OCR
Oxford Cambridge and RSA

GCE

Chemistry A

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

Advanced GCE

Mark Scheme for June 2017

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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.

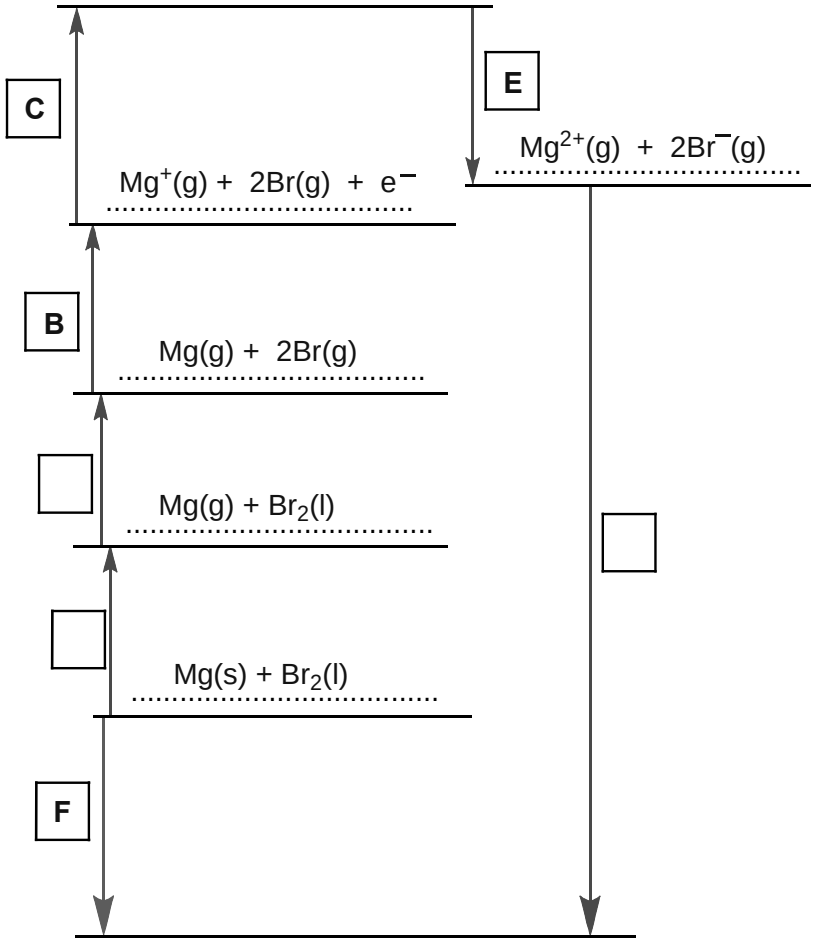
Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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

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

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
$= 7.59 \times 10^4$ ✓

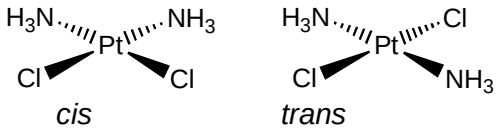
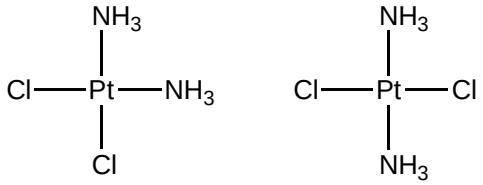
units:
$dm^6\ mol^{-2}\ s^{-1}$ ✓</td><td>3</td><td>FULL ANNOTATIONS MUST BE USED

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**	

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