHOUT**, • Square brackets **NOT REQUIRED** around H_2O_2, H^+ and I^- • **ALLOW** 'doubles' for × 2; quadruples for × 4 **ALLOW** direct comparison of concentrations and rate, e.g. $[H_2O_2]$ changes by $\frac{0.0020}{0.0010} = 2$, rate changes by $\frac{1.14 \times 10^{-5}}{5.70 \times 10^{-6}} = 2$ **AND 1**st order (Expts 1 & 2) **DO NOT ALLOW** I_2 for I^- **IGNORE** $[H^+]$ for Expts 3 & 4
			Calculation of rate constant (3 marks), **EITHER** $k = \frac{5.70 \times 10^{-6}}{0.0010 \times 0.20}$ **OR** 2.85×10^{-2} **OR** 0.0285 **OR** 0.029 ✓ $k = 2.9 \times 10^{-2}$ ✓ (2 SF in standard form) *Subsumes previous mark if no working shown* $dm^3\ mol^{-1}\ s^{-1}$ ✓	**3**	**IGNORE working** **DO NOT ALLOW** 0.03 **ALLOW ECF** from error in powers of 10 **ONLY** e.g. 2.9×10^{-3} by use of 0.010 instead of 0.0010 **DO NOT ALLOW 2.90** $\times 10^{-2}$ **(3 SF)** **OR 29** $\times 10^{-3}$ (Not standard form) **ALLOW** mol^{-1}, dm^3 and s^{-1} in any order, e.g. $mol^{-1}\ dm^3\ s^{-1}$

Question			Answer	Marks	Guidance
2	(b)		H^+ ions are consumed/used up **OR** H^+ ions are in the (overall) equation ✓	1	**ALLOW** H^+ is **not** regenerated/reformed **ALLOW** H^+ is a reactant but not a product **ALLOW** 'it' for H^+ **IGNORE** H^+ is not in the rate equation/does not affect rate **IGNORE** does not take part in rate-determining step
2	(c)	(i)	The slowest/slow step ✓	1	**ALLOW** step that takes the longest time
2	(c)	(ii)	**NO ECF from incorrect rate equation** **Principles** • H_2O_2 and I^- **must be** the reactants in **1st step** • 2nd mark **only to be awarded** if 1st mark scored • Step 4 is independent **Reactants of Step 1 as H_2O_2 + I^-** **1 mark** **Step 1**: $H_2O_2 + I^- \rightarrow$ ✓ **Products of Step 1 AND all of Step 2** **1 mark** **Step 1** $\rightarrow$ $IO^- + H_2O$ **AND Step 2**: $H^+ + IO^- \rightarrow$ HIO ✓ **Step 4 (Independent mark)** **1 mark** $H^+ + OH^- \rightarrow H_2O$ ✓	3	**IGNORE state symbols** Elements can be in any order in formulae **Alternatives for 2nd mark** **Step 1:** $\rightarrow$ $HIO + OH^-$ **AND Step 2**: $H^+ + OH^- \rightarrow H_2O$ ✓ **Step 1:** $\rightarrow$ $H_2O_2I^-$ **AND Step 2**: $H^+ + H_2O_2I^- \rightarrow HIO + H_2O$ ✓ Other possibilities, contact TL **ALLOW** $2H^+ + 2OH^- \rightarrow 2H_2O$ $H_3O^+ + OH^- \rightarrow 2H_2O$
			Total	11	

Question			Answer	Marks	Guidance
3	(a)		(enthalpy change for) 1 mole of gaseous ions **OR** 1 mole of hydrated ions/aqueous ions ✓ gaseous ions forming aqueous/hydrated ions ✓	2	**one mole** can be stated just once **EITHER** with gaseous ions **OR** with aqueous ions, e.g. • 1 mole of gaseous ions **forms** hydrated ions/aqueous ions • Gaseous ions **form 1 mole of** hydrated ions/aqueous ions **ALLOW** 1 mol for 1 mole **IGNORE** 'energy released' **OR** 'energy required' For 2nd mark **IGNORE** gaseous ions are hydrated **IGNORE** gaseous ions dissolve in water ***Particles formed not stated*** **ALLOW** 1 mark for: 1 mole of gaseous **IONS** forms aqueous/hydrated **atoms/ particles/ molecules**

Question			Answer	Marks	Guidance
3	(b)	(i)	**4 marks** for species **AND** state symbols on all 4 energy levels (including added energy level)  **1 mark** for **B**, **C AND D** labels **OR** enthalpy values **AND** arrow directions correct ✓ **ALLOW** $K_2SO_4(aq)$ for $2K^+(aq) + SO_4^{2-}(aq)$ **ALLOW** arrows not touching lines. **Direction** is important: • **FROM** $2K^+(g) + SO_4^{2-}(g)$ line • **FROM** $K_2SO_4(s)$ line **See APPENDIX** '2 ×' is **NOT** required – *part of calculation mark*	5	**IF** extra energy level is **above** top line **OR below** bottom line, **DO NOT ALLOW** mark for species on this line. **See APPENDIX** **ALLOW C** and **D** with associated labels, the other way round:  State symbols are **essential** **IF** no extra energy level is shown with **C** and **D** combined forming $2K^+(aq) + SO_4^{2-}(aq)$, • No mark for the extra energy level with species • No mark for labels as **C** and **D** are combined Therefore 3 max for species on energy levels provided
3	(b)	(ii)	ΔH(hydration) SO_4^{2-} = **–1099** (kJ mol^{-1}) ✓	1	**ONLY** correct answer

Question			Answer	Marks	Guidance
3	(c)	(i)	**Aqueous** particles are more disordered than **solid** (particles) **OR** **Solid** particles are more ordered than **aqueous** (particles) ✓	1	For particles, **ALLOW** ions **DO NOT ALLOW** molecules/atoms **ALLOW** 'When the state changes from solid to aqueous, disorder increases' For more disordered, **ALLOW l**ess ordered/ more freedom/ more ways of arranging energy/ more random For aqueous particles, **ALLOW particles in solution** **IGNORE** dissolved
3	(c)	(ii)	***Calculation (2 marks)*** ΔG = 24 – (298 × 0.225) **OR** 24 – 67.05 *(in kJ)* **OR** 24000 – (298 × 225) **OR** 24000 – 67050 *(in J)* ✓ **Calculation of ΔG (IGNORE UNITS)** ΔG = –43 (kJ mol^{-1}) **OR** –43000 (J mol^{-1}) ✓ *Subsumes 1st calculation mark* **Reason for solubility** Calculated value of ΔG that is **negative** **AND** Statement that: ΔG is negative **OR** ΔG < 0 **OR** –43 < 0 **OR** $\Delta H - T\Delta S$ < 0 **OR** $T\Delta S > \Delta H$ ✓	3	**Contact TL if solely entropy approach rather than ΔG** **ALLOW** –43.1 OR –43.05 (*calculator value*) **ALLOW 1 calculation mark (IGNORE units) for** –67.(026) **OR** –67026 ***ECF** from 225 instead of 0.225* 18.(375) **OR** +18.375 ***ECF** from 25* instead of 298 **ALLOW other ECF** from **ONE** error in 1st step of calc, e.g. incorrect value for ΔH such as –1099 from 3bii → –1166.05 **TAKE CARE** that same units used for ΔH and ΔS **NO reason mark from a +ve value of ΔG**
			Total	12	

Question			Answer	Marks	Guidance
4	(a)		Iodine is non-polar **OR** Iodine does not form H bonds **with water** ✓	1	**IGNORE** iodine is slightly polar **IGNORE** 'cannot bond to water' (too vague) **IGNORE** 'Lack of a lone pair' **IGNORE** 'inability to induce a dipole
4	(b)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF K_c = 104 dm^3 mol^{-1} award 4 marks:** ***3 for calculation of 104 from data, 1 for units*** --- **Equilibrium concentrations (mol × 5) (1 mark)** I_2 = 4.00×10^{-5} × **5** = 2.00×10^{-4} (mol dm^{-3}) **AND** I^- = 9.404×10^{-2} × **5** = 0.4702 (mol dm^{-3}) ✓ **AND** I_3^- = 1.96×10^{-3} × **5** = 9.80×10^{-3} (mol dm^{-3}) **Calculation of K_c and units (3 marks)** $K_c = \frac{[I_3^-(aq)]}{[I_2(aq)] \times [I^-(aq)]}$ **OR** $\frac{9.80 \times 10^{-3}}{2.00 \times 10^{-4} \times 0.4702}$ ✓ = 104 ✓ **Must be 3 SF** dm^3 mol^{-1} **OR** mol^{-1} dm^3 ✓	4	***FULL ANNOTATIONS MUST BE USED*** --- Throughout, at least **3SF** but **ALLOW** absence of trailing zeroes e.g. for 9.80×10^{-3} **ALLOW** 9.8×10^{-3} **FOR I^-** 0.4702, **ALLOW** 0.47(0) (mol dm^{-3}) still →104 for calc State symbols **not** required in K_c expression **ALLOW ECF** from incorrect concentrations Any **ECF** value **MUST** be to **3 SF** for K_c value --- **COMMON ERRORS** **104.2 → 104.2109741 (calc)** *> 3 SF* **2 marks + units** **521** *no × 5 for concs* **2 marks + units** **521.1 → 521.0548703** as above and > 3SF **1 mark + units** **2610** *÷ 5 instead of × 5 for concs* **2 marks + units** **9.60×10^{-3}** K_c upside down, correct concs **2 marks + units** **1.92×10^{-3}** K_c upside down, no × *5 for concs* **1 mark + units** **NOTE**: With K_c upside down, units become mol dm^{-3} by **ECF**

Question			Answer	Marks	Guidance
4	(c)		Ag^+/silver nitrate reacts with I^- to form AgI/silver iodide **OR** $Ag^+ + I^- \rightarrow AgI$ ✓ yellow precipitate/solid forms ✓ **Equilibrium 2** shifts to the left ✓ **Equilibrium 1** shifts to left **AND** I_2 comes out of solution/less I_2 dissolves/ I_2 precipitates/black solid /grey solid /violet solid ✓	4	***FULL ANNOTATIONS MUST BE USED*** --- **DO NOT ALLOW** cream **OR** cream–yellow **ALLOW** just 'yellow' if supported by AgI(s) somewhere
4	(d)		**in all equations ALLOW equilibrium signs** **IGNORE** state symbols --- **Reaction 1: 1 mark** $2I_2 + 5O_2 \rightarrow 2I_2O_5$ ✓ --- **Reaction 2: 2 marks** **1st mark: ALL CORRECT species** e.g.: $I_2 + OH^- \rightarrow I^- + IO_3^- + H_2O$ **2nd mark** for **CORRECT balanced equation** $3I_2 + 6OH^- \rightarrow 5I^- + IO_3^- + 3H_2O$ ✓✓	3	***FULL ANNOTATIONS MUST BE USED*** --- **ALLOW** correct multiples throughout, e.g. $I_2 + 2½O_2 \rightarrow I_2O_5$ --- **For 1st mark, IGNORE** e^- present **ALLOW** species/equation with NaOH or KOH, e.g. $3I_2 + 6NaOH \rightarrow 5I^- + IO_3^- + 3H_2O + 6Na^+$ $3I_2 + 6NaOH \rightarrow 5NaI + NaIO_3 + 3H_2O$ **ALLOW** Species: $I_2 + OH^- \rightarrow I^- + IO_2^+ + H_2O$ ✓ **OR** Equation: $3I_2 + 4OH^- \rightarrow 5I^- + IO_2^+ + 2H_2O$ ✓✓ Species: $I_2 + OH^- \rightarrow I^- + IO^{3+} + H_2O$ ✓ **OR** Equation: $3I_2 + 2OH^- \rightarrow 5I^- + IO^{3+} + H_2O$ ✓✓
			Total	**12**	

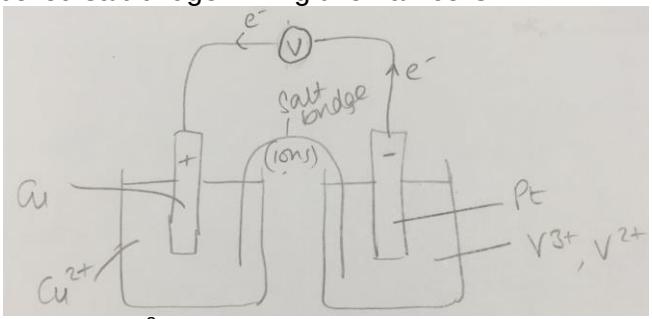
Question			Answer	Marks	Guidance
5	(a)		$(K_a =) \frac{[H^+]\,[NO_2^-]}{[HNO_2]}$ ✓ **IGNORE** state symbols	1	**IGNORE** $\frac{[H^+]^2}{[HNO_2]}$ **OR** $\frac{[H^+]\,[A^-]}{[A]}$ **ALLOW** H_3O^+ for H^+ Square brackets **required**
5	(b)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 2.12 award **2 marks** --- $[H^+] = \sqrt{K_a \times [HNO_2]} = 7.502 \times 10^{-3}$ (mol dm^{-3}) ✓ pH = –log 7.502×10^{-3} = 2.12 ✓ **pH to 2 DP**	2	--- **ALLOW** intermediate value from 3 SF (7.50 up to calculator value of $7.501999733 \times 10^{-3}$ **ALLOW** 1 mark for 2.1 **OR** answer > 2 DP (i.e. not 2 DP) **ONLY ALLOW** pH mark by **ECF** if K_a **AND** 0.120 used and **AND** pH <7 **---** **COMMON ERRORS (MUST be to 2 DP)** **pH = 4.25 No square root:1 mark** $[H^+] = (4.69 \times 10^{-4} \times 0.120) = 5.628 \times 10^{-5}$ (mol dm^{-3}) pH = –log 5.628×10^{-5} = 4.25 ✓ **pH = 0.92 no K_a used: zero marks** pH = –log 0.120 = 0.92 **pH = 13.08 K_w/pOH used: zero marks** pH = –log $\frac{1.00 \times 10^{-4}}{0.120}$ **OR** 14 – log 0.120 = 13.08

Question			Answer	Marks	Guidance
5	(c)	(i)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = **3.43**, **AWARD 4 marks** --- *Expression: K_a × acid/base ratio* Use of $K_a \times \frac{[HNO_2]}{[NO_2^-]}$ **OR** $4.69 \times 10^{-4} \times \frac{[HNO_2]}{[NO_2^-]}$ ✓ *Using correct concs/mol in expression* $[H^+] = 4.69 \times 10^{-4} \times \frac{0.0400}{0.0500}$ ✓ *Subsumes previous mark* *Calculation of* $[H^+]$ $[H^+] = 3.752 \times 10^{-4}$ (mol dm^{-3}) ✓ *pH to 2 DP* ***(****From 3.42573717)* pH = –log 3.752×10^{-4} = 3.43 ✓ **NO marks** are available using K_a square root approach (weak acid pH) $K_w / 10^{-14}$ approach (strong base pH) --- **ALLOW** alternative approach based on Henderson–Hasselbalch equation (**ALLOW** $-\log K_a$ for pK_a) $pH = pK_a + \log \frac{[NO_2^-]}{[HNO_2]}$ **OR** $pK_a - \log \frac{[HNO_2]}{[NO_2^-]}$ ✓ $pH = pK_a + \log \frac{0.0500}{0.0400}$ **OR** $pK_a - \log \frac{0.0400}{0.0500}$ ✓ $pH = pK_a + 0.097$ ✓ pH = 3.329 + 0.097 = 3.43 ✓	4	***FULL ANNOTATIONS MUST BE USED*** **----------** **ALLOW** just $K_a \times \frac{\text{acid}}{\text{salt}}$ *expression* **Mark** by **ECF** from $4.69 \times 10^{-4} \times \frac{[NO_2^-]}{[HNO_2]}$ *inverted expression* **Mark** by **ECF** from incorrect $[HNO_2]$ and $[NO_2^-]$ **ONLY** award **marks** for a pH calculation via K_a **AND** using concentrations/mol derived from the question **DO NOT ALLOW** final pH mark by **ECF** if pH > 7 --- **COMMON ERRORS BUT CHECK WORKING** **pH = 2.82 3 marks** initial concs: 0.200 and 0.0625 **pH = 3.23 3 marks** 0.0400 and 0.0500 acid/base ratio inverted **pH = 3.83 2 marks** initial concs: 0.200 and 0.0625 and ratio inverted **pH = 2.73 3 marks** Incorrect $[NO_2^-]$ = 0.01 and correct $[HNO_2]$ = 0.04 **pH = 4.03 3 marks** correct $[NO_2^-]$ = 0.05 and incorrect $[HNO_2]$ = 0.01

Question			Answer	Marks	Guidance
5	(c)	(ii)	**Equilibrium: 1 mark** $HNO_2 \rightleftharpoons H^+ + NO_2^-$ ✓ (ignore state symbols) **Control of pH: 2 marks (QWC)** ***Added HCl*** NO_2^- reacts with added acid/HCl/H^+ **OR** $NO_2^- + H^+ \rightarrow$ **OR** more HNO_2 forms ✓ ***Added NaOH*** HNO_2 reacts with added alkali/NaOH/OH^- **OR** $HNO_2 + OH^- \rightarrow$ **OR** more NO_2^- forms **OR** H^+ reacts with added alkali/NaOH **OR** $H^+ + OH^- \rightarrow$ ✓ **Equilibrium shift:** **1 mark for shifts in $HNO_2 \rightleftharpoons H^+ + NO_2^-$ (See 1st mark)** Equilibrium for added **acid → left** **AND** Equilibrium for added **alkali → right** ✓ (**QWC**)	4	***FULL ANNOTATIONS MUST BE USED*** --- **IGNORE** $HA \rightleftharpoons H^+ + A^-$ Equilibrium sign **essential** **BUT ALLOW** small slips in its appearance if it is obviously an attempt to show an equilibrium sign rather than an arrow **QWC: Quality of written communication** **DO NOT ALLOW** HA and A^- for HNO_2 and NO_2^- **IGNORE just** acid reacts with added alkali **IGNORE just** conjugate base/salt/base reacts with added acid **DO NOT ALLOW** salt/base reacts with added acid **AWARD** 'shift mark' **ONLY** if correct equilibrium equation has been given **IGNORE** any other equilibria in response

Question			Answer	Marks	Guidance
5	(d)	(i)	Endothermic **AND** K_w increases with temperature **OR** Endothermic **AND** dissociation increases **with temperature** **OR** Endothermic **AND** (dissociation) involves breaking bonds ✓	1	Endothermic **and** reason required for the mark **ALLOW** Endothermic **AND** increasing temperature shifts equilibrium/reaction to the right/favours forward reaction **DO NOT ALLOW** breaking hydrogen bonds **OR** intermolecular bonds/forces
5	(d)	(ii)	***OH^- concentration*** $[OH^-] = \frac{9.311 \times 10^{-14}}{1.00 \times 10^{-7}} = 9.311 \times 10^{-7}$ (mol dm^{-3}) ✓ ***Explanation (dependent on 1st mark)*** $9.311 \times 10^{-7} > 1.(00) \times 10^{-7}$ **OR** $[OH^-] > [H^+]$ **OR** OH^- in excess **AND** Alkaline ✓	2	***H^+ OR OH^- concentration (neutral pH)*** $[H^+] = [OH^-] = \sqrt{(9.311 \times 10^{-14})} = 3.05 \times 10^{-7}$ (mol dm^{-3}) ✓ ***Explanation (dependent on 1st mark)*** pH = –log $(3.05 \times 10^{-7}) = 6.5 \rightarrow 6.515501837$ (calc) **AND** Alkaline ✓
5	(d)	(iii)	pK_w = 13.03 ✓	1	**ONLY** correct answer

Question			Answer	Marks	Guidance
5	(d)	(iv)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = **10.76**, award **3 marks** --- ***Dilution 1 mark*** $[OH^-(aq)] = [NaOH(aq)] = \frac{0.0270}{5} = 0.00540$ (mol dm^{-3}) ✓ ***[H$^+$] 1 mark*** $[H^+(aq)] = \frac{9.311 \times 10^{-14}}{0.00540} = 1.72 \times 10^{-11}$ (mol dm^{-3}) ✓ Calculator: $1.724259259 \times 10^{-11}$ ***pH 1 mark*** pH = –log 1.72×10^{-11} = **10.76** ✓ --- **ALLOW** pOH method for 2nd and 3rd mark: pOH = –log 0.00540 = 2.27 ✓ (calculator 2.26760624) pH = 13.03 – 2.27 = 10.76 ✓	**3**	***FULL ANNOTATIONS MUST BE USED*** --- **ALLOW** dilution **AFTER** calculation of $[H^+(aq)]$ i.e. original $[H^+] = \frac{9.311 \times 10^{-14}}{0.0270} = 3.45 \times 10^{-12}$ (mol dm^{-3}) ✓ After dilution, $[H^+] = 3.45 \times 10^{-12} \times 5 = 1.72 \times 10^{-11}$ (mol dm^{-3})✓ pH = –log 1.72×10^{-11} = **10.76** ✓ **ALLOW ECF** from incorrect $[H^+(aq)]$ provided that pH >7 --- **COMMON ERRORS (MUST be to 2 DP)** **pH = 11.73** At 25ºC (1.00×10^{-14}): **2 marks** pH = –log 1.85×10^{-12} = **11.73** **pH = 11.46** No dilution at 60ºC (9.311×10^{-14}) **2 marks** pH = –log(3.45×10^{-12}) = **11.46** **pH = 12.43** No dilution **AND** 25ºC (1.00×10^{-14}) **1 mark** pH = –log(3.70×10^{-13}) = **12.43** **pH = 12.16** ×5 instead of ÷ 5 at 60ºC (9.311×10^{-14}) **2 marks** pH = –log(6.879×10^{-13}) = **12.16** **pH = 13.13** ×5 instead of ÷ 5 at 25ºC (1.00×10^{-14}) **1 mark** pH = –log(7.407×10^{-14}) = **13.13** **NOTE:** Attempts at dilution → 0.0270 with error in powers of 10 → 12.46 from 0.00270, etc may give 2 marks by **ECF**
			Total	**18**	

Question			Answer	Marks	Guidance
6	(a)		**Definition** The e.m.f. (of a half-cell) compared with/connected to a (standard**)** hydrogen half-cell/(standard**)** hydrogen electrode ✓ **Standard conditions** *Units essential* Temperature of 298 K / 25ºC **AND** (solution) concentrations of 1 mol dm^{-3} **AND** pressure of 100 kPa **OR** 10^5 Pa **OR** 1 bar ✓	**2**	For e.m.f., **ALLOW** voltage **OR** potential difference/p.d. **OR** electrode/reduction/redox potential **ALLOW** e.m.f. of a cell ….. **ALLOW** /(standard) hydrogen cell **IGNORE** S.H.E. (as abbreviation for standard hydrogen electrode) **DO NOT ALLOW** hydrogen fuel cell **ALLOW** 1M **OR** 1 mol/dm^3 **DO NOT ALLOW** 1 mol **OR** 1 mole **ALLOW** 1 atmosphere/1 atm **OR** 101 kPa **OR** 101325 Pa
6	(b)	(i)	**Complete** circuit with voltmeter **AND** labelled salt bridge linking two half-cells ✓  Cu electrode in Cu^{2+} ✓ Pt electrode in V^{2+} **AND** V^{3+} ✓ Cu shown as + **AND** Pt shown as – ✓ electrons in wire **AND** ions in salt bridge ✓ *On diagram or stated*	**5**	Half cells can be drawn in either order Half cells must show electrodes dipping into solutions **ALLOW** small gaps in circuit **DO NOT ALLOW** half-cell with H_2 added **IGNORE** any stated concentrations **IGNORE** ‘anode’ and ‘cathode’ In salt bridge, **ALLOW** any stated ion that may be present, e.g. K^+, NH_4^+, NO_3^-, Cu^{2+}, V^{2+}, V^{3+} **IGNORE** direction of travel of ions and electrons. **ALLOW** Cu half cell as + **AND** V half cell as –

Question			Answer	Marks	Guidance
6	(b)	(ii)	0.60 **OR** 0.6 (V) ✓	1	**IGNORE** any sign
6	(c)		**Definitions:** ***1 mark*** Oxidising agent removes/accepts/gains electrons **OR** increases oxidation number (of another species) **AND** Reducing agent adds/donates/loses electrons **OR** decreases oxidation number (of another species) ✓ **Oxidising agent:** ***2 marks*** Cr^{3+} oxidises Al **OR** Cr^{3+} acts as oxidising agent **AND** $3Cr^{3+} + Al \rightarrow 3Cr^{2+} + Al^{3+}$ ✓ ***Explanation (dependent on Cr^{3+} oxidising Al above)*** *E* of redox system 2 (Cr^{3+}/Cr^{2+}) is **more** positive /**less** negative (than *E* of system 1 (Al^{3+}/Al)) **ORA**, i.e. in terms of 1 being more negative (than 2) ✓ **Reducing agent:** ***3 marks*** Cr^{3+} reduces $FeO_4^{2-}(/H^+)$ ✓ $2Cr^{3+} + 2FeO_4^{2-} + 2H^+ \rightarrow Cr_2O_7^{2-} + 2Fe^{3+} + H_2O$ ✓ ***Explanation (dependent on Cr^{3+} reducing FeO_4^{2-} above)*** *E* of redox system 5 ($Cr_2O_7^{2-}/Cr^{3+}$) is **less** positive/ **more** negative (than *E* of system 6 (FeO_4^{2-}/Fe^{3+})) **ORA**, i.e. in terms of 6 being more positive (than 5) ✓	6	***FULL ANNOTATIONS MUST BE USED*** **----------** **ALLOW** oxidising agent decreases its oxidation number **AND** reducing agent increases its oxidation number **IGNORE** oxidising agent oxidises/is reduced **OR** reducing agent reduces/is oxidised **In equations,** • **IGNORE** state symbols (even if incorrect) • **ALLOW** ⇌ in equation **IF** more than one equation shown for **Cr^{3+} as oxidising agent**, **CON** and **zero marks** for 2 oxidising agent marks **IGNORE** equations with Cr^{2+} as reactant Explanations **MUST** be in terms of positive/negative: **IGNORE** 'higher' *E* **OR** 'greater' **ALLOW** E_{cell} = +1.25 V (+ sign required) **IF** more than one equation shown for **Cr^{3+} as a reducing agent**, **CON** and **zero marks** for 3 reducing agent marks **IGNORE** equations with Cr^{2+} as reactant Explanations **MUST** be in terms of positive/negative: **IGNORE** 'higher' *E* **OR** 'greater' **ALLOW** E_{cell} = +0.87 V (+ sign required)
			Total	14	

Question			Answer	Marks	Guidance
7	(a)	(i)	**IGNORE** any charges shown within complexes (treat as rough working) **Complex ion C**: $[Ni(H_2O)_6]^{2+}$ ✓ **Solid D**: $Ni(OH)_2$ ✓ **Complex ion E**: $[Ni(CN)_4]^{2-}$ ✓	**3**	**ALLOW** +2 and –2 for charges Square brackets required **ALLOW** $Ni(H_2O)_4(OH)_2$ $(H_2O)_4$ and $(OH)_2$ in any order **IGNORE** any square brackets Square brackets required **TAKE CARE** for round brackets within complex ion, i.e. (H_2O), (OH) and (CN)

Question			Answer	Marks	Guidance
7	(a)	(ii)	**Mark independently of 7(a)(i)** **ALLOW** +2 and –2 for charges **IGNORE** any charges shown within complexes (treat as rough working) $Ni^{2+} + 2OH^- \rightarrow Ni(OH)_2$ ✓ Type of reaction: precipitation ✓ **INDEPENDENT of equation** $[Ni(H_2O)_6]^{2+} + 4CN^- \rightarrow [Ni(CN)_4]^{2-} + 6H_2O(l)$ ✓ Type of reaction: ligand substitution ✓ **INDEPENDENT of equation**	4	**For equations: IGNORE** state symbol (even if wrong) Square brackets **not** required for $Ni(OH)_2$ **ALLOW** $[Ni(H_2O)_6]^{2+} + 2OH^- \rightarrow [Ni(H_2O)_4(OH)_2] + 2H_2O$ **ALLOW** $[Ni(H_2O)_6]^{2+} + 2OH^- \rightarrow Ni(OH)_2 + 6H_2O$ **ALLOW** $NiSO_4(aq) + 2OH^-(aq) \rightarrow Ni(OH)_2(s) + SO_4^{2-}(aq)$ **ALLOW** $NiSO_4(aq) + 2KOH(aq) \rightarrow Ni(OH)_2(s) + K_2SO_4(aq)$ **ALLOW** acid/base **OR** neutralisation **OR** deprotonation **ONLY IF** $[Ni(H_2O)_6]^{2+}$ **AND** $[Ni(H_2O)_4(OH)_2]$ used **ALLOW** precipitate **ALLOW** $[Ni(H_2O)_6]^{2+} + 4KCN \rightarrow [Ni(CN)_4]^{2-} + 6H_2O + 4K^+$ **LOOK** at formulae for **E** from **7(a)(i)** (copied at bottom) **ALLOW ECF** in **7aii** Equation for no round brackets around CN, i.e. $[NiCN_4]^{2-}$ in **7a(i)** This is the only **ECF** allowed from **7ai** structures. **ALLOW** ligand exchange
7	(b)	(i)	linear ✓	1	**IGNORE** planar

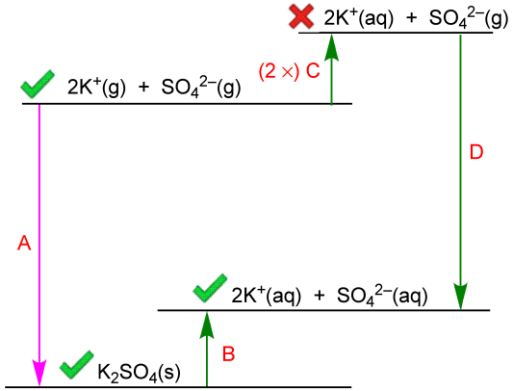
Question			Answer	Marks	Guidance
7	(b)	(ii)	Au/Gold has been **oxidised** from 0 to +1 ✓ O/Oxygen/O_2 has been **reduced** from 0 to –2 ✓	2	**IF** Ag referred to, rather than Au, treat as a slip and apply **BOD** **ALLOW** 0 to 1 (i.e. no + sign for +1) **ALLOW** 1 mark for **ALL** oxidation numbers correct with no oxidised or reduced **OR** oxidation and reduction wrong way round, e.g. Au goes from 0 to +1 and O goes from 0 to –2 ✓ Au is reduced from 0 to +1 and O is oxidised from 0 to –2 ✓
7	(b)	(iii)	**IGNORE** any charges shown within complexes (treat as rough working) $4Au + 8CN^- + 2H_2O + O_2 \rightarrow 4[Au(CN)_2]^- + 4OH^-$ ✓✓ First mark for all 6 species Second mark for balancing	2	**IF** Ag referred to, rather than Au, treat as a slip and apply **BOD** **IGNORE** state symbols **CARE**: In $[Au(CN)_2]^-$, – sign is **OUTSIDE** square brackets **For 1st mark, IGNORE** e^- present **ALLOW** 1 mark for balanced equation with CN^- missing, i.e. $4Au + 2H_2O + O_2 \rightarrow 4Au^+ + 4OH^-$ **ALLOW** 1 mark rogue e^- on either side **ALLOW** multiples, e.g. $2Au + 4CN^- + H_2O + ½O_2 \rightarrow 2[Au(CN)_2]^- + 2OH^-$ $Au + 2CN^- + ½ H_2O + ¼ O_2 \rightarrow [Au(CN)_2]^- + OH^-$
7	(b)	(iv)	$ClO^- + 2H^+ + 2e^- \rightarrow Cl^- + H_2O$ ✓	1	**IGNORE** state symbols **ALLOW** e for electron **ALLOW** multiples
			Total	13	

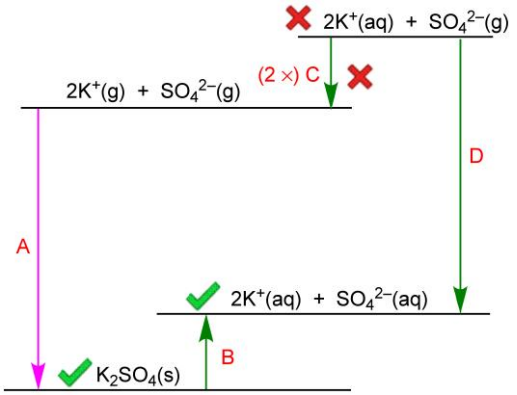
Question			Answer	Marks	Guidance
8	(a)		Cu^{2+}: $(1s^2)\ 2s^2 2p^6 3s^2 3p^6 3d^9$ ✓ Cu^{+}: $(1s^2)\ 2s^2 2p^6 3s^2 3p^6 3d^{10}$ ✓	2	**IGNORE** repeated $1s^2$ after $1s^2$ prompt on answer line **ALLOW** $4s^0$, either before or after 3d **ALLOW** upper case D, etc and subscripts, e.g. …...$3S_2 3P^6$ **DO NOT ALLOW** [Ar] as shorthand for $1s^2 2s^2 2p^6 3s^2 3p^6$
8	(b)		**IGNORE** any charges shown within formulae (treat as rough working) $CuCO_3 + 2HCOOH \rightarrow Cu(HCOO)_2 + H_2O + CO_2$ **OR** $CuO + 2HCOOH \rightarrow Cu(HCOO)_2 + H_2O$ **OR** $Cu(OH)_2 + 2HCOOH \rightarrow Cu(HCOO)_2 + \mathbf{2}H_2O$ ✓	1	**IGNORE** state symbols In formula of HCOOH/HCOO, **ALLOW** H, C and O in **ANY** order **ALLOW** H_2CO_3 for H_2O and CO_2 in carbonate equation **ALLOW** $(HCOO)_2Cu$ for $Cu(HCOO)_2$ **DO NOT ALLOW** equation with $CuSO_4$
8	(c)		$2Cu^{2+} + 4I^- \rightarrow 2CuI\mathbf{(s)} + I_2$ ✓ State symbol for CuI(s) **ONLY** required	1	**ALLOW** multiples, e.g. $Cu^{2+} + 2I^- \rightarrow CuI\mathbf{(s)} + ½I_2$ **IGNORE** other state symbols, even if incorrect
8	(d)		Starch ✓ Blue/black to colourless/white ✓ **MARK INDEPENDENTLY**	2	 **IGNORE** 'brown' in composite colour with blue or black, i.e. **ALLOW** blue/brown to colourless **ALLOW** black/brown to colourless **DO NOT ALLOW** just 'it turns colourless/is decoloured' *Initial colour required* **IGNORE** clear for colourless

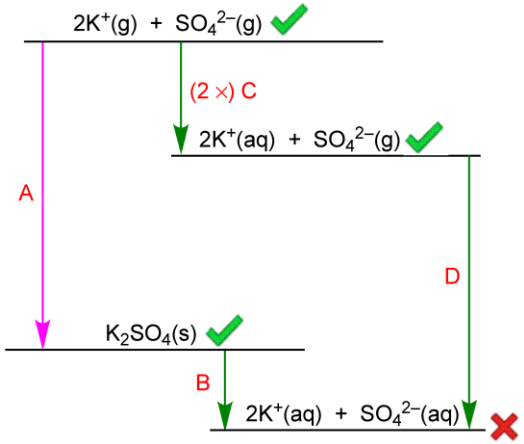
Question			Answer	Marks	Guidance
8	(e)		**WORKING REQUIRED** Correct answer: x = 4 required evidence of working --- $n(S_2O_3^{2-})$ **OR** $n(Cu^{2+}) = \frac{0.0420 \times 23.5}{1000} = 9.87 \times 10^{-4}$ (mol) ✓ In 250.0 cm^3 solution, $n(Cu^{2+}) = 9.87 \times 10^{-3}$ (mol) ✓ $M(Cu(HCOO)_2 \cdot 4H_2O) = \frac{2.226}{9.87 \times 10^{-3}} = 225.5$ (g mol^{-1}) ✓ $\boldsymbol{x}(H_2O)$ has mass of $225.5 - M(Cu(HCOO)_2)$ $= 225.5 - 153.5$ $= 72(.0)$ ✓ $\boldsymbol{x} = \frac{72(.0)}{18(.0)} = \mathbf{4}$ **WHOLE NUMBER** needed **AND** evidence of working ✓	**5**	***FULL ANNOTATIONS MUST BE USED*** --- At least **3 SF** required throughout *Alternative approach for final 3 marks based on mass:* mass $Cu(HCOO)_2 = 9.87 \times 10^{-3} \times 153.5 = 1.515$ g ✓ $n(H_2O) = \frac{2.226 - 1.515}{18(.0)} = \frac{0.711}{18(.0)} = 0.0395$ (mol) ✓ $\boldsymbol{x} = \frac{0.0395}{9.87 \times 10^{-3}} = 4$ ✓ **ALLOW** $Cu(HCOO)_2 \cdot 4H_2O$ --- **COMMON ERRORS for 4 marks** ***x*** = 117 (calc 116.78) *Use of 9.87×10^{-4} (no scaling × 10)* → *M* = 2255.319 ***x*** = 17 (calc 16.53) 4 marks *Use of 4.935×10^{-4} (Use of $0.5 \times 9.87 \times 10^{-3}$)* Check $n(Cu^{2+})$ for other **ECF**s Check for **ECF**s from incorrect *M*(anhydr salt) Actual = 153.5
			Total	**11**	

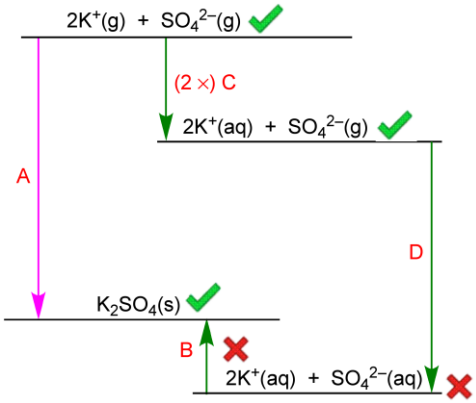
APPENDIX Q3(b)

<table>
<tr>
<td>Extra energy line placed ABOVE top line
3 out of 4 marks awarded for energy lines and species.

Top arrow is shown FROM $2K^+(g) + SO_4^{2-}(g)$ and arrow directions correct. Letter labels correct so last mark is awarded. 4/5 marks
 
</td>
<td>Same as left-hand response

BUT top arrow shown TO $2K^+(g) + SO_4^{2-}(g)$ so last mark not awarded 3/5 marks
 
</td>
</tr>
<tr>
<td>Extra energy line placed BELOW bottom line
3 out of 4 marks awarded for energy lines and species.

Top arrow is shown FROM $K_2SO_4(s)$ and arrow directions correct. Letter labels correct so last mark is awarded. 4/5 marks
 
</td>
<td>Same as left-hand response

BUT bottom arrow shown TO $K_2SO_4(s)$ so last mark not awarded 3/5 marks
 
</td>
</tr>
</table>

OCR
Oxford Cambridge and RSA

GCE

Chemistry A

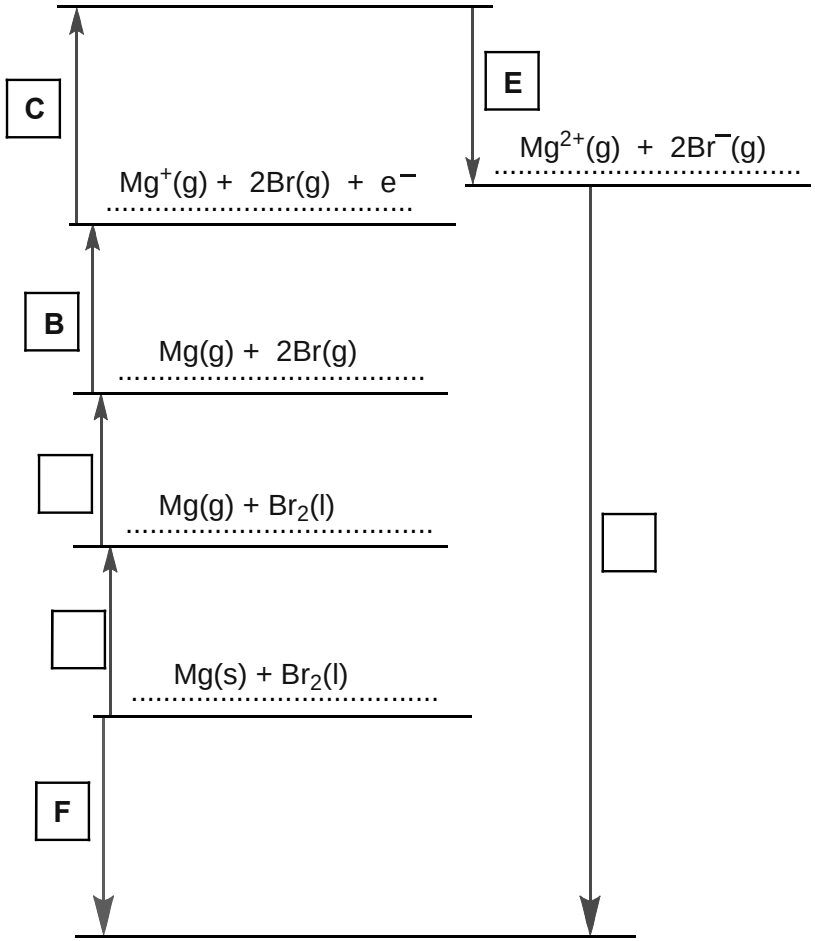
Unit **F325:** Equilibria, Energetics and Elements

Advanced GCE

Mark Scheme for June 2017

Question			Answer	Marks	Guidance
1	(a)		**Formation** of **one mole** of a(n ionic) compound ✓ from its **gaseous ions** ✓ **IGNORE** standard conditions	2	**IGNORE** 'Energy needed' **OR** 'energy required' For '*compound'*, **ALLOW**: lattice, crystal, substance, solid **Special case: 1 mark for gaseous ions ONLY** 'Formation of 1 mole of compound from 1 mole of gaseous ions.' Duplicate 1 mole is a **CON** for 1st marking point
1	(b)		***FULL ANNOTATIONS MUST BE USE*** For **ALL** marking points, assume the following: • For 'ions', **ALLOW** 'atoms', *e.g.* Na has a larger (atomic) radius • For Mg^{2+}, Na^{+}, Br^{-} and Cl^{-}, **ALLOW** symbols: *e.g*. Mg, Na, Br and Cl • **ALLOW** names: e.g. magnesium, sodium, bromine, bromide, chlorine, chloride • **DO NOT ALLOW** 'composite' particles, e.g. 'magnesium bromide/$MgBr_2$ has a larger ionic radius' **DO NOT ALLOW** molecules **IGNORE** idea of close packing of ions **IGNORE** electronegative		

Question			Answer	Marks	Guidance
			Comparing cation size AND charge (ORA based on Na^+) Mg^{2+} is smaller **AND** Mg^{2+} has a greater charge **OR** Mg^{2+} has a greater charge density ✓ ***Comparing of anion size (ORA based on Cl^-)*** Br^- is larger **OR** Br^- has a smaller charge density ✓ ***Comparing cation ⇔ anion attraction*** Mg^{2+} has stronger attraction **AND** Cl^- has stronger attraction ✓ ***IGNORE*** *'nuclear' attraction*	**3**	**ALLOW** reverse argument throughout (**ORA**) **----------** For 'greater charge' part of mark, **ALLOW** Mg^{2+} **AND** Na^+ seen anywhere **ALLOW** Mg is 2+ **AND** Na is 1+ **IGNORE** just Mg^{2+} is small *comparison required* **IGNORE** just Br^- is large *comparison required* **ALLOW** pull for attraction **ALLOW** '**attracts** with more force' for greater attraction **BUT** … **IGNORE** just 'greater force' (*could be repulsion*) **OR** comparison of bond strength/energy to break bonds **IGNORE** comparisons of numbers of ions

Question			Answer	Marks	Guidance
1	(c)	(i)	 **5 marks** for species **AND** state symbols on the dotted lines ✓✓✓✓✓ **1 mark** for **ALL** 4 correct letters in boxes ✓ *Place tick or cross by top right letter (E when correct)* **6**	**6**	Correct species **AND** state symbols required for marks on dotted lines **ALLOW** e for e^- **TAKE CARE**: e^- may be in centre of response and more difficult to see than at end, e.g. $Mg^+(g) + e^- + 2Br(g)$ **ONE** correct response for each line **Mark each marking point independently** --- No **ECF** except for (g) and (s) state symbol of $\mathbf{Br_2}$(l) i.e.: $Mg(g) + Br_2(g)$ ✓ **ECF** ↑ $Mg(s) + Br_2(g)$ × --- $Mg(g) + Br_2(s)$ ✓ **ECF** ↑ $Mg(s) + Br_2(s)$ × --- **DO NOT ALLOW ECF** for same change with (aq), i.e. $Mg(g) + Br_2(aq)$ × ↑ $Mg(s) + Br_2(aq)$ × ---

Question			Answer	Marks	Guidance
1	(c)	(ii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = –2433 (kJ mol^{-1}) award 2 marks** --- **Cycle** (–524) = 146 + (2 × +112) + 738 + 1451 + (2 × –325) + LE **OR** LE = –524 – (146 + (2 × +112) + 738 + 1451 + (2 × –325) **OR** –524 – 1929 ✓ **Lattice energy** LE = **– 2433** ✓ (kJ mol^{-1})	**2**	For alternative answers, **ALLOW ECF** **See list below for marking of answers from common errors** --- **ALLOW** for 1 mark: +2433 wrong sign –2321 +112 used instead of **2 ×** 112 –2758 –325 used instead of **2 ×** –325 –3733 wrong sign for **2 ×** 325 –1385 wrong sign for 524 –2141 wrong sign for 146 –1985 wrong sign for 2 **×** 112 –957 wrong sign for 738 +469 wrong sign for 1451 Any other number: **CHECK** for **ECF** from 1st marking point for expressions with **ONE** error only e.g. one transcription error: e.g. +461 instead of +416
			Total	**13**	

Question			Answer	Marks	Guidance
2	(a)		positive **OR** + **AND** solid forms liquid **OR** liquid has more disorder ✓	3	For 'liquid has more disorder': **ALLOW** liquid has more ways of arranging energy/ more freedom/ more random molecules
			positive **OR** + **AND** gas (H_2) forms **OR** Mg dissolves/disappears ✓		**ASSUME** gas is H_2 unless otherwise stated **BUT DO NOT ALLOW** an incorrect gas (e.g. CO_2) **IGNORE** liquid forms **IGNORE** equation with state symbols *Response should communicate why entropy increases*
			negative **OR** – **AND** **9** mol **gas** form **4** mol **gas OR** forms **5 fewer** mol of **gas** ✓		**Numbers and gas** are **essential** **IGNORE** 'forms fewer moles of gas' For mol, **ALLOW** molecules **IGNORE** numbers around equation *Treated as rough working*

Question			Answer	Marks	Guidance
2	(b)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = **185** (J K^{-1} mol^{-1}) award **2 marks** *Conversion of ºC to K* ***AND** substitution of values into $\Delta G = \Delta H - T\Delta S$* $-1041 = -907 - 723 \times \Delta S$ ✓ *Calculation of ΔS **AND** conversion to J K^{-1} mol^{-1}* $\Delta S = \frac{1041 - 907}{723} \times 1000 = \frac{134}{723} \times 1000$ = 185 **OR** 185.3 (J K^{-1} mol^{-1}) ✓ ***ALLOW** 3 SF up to calc value of 185.3388658 correctly rounded*	**2**	Conversion to J may be carried out at start but no mark **JUST** for this conversion **ALLOW ECF ONLY** from use of values from question: (–)907 **AND** (–)1041 **AND** 450/723 **----------** **COMMON ERRORS** **–185** wrong sign 1 mark **0.185** no conversion from kJ to J 1 mark **1.85×10^{-4}** ÷ by 1000 instead of × 1 mark **298/297.8 (calc 297.7 recurring)** Use of 450 ºC instead of 723 K 1 mark **–2694** wrong sign for 1041 1 mark **2694** wrong sign for 907 1 mark **±4329** Wrong sign **AND** 450ºC 0 marks

Question			Answer	Marks	Guidance
2	(c)		**Signs of ΔH and ΔS** ΔH is positive **AND** ΔS is positive ✓ ***T*Δ*S* and temperature** 'Value of' $T\Delta S$ increases with temperature ✓ **Feasibility** At high temperatures, ΔG is –ve **OR** $\Delta G < 0$ **AND** At low temperatures, ΔG is +ve **OR** $\Delta G > 0$ **OR** $\Delta H - T\Delta S$ decreases with (increasing) temperature **OR** $\Delta H - T\Delta S$ from +ve to –ve with (increasing) temperature ✓ **OR** the idea: As temperature increases, $T\Delta S$ outweighs ΔH to make $\Delta G < 0$	3	***FULL ANNOTATIONS MUST BE USED*** **ALLOW** ΔH is endothermic for ΔH is positive **IGNORE** sign of $T\Delta S$ *(treated as* $\lvert T\Delta S \rvert$ *)* *i.e.* ***ALLOW*** $T\Delta S$ *becomes more/less positive* ***OR*** $T\Delta S$ *becomes more/less negative* **IGNORE** ΔS increases with temperature **ONLY** award feasibility mark if signs of ΔH and ΔS are correct, i.e. ΔH +ve **AND** ΔS +ve (1st marking point) **ALLOW** $\Delta H - T\Delta S$ for ΔG, e.g. At high temperatures, $\Delta H - T\Delta S < 0$ **OR** $\Delta H < T\Delta S$ ***AND*** At low temperatures, $\Delta H - T\Delta S > 0$ **OR** $\Delta H > T\Delta S$
			Total	8	

<table>
<tr><th colspan="3">Question</th><th>Expected answers</th><th>Marks</th><th>Additional guidance</th></tr>
<tr><td>3</td><td>(a)</td><td></td><td>NO: 2 /Second
AND H_2: 1 /First
AND Overall: 3 /Third ✓</td><td>1</td><td></td></tr>
<tr><td>3</td><td>(b)</td><td></td><td>rate × 125 ✓</td><td>1</td><td>DO NOT ALLOW just ‘increases by 5 and then by 25 / 5^2
OR increases by 5^3</td></tr>
<tr><td>3</td><td>(c)</td><td></td><td>FIRST, CHECK THE ANSWER ON ANSWER LINE
IF answer = 7.59×10^4 award 2 marks
THEN IF units are $dm^6\ mol^{-2}\ s^{-1}$, award 1 further mark

Initial working
$k = \dfrac{4.34 \times 10^{-2}}{(3.24 \times 10^{-3})^2 \times 5.45 \times 10^{-2}}$

OR 75858.31764 to 3 SF or more ✓

3 SF and standard form
$= 7.59 \times 10^4$ ✓

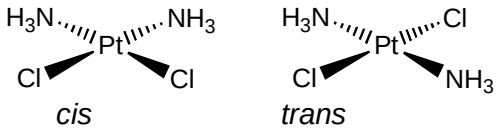
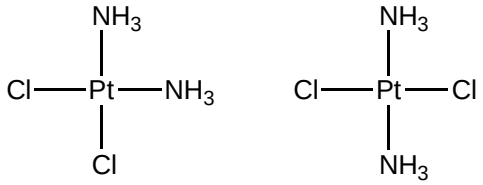
units:
$dm^6\ mol^{-2}\ s^{-1}$ ✓</td><td>3</td><td>FULL ANNOTATIONS MUST BE USED

NO ECF from incorrectly rearranged k expression

ALLOW $mol^{-2}\ dm^6\ s^{-1}$ OR any order
DO NOT ALLOW other units from incorrect k expression
(Rate equation supplied on paper – not derived from data)</td></tr>
<tr><td>3</td><td>(d)</td><td></td><td><table><tr><td>Change</td><td>Effect on rate</td><td>Effect on k</td></tr><tr><td>Increase in pressure</td><td>increases</td><td>none</td></tr><tr><td>Increase in temperature</td><td>increases</td><td>increases</td></tr></table>Mark by column: ✓ ✓</td><td>2</td><td>ALL boxes are ‘increases’ EXCEPT top right is ‘none’.</td></tr>
</table>

Question			Expected answers	Marks	Additional guidance
3	(e)		**Overall equation must be sum of step 1 and step 2** **step 1**: $H_2(g) + 2\,NO(g) \rightarrow N_2O(g) + H_2O(g)$ ✓ **overall**: $2NO(g) + 2H_2(g) \rightarrow N_2(g) + 2H_2O(g)$ ✓ **NO ECF** for from **incorrect** step 1 equation	**2**	**IGNORE** any state symbols *For other possible correct responses, contact Team Leader*
			Total	**9**	

Question			Answer	Marks	Guidance
4	(a)	(i)	**Note:** Examples must be for V, not other d block elements **d block element:** (3)d is **highest energy** sub-shell/orbital ✓ **Transition element:** has an **ion** with incomplete/partially-filled **d sub-shell/orbital** ✓ **V** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 4s^2$ ✓ ***full*** *electron configuration required* **V^{2+}:** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3$ ✓ ***full*** *electron configuration required*	4	***FULL ANNOTATIONS MUST BE USED*** **DO NOT ALLOW highest energy** shell **ALLOW** 4s before 3d, ie $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^3$ **ALLOW** upper case D, etc and subscripts, e.g. $[Ar]4S_2 3D_8$ **DO NOT ALLOW USE OF** [Ar] for $1s^2 2s^2 2p^6 3s^2 3p^6$ for configuration of V and V^{2+} **ALLOW** electron configuration with $4s^0$
4	(a)	(ii)	$VO_3^- + 6\,H^+ + 3\,e^- \longrightarrow V^{2+} + 3\,H_2O$ ✓ $Zn \longrightarrow Zn^{2+} + 2\,e^-$ ✓ $2\,VO_3^- + 12\,H^+ + 3\,Zn \longrightarrow 2\,V^{2+} + 6\,H_2O + 3\,Zn^{2+}$ ✓ **Multiples of this equation are the ONLY correct answer**	3	**ALLOW** multiples **NO ECF** from incorrect half equations **ALLOW** multiples, e.g. $VO_3^- + 6\,H^+ + 1½\,Zn \longrightarrow V^{2+} + 3\,H_2O + 1½\,Zn^{2+}$

Question			Answer	Marks	Guidance
4	(b)	(i)	Pt: Pt^{2+} **OR** +2/2+ **AND** Cl: 2 × Cl^- **OR** 2 × –1 **OR** 2 Cl^-/Cl with oxidation number –1 ✓	1	**DO NOT ALLOW** response in terms of 'Cl_2'or 'Cl **molecule**', rather than Cl^- **DO NOT ALLOW** 'charges cancel' without the charges/oxidation numbers involved being stated **DO NOT ALLOW** if NH_3 shown to have charge
4	(b)	(ii)	 *cis* *trans* **OR**  *cis* *trans* ✓✓ For each structure **AND** correct *cis* and *trans* labels **AWARD** 1 mark for **TWO** correct structures with incorrect *cis* and *trans* labels **OR** no labels. --- Ligands **donates** electron pairs **OR** Pt/Pt^{2+}/metal (ion) **accepts** lone pairs ✓	3	**IGNORE** any charge, i.e. Pt^{2+} OR Cl^-, even if wrong Bonds **MUST** go to **N** of to **NH_3** **IGNORE** labelled bond angles (even if wrong) **DO NOT ALLOW any** structure that cannot be in one plane If ligands are orientated correctly in *cis* **AND** *trans*, but connectivity to N is poor **ALLOW** 1 mark for two diagrams --- **ALLOW** coordinate bonds shown on diagrams provide that they start from a lone pair on ligands
4	(b)	(iii)	***cis***-platin binds to DNA (of cancer cells) **OR *cis***-platin stops (cancer) cells dividing/replicating ✓	1	***ALLOW*** *cis-isomer:* ***cis*** is essential **IGNORE** simply '*cis*-platin used in cancer treatment'

Question			Answer	Marks	Guidance
4	(c)		**Colour of $Co^{2+}(aq)$ OR $[Co(H_2O)_6]^{2+}$ 1 mark** Pink solution seen at least once **AND** not contradicted ✓ ***REACTION OF Co^{2+} with NaOH(aq) 3 marks*** **Correct equation** $Co^{2+}(aq) + 2OH^-(aq) \longrightarrow Co(OH)_2(s)$ ✓ state symbols **not** required **Observation** blue precipitate/solid ✓ **Type of reaction** precipitation ✓	7	***FULL ANNOTATIONS MUST BE USED*** **ALLOW equilibrium signs in all equations** **IGNORE state symbols** **IGNORE an incorrect formula for an observation** --- **ALLOW** '$Co^{2+}(aq)$ is pink' or similar wording (aq) **OR** $[Co(H_2O)_6]^{2+}$ is equivalent to 'solution' **DO NOT ALLOW** pink **precipitate** **ALLOW** $[Co(H_2O)_6]^{2+} + 2OH^- \rightarrow Co(OH)_2(H_2O)_4 + 2H_2O$ **ALLOW** 'hybrid' equations, e.g. $Co^{2+} + 2NaOH \rightarrow Co(OH)_2 + 2Na^+$ $[Co(H_2O)_6]^{2+} + 2OH^- \rightarrow Co(OH)_2 + 6H_2O$ **ALLOW** any shade of blue **IGNORE** changes in colour over time **DO NOT ALLOW** 'precipitate reaction' **IF** equation with $[Co(H_2O)_6]^{2+}$ has been shown, **ALLOW** acid–base **OR** neutralisation
			REACTION OF Co^{2+} WITH HCl(aq) 3 marks **Correct equation** $[Co(H_2O)_6]^{2+} + 4Cl^- \longrightarrow [CoCl_4]^{2-} + 6H_2O$ ✓ **Observation** blue (solution) ✓ **Type of reaction** ligand substitution ✓		**ALLOW** $CoCl_4^{2-}$ i.e. no brackets **OR** $Co(Cl)_4^{2-}$ **ALLOW** $[Co(H_2O)_6]^{2+} + 4HCl \longrightarrow [CoCl_4]^{2-} + 6H_2O + 4H^+$ **IGNORE** $Co^{2+} + 4Cl^- \longrightarrow CoCl_4^{2-}$ **ALLOW** any shades of blue **DO NOT ALLOW** blue **precipitate** **ALLOW** ligand exchange

Question	Answer	Marks	Guidance
	Total	**19**	

Question			Answer	Marks	Guidance
5	(a)	(i)	partlially dissociates ✓	1	For dissociates, **ALLOW** ionises
5	(a)	(ii)	$(K_a =) \frac{[H^+(aq)][CH_3COO^-(aq)]}{[CH_3COOH(aq)]}$ ✓ All species **MUST** have square brackets	1	**ALLOW** $[H_3O^+]$ for $[H^+]$ **IGNORE** $\frac{[H^+]^2}{[C_2H_5COOH]}$ **OR** $\frac{[H^+]\,[A^-]}{[HA]}$ **IGNORE** state symbols

Question			Answer	Marks	Guidance
5	(a)	(iii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = **3.22**, award **2 marks** --- $[H^+] = \sqrt{(1.30 \times 10^{-5}) \times (2.85 \times 10^{-2})}$ **OR** 6.09×10^{-4} (mol dm^{-3}) ✓ pH = –log 6.09×10^{-4} = **3.22** ✓ *Must be from a calculated $[H^+]$* **NOTE**: The marks are **ONLY** available from attempted use of K_a **AND** $[C_2H_5COOH]$	**2**	**ALLOW** 6.09×10^{-4} to calculator value of $6.086871117 \times 10^{-4}$ correctly rounded **ALLOW ECF** from incorrect $[H^+]$ derived from K_a **AND** $[H^+]$ **ALLOW** use of quadratic equation – gives same answer of 3.22 --- **COMMON ERRORS (MUST be to 2 DP)** Mark other errors by **ECF** **pH = 6.43 1 mark** –log $(1.30 \times 10^{-5}) \times (2.85 \times 10^{-2})$ *No* √ **pH = 3.16 1 mark** Wrong acid ($K_a = 1.70 \times 10^{-5}$) but all else correct **pH = 4.89 0 marks** $-\log(1.30 \times 10^{-5}) = 4.89$ *–log K_a* **pH = 1.55 0 marks** $-\log(2.85 \times 10^{-2}) = 4.87$ *–log $[H^+]$*

Question			Answer	Marks	Guidance
5	(a)	(iv)	$C_2H_5COOH + CH_3COOH \rightleftharpoons \mathbf{C_2H_5COOH_2^+ + CH_3COO^-}$ ✓ **Base 2 Acid 1 Acid 2 Base 1** ✓ *1st mark for correct products, $C_2H_5COOH_2^+$ **AND** CH_3COO^-* *2nd mark for correct labels*	2	**ALLOW ECF** for 2nd mark if H^+ transfer shown other way round, i.e. $C_2H_5COOH + CH_3COOH \rightleftharpoons \mathbf{C_2H_5COO^- + CH_3COOH_2^+}$ × **Acid 1 Base 2 Base 1 Acid 2** ✓ **ECF** **NO OTHER ECF** **ALLOW** A1, B1, etc or any unambiguous labels
5	(b)	(i)	proton/H^+ acceptor ✓	1	**DO NOT ALLOW** OH^- donor
5	(b)	(ii)	**FIRST CHECK THE ANSWER ON THE ANSWER LINE** **IF** answer = 5.35 (g) award **3 marks** $n(Ba(OH)_2) = (250/1000) \times 0.1250 = 0.03125$ (mol) ✓ $M(Ba(OH)_2) = 171.3$ (g mol^{-1}) ✓ mass = $0.03125 \times 171.3 = 5.35$ (g) ✓ **NOTE**: Answer to **two** decimal places	3	**ALLOW ECF** but answer required to **two** decimal places

Question			Answer	Marks	Guidance
5	(b)	(iii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = **13.40** award **3 marks** $[OH^-] = 2 \times 0.1250 = 0.25(0)$ (mol dm^{-3}) ✓ $[H^+] = \frac{1.00 \times 10^{-14}}{0.25(0)}$ **OR** $4(.00) \times 10^{-14}$ (mol dm^{-3}) ✓ *Subsumes 1st mark* pH = –log 4.00×10^{-14} = **13.40** ✓ *Must be from a calculated $[H^+]$* --- **pOH variation (also worth 3 marks)** $[OH^-] = 2 \times 0.125 = 0.25(0)$ (mol dm^{-3}) ✓ pOH = –log 0.25(0) = 0.60 ✓ pH = 14.00 – 0.60 = 13.40 ✓ *Must be from a calculated pOH*	3	**Marks are for correctly calculated values. Working shows how values have been derived.** **ALLOW** by **ECF** $\frac{1.00 \times 10^{-14}}{\text{calculated value of } [OH^-]}$ **DO NOT ALLOW** 13.4 *not **two** decimal places* --- **COMMON ERRORS for pH** 13.4 ✓✓ *not 2 DP* 13.10 ✓✓ *no × 2 for $[OH^-]$* 13.1 ✓ *no × 2 for $[OH^-]$ **AND** 1 DP only* 12.80 ✓✓ ÷2 instead of × *2 for $[OH^-]$* 0.60 ✓ 2 × 0.1250 expressed as pH 0.90 **no marks** *–log 0.125*

Question			Answer	Marks	Guidance
5	(c)		**Possible conclusion from mixing C_2H_5COOH and $Ba(OH)_2$** Buffer forms when • acid / C_2H_5COOH is in excess • **OR** buffer contains C_2H_5COOH **AND** $C_2H_5COO^-$ / $(C_2H_5COO)_2Ba$ ✓ Independent of calculations ***n*(Ba(OH)$_2$)** = (100/1000) × 0.1250 = 0.0125 (mol) ✓ ***n*(C_2H_5COOH)** = (200/1000) × 0.324 = 0.0648 (mol) ✓ **Correct calculation showing that C_2H_5COOH is in excess** **Must use** 2 × 0.0125 **OR** 0.0250 ✓ Possible calculations could show: • C_2H_5COOH is 0.0398 mol in excess • ratio $n(C_2H_5COOH)/n(Ba(OH)_2 > 2/1$ • $n(C_2H_5COOH) > n(OH^-)$	4	**ORA** Buffer does **not** form when • acid / C_2H_5COOH is **not** in excess/ $Ba(OH)_2$ is in excess • **OR** buffer does **not** contains C_2H_5COOH **AND** $C_2H_5COO^-$ / $(C_2H_5COO)_2Ba$ ✓ $n(C_2H_5COOH) = 0.0648 – 0.0250 = 0.0398$ ratio $n(C_2H_5COOH)/n(Ba(OH)_2) = 0.0648/0.0125 = 5.184/1$ $n(C_2H_5COOH) > n(OH^-) = 0.0648 > 0.0250$

Question			Answer	Marks	Guidance
5	(d)		• **Quality of written communication, QWC** • 2 marks are available for explaining how the equilibrium system allows the buffer solution to control the pH on addition of H^+ and OH^- (see below) • ---------- • $H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$ ✓ • • ---------- • • H_2CO_3 reacts with added alkali /OH^- • **OR** $H_2CO_3 + OH^- \rightarrow$ • **OR** added alkali reacts with H^+ • **OR** $H^+ + OH^- \rightarrow$ ✓ Equilibrium → right **OR** Equilibrium → HCO_3^- ✓ (**QWC**) • • HCO_3^- reacts with added acid /H^+ ✓ Equilibrium → left **OR** Equilibrium → H_2CO_3 ✓ (**QWC**)	5	***FULL ANNOTATIONS MUST BE USED*** **----------** **Note: If there is no equilibrium equation then the two subsequent equilibrium marks are not available: max 2** **DO NOT ALLOW** HA $\rightleftharpoons$ $H^+ + A^-$ **DO NOT ALLOW** more than one equilibrium equation. **----------** **ALLOW** response in terms of H^+, A^- and HA **IF** more than one equilibrium shown, it **must** be clear which one is being referred to by labeling the equilibria. **ALLOW** weak acid reacts with added alkali **DO NOT ALLOW** acid reacts with added alkali **ALLOW** conjugate base reacts with added acid **DO NOT ALLOW** salt/base reacts with added acid
			Total	**22**	

Question			Answer	Marks	Guidance
6	(a)		$(K_c =) \frac{[NH_3]^2}{[N_2]\,[H_2]^3}$ ✓	1	Must be square brackets **IGNORE** state symbols

Question			Answer	Marks	Guidance
6	(b)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 0.0368 $dm^6\ mol^{-2}$, award **6 marks** **IF** answer = 0.0368 with incorrect units, award **5 mark** --- **Equilibrium amounts in mol 2 MARKS** $n(N_2)$ = 10.40 – 5.60/2 = 7.6(0) (mol) ✓ $n(H_2)$ = 22.50 – 1.5 × 5.60 = 14.1(0) (mol) ✓ **Equilibrium concentrations (moles ÷ 5) 1 MARK** N_2 = 7.60/5 = 1.52 (mol dm^{-3}) **AND** H_2 = 14.1/5 = 2.82 (mol dm^{-3}) **AND** NH_3 = 5.60/5 = 1.12 (mol dm^{-3}) ✓ **Calculation of K_c and units 3 MARKS** $K_c = \frac{1.12^2}{1.52 \times 2.82^3}$ ✓ K_c = 0.0368 ✓ $dm^6\ mol^{-2}$ ✓ ***3SF** required* --- ***NOTE**: If inverted K_c expression used, look back to Q6(a) Then apply ECF with ALL marks being available in 16(b).* *Expected answer = 27.2* *Expected units* = $mol^2\ dm^{-6}$ *See also Common errors*	6	**FULL ANNOTATIONS NEEDED** **IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below --- **ALLOW ECF** from incorrect moles of SO_2, O_2 **AND** SO_2 **ALL three** concentrations required for this mark **ALLOW ECF** from incorrect concentrations or moles (if concentration stage is omitted) **ALLOW ECF** from wrong K_c expression for K_c value and units For units, **ALLOW** $mol^{-2}\ dm^6$ **DO NOT ALLOW** dm^6/mol^2 **Common errors for K_c** **1.47×10^{-3}** *missing ÷ 5 to calculate concentrations* *4 marks + units mark (i.e. just one mark dropped)* **0.0338** *Subtracting 5.60 from initial moles of N_2 and H_2* *3 marks + units mark* **6.62×10^{-3}** *Use of initial concentrations of N_2 and H_2* *(3 marks + units mark)* **2.65×10^{-4}** *Use of initial moles of N_2 and H_2 and no ÷5 for concs* *(2 marks + units mark)* **27.2** *Calculated value from inverted K_c* *4 marks + units mark for $mol^2\ dm^{-6}$*
			24		

Question			Answer	Marks	Guidance
6	(c)	(i)	K_c is smaller **AND** (forward) reaction is **exothermic OR** ΔH is negative ✓	1	Link to ΔH/exothermic essential **ALLOW reverse** reaction is **endothermic** **DO NOT ALLOW** equilibrium shifts to the right (**CON**)
6	(c)	(ii)	K_c is the same **AND** K_c is temperature dependent/only changed by temperature **OR** K_c is not changed by pressure ✓	1	**ALLOW** K_c is **only** changed by temperature **IGNORE** same number of moles on both side
			Total	**9**	

Question			Answer	Marks	Guidance
7	(a)	(i)	complete circuit with voltmeter **AND** salt bridge linking two half-cells ✓ Cr electrode in Cr^{3+} solution ✓ Pt electrode in solution containing Fe^{2+} **AND** Fe^{3+} ✓ **Conditions** *Units essential* (Temperature of) 298 K / 25ºC **AND** (solution concentrations of) 1 mol dm^{-3} ✓ (**may be on diagram**)	**4**	***FULL ANNOTATIONS MUST BE USED*** circuit shown **must** be complete, *ie* must be capable of working salt bridge **must** be labelled and must dip into both solutions Half cells can be drawn in either order Half cells must show electrodes dipping into solutions **ALLOW** small gaps in circuit **ALLOW** 1M and 1 mol/dm^3 **DO NOT ALLOW** 1 mol **IGNORE** pressure *(No gases in this cell)*
7	(a)	(ii)	$Cr(s) + 3Fe^{3+}(aq) \rightarrow Cr^{3+}(aq) + 3Fe^{2+}(aq)$ ✓ *State symbols **not** required*	**1**	**IGNORE** state symbols **ALLOW** equilibrium sign providing reactants and products are on correct sides of equation
7	(a)	(iii)	*E* = 1.51 (V) **AND** Sign of Cr electrode: – /negative ✓	**1**	**IGNORE** sign for *E*
7	(b)		**Assume Cr^{3+}|Cr OR Cr half-cell unless otherwise stated.** $[Cr^{3+}]$ increases **OR** > 1 mol dm^{-3} ✓ Equilibrium (shown in table) shifts to right **OR** towards Cr ✓ Electrons are removed/used up/fewer electrons released **OR**	**3**	***FULL ANNOTATIONS MUST BE USED*** --- **ALLOW** $[Cr^{3+}]$ more than standard concentration/1 mol dm^{-3} **IGNORE** $CrCl_3$ reacts **Take care:** Response may refer to a **reverse** half equation written by candidate. The equilibrium then shifts to left. **IGNORE** comments about $E^{\ominus}$ changing

Question			Answer	Marks	Guidance
			E (for $Cr^{3+}|Cr$) is less negative / more positive **OR** The cell has a smaller **difference** in E ✓		**IGNORE** just 'cell potential decreases' (in the question)
7	**(c)**	**(i)**	$HCOOH(l) \rightarrow CO_2(g) + 2H^+ + 2e^-$	**1**	**ALLOW** multiples e.g. $2HCOOH(l) \rightarrow 2CO_2(g) + 4H^+ + 4e^-$
7	**(c)**	**(ii)**	HCOOH is a **liquid OR** is **less** volatile **AND** HCOOH is easier to store/transport/stored more safely **OR** H_2 is more explosive/more flammable ✓	**1**	Assume that '**it**' refers to HCOOH **ALLOW ORA** throughout **IGNORE** comments about efficiency **IGNORE** comments about biomass and renewable
7	**(d)**	**(i)**	amount MnO_4^- used = $0.01500 \times \frac{25.40}{1000}$ = **3.81×10^{-4}** (mol) ✓ amount SO_3^{2-} = **$3.81 \times 10^{-4} \times 2.5$** = **$9.525 \times 10^{-4}$** (mol) ✓ amount SO_3^{2-} in original 250 cm^3 = **10 ×** 9.525×10^{-4} = **9.525×10^{-3}** mol ✓ Mass of Na_2SO_3 in sample = **126.1** × 9.525×10^{-3} g = **1.20 g** ✓ $n(H_2O) = \frac{2.40 - 1.20}{18.0}$ = **6.67×10^{-2}** (mol) ✓	**6**	***FULL ANNOTATIONS MUST BE USED*** **IF** a step is omitted but subsequent step subsumes previous, then award mark for any missed step **Working: at least 3 SF throughout until final % mark** **BUT** ignore trailing zeroes, ie for 0.01500 allow 0.015/0.0150 --- **ALLOW ECF at all stages** **ALLOW** M(hydrated sodium sulfite) = $\frac{2.40}{9.525 \times 10^{-3}}$ = 252 ✓ Molar mass of H_2O = 252 – 126.1 = 125.9 ✓

Question			Answer	Marks	Guidance
			$n(Na_2SO_3) : n(H_2O) = 9.525 \times 10^{-3} : 6.67 \times 10^{-2} = 1 : 7$ Formula = **$Na_2SO_3 \bullet 7H_2O$** ✓ *Formula is required. 1:7 ratio is insufficient*		*Number of* H_2O of crystallisation = $\frac{125.9}{18.0} = 7$ Formula = **$Na_2SO_3 \bullet 7H_2O$** ✓
	(d)	**(ii)**	***MARK INDEPENDENTLY*** ***Except for multiples, equations are only correct answers*** *Overall:* $2MnO_4^- + 6H^+ + 5SO_3^{2-} \rightarrow 2Mn^{2+} + 5SO_4^{2-} + 3H_2O$ ✓ *Half equations*: $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$ ✓ $SO_3^{2-} + H_2O \rightarrow SO_4^{2-} + 2H^+ + 2e^-$ ✓	**3**	**ALLOW multiples and equilibrium signs throughout** **IGNORE** state symbols throughout e.g. $MnO_4^- + 3H^+ + 2½\ SO_3^{2-} \rightarrow Mn^{2+} + 2½\ SO_4^{2-} + 1½\ H_2O$
			Total	**20**	