GCE

Chemistry A

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

Advanced GCE

Mark Scheme for June 2015

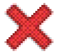
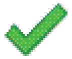
This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

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

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

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

1. These are the annotations, (including abbreviations), including those used in scoris, which are used when marking

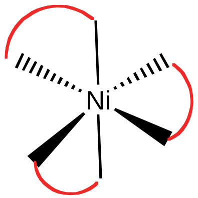
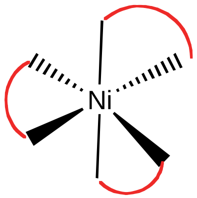
Annotation	Meaning of annotation
BOD	Benefit of doubt given
CON	Contradiction
	Incorrect response
ECF	Error carried forward
I	Ignore
NAQ	Not answered question
NBOD	Benefit of doubt not given
POT	Power of 10 error
^	Omission mark
RE	Rounding error
SF	Error in number of significant figures
	Correct response

2. Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

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

3. The following questions should be annotated with **ALL annotations** to show where marks have been awarded in the body of the text:
1(d)
3(b)(i)
3(b)(iv)
4(e)(iii)
5(b)(ii)
7(b)

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. $Cu^{2+} + 2NaOH \rightarrow Cu(OH)_2 + 2Na^{+}$ $[Cu(H_2O)_6]^{2+} + 2OH^{-} \rightarrow Cu(OH)_2 + 6H_2O$ $CuSO_4 + 2NaOH \rightarrow Cu(OH)_2 + Na_2SO_4$ **ALLOW** any shade of blue
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*** $\boldsymbol{Co^{2+}}$ -- **REACTION OF** $\mathbf{Co^{2+}}$ **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** $\mathbf{Cu^{2+}}$ **and some for** $\mathbf{Co^{2+}}$ **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. $Co^{2+} + 2NaOH \rightarrow Co(OH)_2 + 2Na^+$ $[Co(H_2O)_6]^{2+} + 2OH^- \rightarrow Co(OH)_2 + 6H_2O$ $CoSO_4 + 2NaOH \rightarrow Co(OH)_2 + Na_2SO_4$ **ALLOW** any shade of blue **IGNORE** changes in colour over time
1	(d)		**REACTION OF** $\mathbf{Co^{2+}}$ **WITH excess** $\mathbf{NH_3(aq)}$ **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** $\mathbf{Co(OH)_2}$ **ALLOW** any shade of brown or yellow **DO NOT ALLOW** brown/yellow precipitate for observation
1	(d)		**REACTION OF** $\mathbf{Co^{2+}}$ **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 ✓

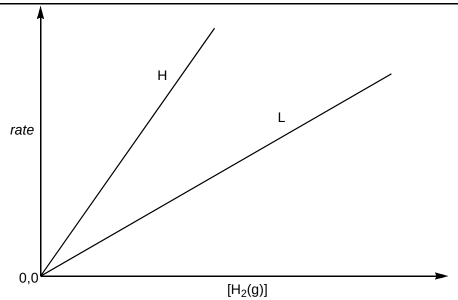
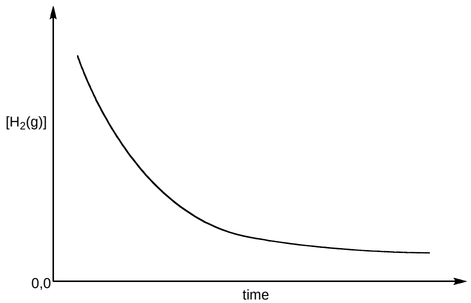
UNITS FOR 1 MARK:
$dm^6\ mol^{-2}\ s^{-1}$ ✓
</td>
<td>4</td>
<td>
Note: rate and [NO] are any correct pair of readings from the graph,
The [NO] below are the most commonly seen.
For these [NO] values, these are the ONLY rates allowed
<table>
<tr><th>[NO]</th><th>rate</th><th>k</th><th>k</th></tr>
<tr><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 × 206) – (4 × S + 238) **OR** 4 S = 164 + (186 + 2 × 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 Δ*G* calculation** --- **Δ*G* calculation: 2 marks** ΔG = –234 – 298 × –0.164 ✓ = –185 (kJ mol^{-1}) ✓ **IGNORE** units (even if wrong) –185 subsumes 1st mark) **Feasibility comment for negative Δ*G* answer: 1 mark** (Forward) reaction is feasible / spontaneous **AND** Δ*G* < 0 / ΔH – TΔS < 0 ✓	2 1	**ALLOW** Δ*G* correctly calculated from 3 SF up to calculator value of –185.128 **ALLOW** working in J, *ie*: Δ*G* = –234000 – 298 × –164 ✓ = –185000 (J mol^{-1}) ✓ **ALLOW** 1 mark for use of 25 **OR** mixture of kJ and J, e.g. Δ*G* = –234 – 25 × –0.164 = –229.9 Δ*G* = –234 – 298 × –164 = +48638 **ALLOW ECF** if calculated value for Δ*G* is +ve Then 'correct' response for 3rd mark would be **not** feasible/not spontaneous **AND** Δ*G* > 0 / ΔH – TΔS > 0
3	(a)	(iv)	(Δ*G* =) –234 – 1427 × $\frac{-164}{1000}$ = 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 Δ*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*Δ*S* and Δ*H*, *e.g IGNORE T*Δ*S is more negative than* Δ*H*

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**

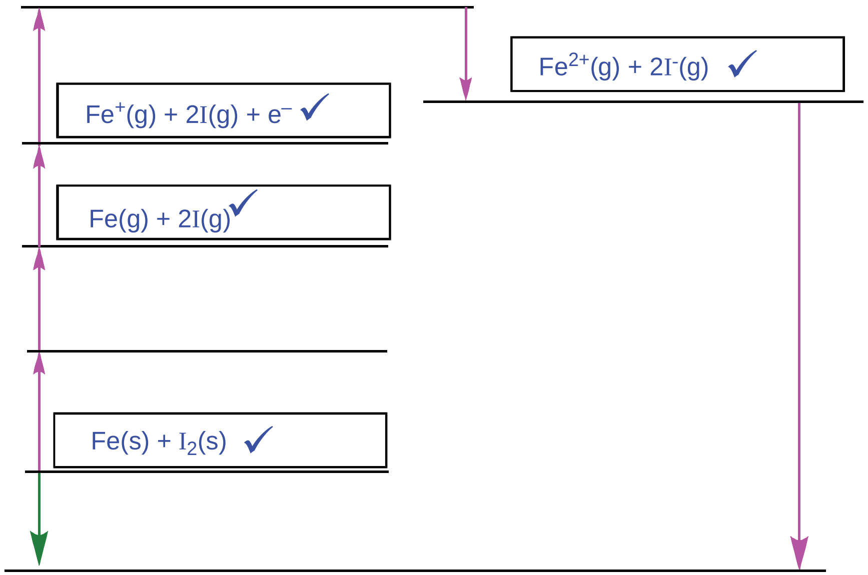
Question			Answer	Marks	Guidance
3	(b)	(iii)	ΔH is negative / '– ' / –ve **AND** yield of SO_3 decreases ✓	**1**	**IGNORE** exothermic and endothermic
3	(b)	(iv)	**IGNORE** le Chatelier responses -- ***Each marking point is independent*** ***K_c*** K_c does not change (with pressure/ concentration) ✓ ***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** --- $[H^+] = \dfrac{1.00 \times 10^{-14}}{0.5(00)}$ **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 =) $\dfrac{[H^+]\,[C_2H_5COO^-]}{[C_2H_5COOH]}$ ✓	1	**IGNORE** $\dfrac{[H^+]^2}{[C_2H_5COOH]}$ **OR** $\dfrac{[H^+]\,[A^-]}{[HA]}$ **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} ✓ $[H^+] = \sqrt{K_a \times [C_2H_5COOH]} = \sqrt{1.35 \times 10^{-5} \times 0.12(0)}$ **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** $-\log\sqrt{(1.35 \times 10^{-5} \times 0.480)}$ *Original conc* **pH = 5.79 2 marks** $-\log(1.35 \times 10^{-5} \times 0.120)$ *No √* **pH = 5.19 1 mark** $-\log(1.35 \times 10^{-5} \times 0.480)$ *Original conc, no √* **pH = 4.87 0 marks** $-\log(1.35 \times 10^{-5}) = 4.87$ *–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 $\rightarrow C_2H_5COO^-$ **OR** Equilibrium $\rightarrow$ 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)** $n(\text{Mg}) = \frac{6.075}{24.3} = 0.25(0)$ 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 = $-\log 4.5 \times 10^{-6}$ = **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 for 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 = $-\log 8.1 \times 10^{-6}$ = **5.09** **2.** $[H^+] = 1.35 \times 10^{-5} \times \frac{0.50}{1.25}$ pH = $-\log 5.4 \times 10^{-6}$ = **5.27** **3.** $[H^+] = 1.35 \times 10^{-5} \times \frac{0.75}{1.50}$ pH = $-\log 6.75 \times 10^{-6}$ = **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 $\text{pH} = \text{p}K_a + \log\frac{1.5}{0.5}$ **OR** $\text{p}K_a - \log\frac{0.5}{1.5}$ pH = 4.87 + 0.48 = 5.35 ✓ **ALLOW** $-\log K_a$ for $\text{p}K_a$		
			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+}: $1s^22s^22p^63s^23p^63d^6$ ✓ Br^-: $1s^22s^22p^63s^23p^63d^{10}4s^24p^6$ ✓	2	**ALLOW** 4s before 3d, ie $1s^22s^22p^63s^23p^64s^23d^{10}4p^6$ **ALLOW** $1s^2$ written after answer prompt (*ie* $1s^2$ twice) **ALLOW** upper case D, etc and subscripts, e.g. ……$4S_23D_1$ **ALLOW** for Fe^{2+} **……….**$4s^0$ **DO NOT ALLOW** [Ar] as shorthand for $1s^22s^22p^63s^23p^6$ Look carefully at $1s^22s^22p^63s^23p^6$ – 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. $½H_2 + Ag^+ \rightarrow Ag + H^+$ State symbols **NOT** required **ALLOW** equilibrium sign
6	(c)	(i)	CN^- + H_2O ⇌ **HCN** + **OH^-** **AND** Base 2 Acid 1 Acid 2 Base 1 ✓	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. $3O_2 + 12H^+ + 12e^- \rightarrow 6H_2O$ $\frac{1}{2}O_2 + 2H^+ + 2e^- \rightarrow H_2O$ **ALLOW** e (*ie* no − sign) **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** $Na_2O + H_2O \rightarrow 2NaOH$ ✓ $NaFeO_2 + 2H_2O \rightarrow Fe(OH)_3 + NaOH$ ✓	2	**ALLOW** multiples throughout **IGNORE** state symbols **ALLOW** $Na_2O + H_2O \rightarrow 2Na^+ + 2OH^-$ **DO NOT ALLOW** equations with uncancelled species. e.g. $Na_2O + 2H_2O \rightarrow 2NaOH + H_2O$ **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 = $0.1000 \times \frac{25.50}{1000}$ = $\mathbf{2.550 \times 10^{-3}}$ (mol) ✓ amount I_2 = 2.550×10^{-3} **÷ 2** $\mathbf{1.275 \times 10^{-3}}$ (mol) ✓ amount CrO_4^{2-} = **2/3 ×** 1.275×10^{-3} **OR** 1.275×10^{-3} **÷ 1.5** = $\mathbf{8.5(00) \times 10^{-4}}$ (mol) ✓ amount CrO_4^{2-} in original 1000 cm^3 = **40 ×** $8.5(00) \times 10^{-4}$ = $\mathbf{3.4(00) \times 10^{-2}}$ 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*: $CrO_4^{2-} + 3I^- + 4H_2O \rightarrow Cr^{3+} + 1½\ I_2 + 8OH^-$ ✓ *Half equations*: $CrO_4^{2-} + 4H_2O + 3e^- \rightarrow Cr^{3+} + 8OH^-$ ✓ $2I^- \rightarrow I_2 + 2e^-$ ✓	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. $CrO_4^{2-} + 8H^+ + 3e^- \rightarrow Cr^{3+} + 4H_2O$
			Total	**11**	

OCR (Oxford Cambridge and RSA Examinations)
1 Hills Road
Cambridge
CB1 2EU

OCR Customer Contact Centre

Education and Learning
Telephone: 01223 553998
Facsimile: 01223 552627
Email: general.qualifications@ocr.org.uk

www.ocr.org.uk

For staff training purposes and as part of our quality assurance programme your call may be recorded or monitored

Oxford Cambridge and RSA Examinations
is a Company Limited by Guarantee
Registered in England
Registered Office; 1 Hills Road, Cambridge, CB1 2EU
Registered Company Number: 3484466
OCR is an exempt Charity

OCR (Oxford Cambridge and RSA Examinations)
Head office
Telephone: 01223 552552
Facsimile: 01223 552553