

Markscheme

November 2025

Chemistry

Higher level

Paper 2

21 pages

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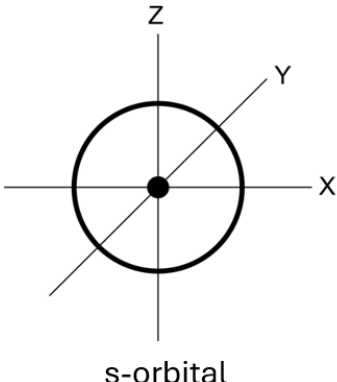
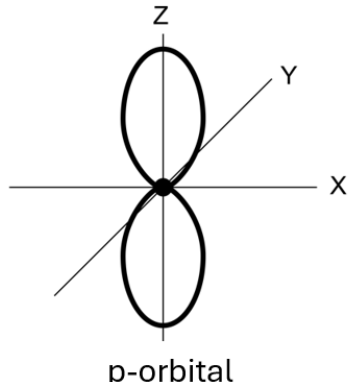
Subject Details: Chemistry Higher Level Paper 2 Markscheme

Candidates are required to answer **ALL** questions. Maximum total = **[90 marks]**.

1. Each row in the “Question” column relates to the smallest subpart of the question.
2. The maximum mark for each question subpart is indicated in the “Total” column.
3. Each marking point in the “Answers” column is shown by means of a tick (✓) at the end of the marking point.
4. A question subpart may have more marking points than the total allows. This will be indicated by “**max**” written after the mark in the “Total” column. The related rubric, if necessary, will be outlined in the “Notes” column.
5. An alternative word is indicated in the “Answers” column by a slash (/). Either word can be accepted.
6. An alternative answer is indicated in the “Answers” column by “**OR**”. Either answer can be accepted.
7. An alternative markscheme is indicated in the “Answers” column under heading **ALTERNATIVE 1** *etc.* Either alternative can be accepted.
8. Words inside chevrons « » in the “Answers” column are not necessary to gain the mark.
9. Words that are underlined are essential for the mark.
10. The order of marking points does not have to be as in the “Answers” column, unless stated otherwise in the “Notes” column.
11. If the candidate’s answer has the same “meaning” or can be clearly interpreted as being of equivalent significance, detail and validity as that in the “Answers” column then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by **OWTTE** (or words to that effect) in the “Notes” column.
12. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.
13. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking, indicate this by adding **ECF** (error carried forward) on the script.
14. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the “Notes” column.
15. If a question specifically asks for the name of a substance, do not award a mark for a correct formula unless directed otherwise in the “Notes” column. Similarly, if the formula is specifically asked for, do not award a mark for a correct name unless directed otherwise in the “Notes” column.
16. If a question asks for an equation for a reaction, a balanced symbol equation is usually expected, do not award a mark for a word equation or an unbalanced equation unless directed otherwise in the “Notes” column.

Ignore missing or incorrect state symbols in an equation unless directed otherwise in the “Notes” column.

Question			Answers	Notes	Total
1.	(a)	(i)	3p 1 1 1 3s 1↓ 2p 1↓ 1↓ 1↓ 2s 1↓ 1s 1↓ correct labels ✓ correct electron configuration ✓	3 rd shell orbitals must be higher than 2 nd shell for M2.	2

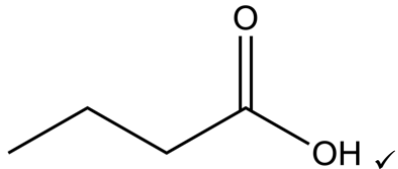
1.	(a)	(ii)	  s-orbital p-orbital correct shape AND label for each. ✓. ✓	The p orbital must be aligned with an axis and the node must be at or close to the origin. Accept p-orbital aligned to any of the three axes.	2
1.	(a)	(iii)	«electron removed from» higher orbital/shell/energy level / further away from the nucleus. ✓ more shielded/lower attractive force «between the nucleus and outer electron ». ✓	Do not accept increase in atomic radius on its own for M1	2
1.	(a)	(iv)	«$1.012 \times 10^6 \text{ J mol}^{-1} / 6.02 \times 10^{23} =$ » $1.68 \times 10^{-18} \text{ «J»}$ ✓ «$1.68 \times 10^{-18} \text{ J} / 6.63 \times 10^{-34} \text{ J s}^{-1} =$ » $2.54 \times 10^{15} \text{ «s}^{-1}\text{»}$ ✓	Award [2] for the correct final answer.	2
1.	(b)	(i)	«$(7.75/30.97) \times 6.02 \times 10^{23}$» = 1.51×10^{23} ✓		1
1.	(b)	(ii)	«$13.75 - 7.75 = 6.00 \text{ g of oxygen}$» «$7.75/30.97, 6.00/16.00 =$» = 0.250 mol P AND 0.375 mol O ✓ «$0.375/0.250 =$» 1.5 ✓ P₂O₃ ✓	Award [1] for P₂O₃, if no working shown.	3

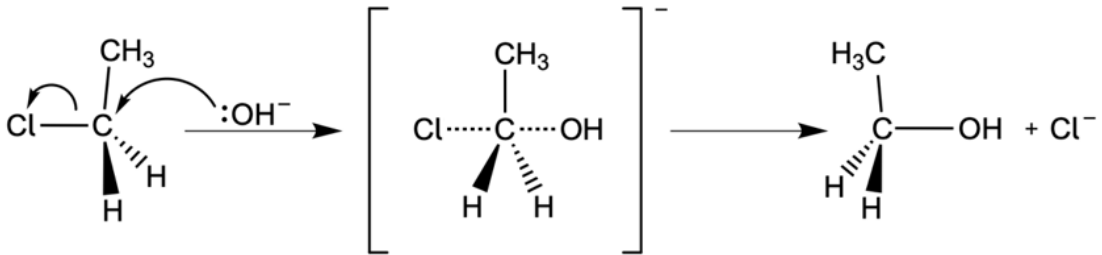
1.	(b)	(iii)	«empirical mass = $109.94 \text{ g mol}^{-1} / (219.88 \div 109.94 = 2)$ » P_4O_6 ✓	<i>Working must be shown</i>	1
1.	(b)	(iv)	simple / molecular AND «polar» covalent ✓ London dispersion forces/dipole-dipole / intermolecular forces are weak ✓		2
1.	(b)	(v)	« $3.4 - 2.2 = 1.2$, $(3.4 + 2.2)/2 = 2.8$ » Electronegativity difference is 1.2. AND Average electronegativity is 2.8 ✓ polar covalent ✓		2
1.	(c)	(i)	$ \begin{array}{c} :\ddot{\text{Cl}}: \\ \\ :\ddot{\text{Cl}}-\text{P}-\ddot{\text{Cl}}: \\ \vdots \quad \vdots \quad \vdots \end{array} $ ✓	<i>Accept any combination of lines and dots/crosses to represent electron pairs.</i>	1
1.	(c)	(ii)	PCl_3 . trigonal pyramid ✓ PCl_5 . trigonal bipyramid ✓		2
1.	(c)	(iii)	$107^\circ - 100^\circ$ ✓ (actual value 100.3°)		1

Question			Answers	Notes	Total
2.	(a)		delocalised «cloud of» π /pi electrons / bonds ✓	<i>π/pi electrons / bonds must be mentioned.</i> <i>Accept answers describing a resonance structure.</i>	1
2.	(b)		Chemical reason: <i>Any one of:</i> does not «easily» undergo «electrophilic» addition. OR undergoes electrophilic substitution reactions. OR enthalpy of hydrogenation is not 3x that of cyclohexene/ less exothermic than 3x that of cyclohexene. OR all «C-C» bond energies are the same. ✓ Physical reason: <i>Any one of:</i> all bond lengths are the same. OR all bond angles are the same / molecule is planar. ✓	<i>Award [1 max] for each property.</i> <i>Award [1 max] if properties are reversed.</i>	2

2.	(c)	correct structure AND continuation bonds shown ✓ addition «polymerisation» ✓	<i>Accept either structure for the benzene ring.</i> <i>Accept phenyl rings on either side of the polymer backbone</i>	2
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Question			Answers	Notes	Total
3.	(a)	(i)	conjugate acid $\text{H}_3\text{O}^+\text{«(aq)»}$ AND conjugate base $\text{H}_2\text{O}\text{«(l)»}$ ✓ conjugate acid $\text{HNO}_2\text{«(aq)»}$ AND conjugate base $\text{NO}_2^-\text{«(aq)»}$ ✓		2
3.	(a)	(ii)	$K_a \text{ «}10^{-3.25}\text{»} = 5.62 \times 10^{-4}$ ✓ $\text{« [H}^+\text{] = }10^{-3.00}\text{ »} = 0.001 \text{ «mol dm}^{-3}\text{ »}$ ✓ $\text{« [A}^-\text{] = (5.62 x }10^{-4}\text{ x 1.00)/ 0.001}\text{ »} = 0.562 \text{ «mol dm}^{-3}\text{ »}$ ✓ <i>Alternative solution:</i> $\text{pH} = \text{p}K_a + \log_{10}[\text{salt}]/[\text{acid}]$ ✓ $\text{« log}_{10}[\text{salt}]/[\text{acid}]\text{ »} = -0.25$ OR $\text{«[salt]/[acid]»} = 0.562$ ✓ $\text{« [A}^-\text{] = 0.562/1.00 »} = 0.562 \text{ «mol dm}^{-3}\text{ »}$ ✓	Award [3] for correct final answer.	3
3.	(a)	(iii)	+3 ✓	Accept (III). Do not accept 3+ or 3.	1
3.	(b)	(i)	IUPAC/ international system to name substances/ systematic naming. ✓ names based on their structure/ following rules based on their structure. ✓		2
3.	(b)	(ii)	carboxyl ✓ phenyl «ring» ✓	Do not accept carboxylic acid/benzene/aromatic ring	2

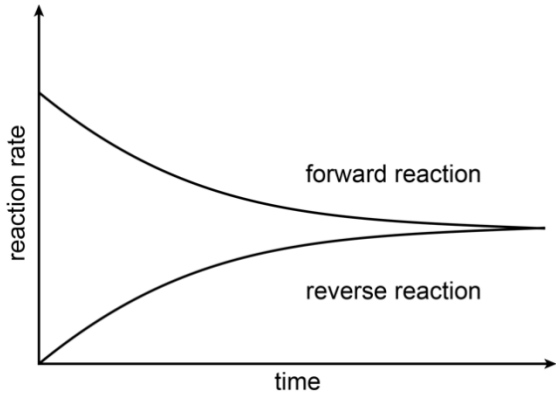
3.	(b)	(iii)	 butanoic acid ✓	Accept any valid isomer of $C_4H_8O_2$ that is not an ester for M1 or M2 Do not accept molecular formula for M1.	2
3.	(c)	(i)	increases rate of reaction ✓ lowers activation energy / by providing an alternative/lower energy pathway / greater number of particles have energy greater than activation energy ✓		2
3.	(c)	(ii)	ultraviolet/UV«light»	Accept sunlight. Do NOT accept light. Accept heat.	1

3.	(c)	(iii)	 curly arrow going from lone pair/negative charge on O in HO⁻ to C ✓ curly arrow from C–Cl to Cl ✓ transition state showing negative charge AND partial bonds ✓ formation of organic product CH₃CH₂OH AND Cl⁻ ✓	Accept curly arrow either going from C–Cl bond to Cl in chloroethane or in the transition state. Do not penalize if HO and Cl are not at 180° to each other. Award [3 max] for S_N1. Do not award M3 if OH ---- C connection is seen.	4
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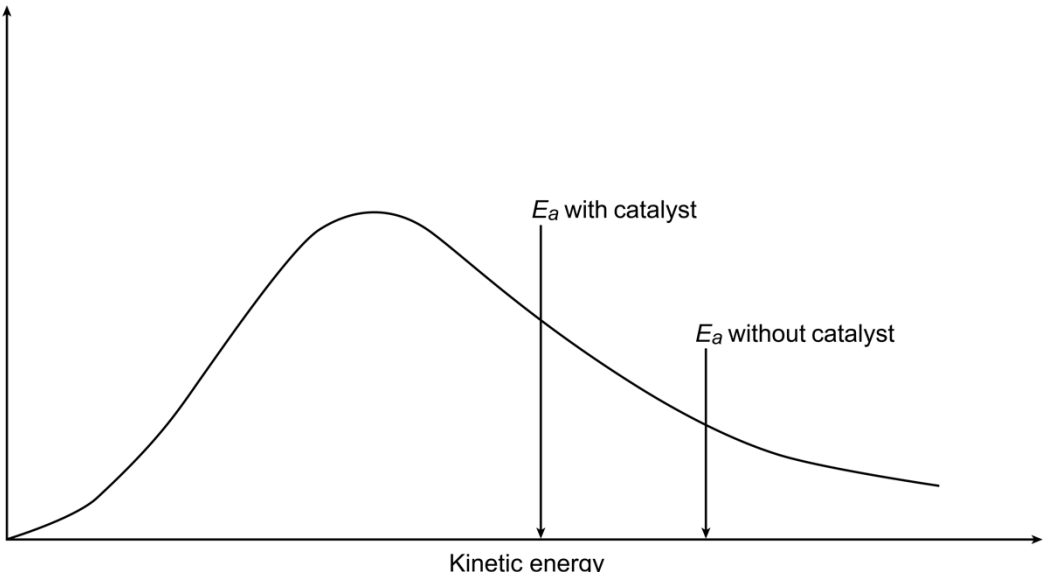
3.	(c)	(iv)	<i>Number of signals:</i> 3 ✓ <i>Chemical shift (ppm) range of each signal:</i> 0.9–1.0 «ppm» AND 3.3–3.7 «ppm» AND 1.0–6.0 «ppm» ✓ <i>Integration traces:</i> 3 AND 2 AND 1 ✓ <i>Splitting pattern expected:</i> triplet/3 AND quartet/quadruplet/4 / multiplet AND «broad» singlet/1/triplet/3 ✓	<i>Accept the chemical shifts and splitting patterns in any order.</i> <i>Accept “3,4 and 1” for the splitting pattern, in any order.</i> <i>Accept any three correct answers for a single signal for [1] each.</i>	4
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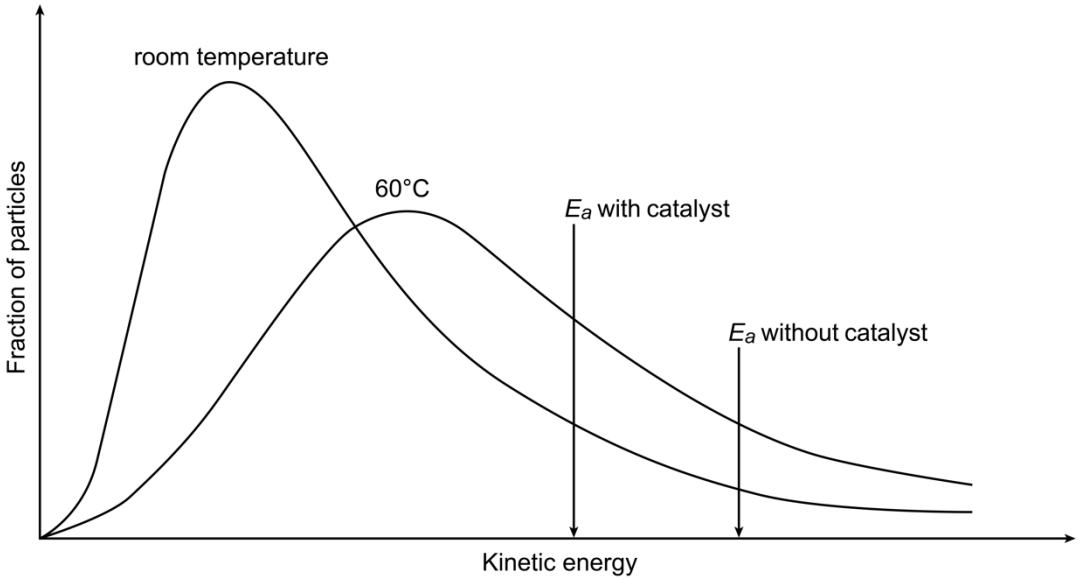
3.	(d)	(i)	Alternative 1: «bonds broken» $1\frac{1}{2} \text{ O}=\text{O} + 4\text{C}-\text{H} + \text{Cl}-\text{Cl} / 1\frac{1}{2} \times 498 + 4 \times 414 + 242 / 2645 \text{ «kJ mol}^{-1}\text{»} \checkmark$ «bonds formed» $\text{C}=\text{O} + 2\text{C}-\text{O} + 2\text{H}-\text{O} + 2\text{H}-\text{Cl} / 804 + 2 \times 358 + 2 \times 463 + 2 \times 431 / 3308 \text{ «kJ mol}^{-1}\text{»} \checkmark$ $\Delta H = \text{«}2645 - 3308 \text{ =» } -663 \text{ «kJ mol}^{-1}\text{» (correct calculation: reactants-products)} \checkmark$ OR Alternative 2: «Bonds broken» $[12(414) + 2(346) + 242 + 1.5(498)] = 6649 \checkmark$ «Bonds formed» $[8(414) + 804 + 2(358) + 2(346) + 2(431) + 2(463)] = 7312. \checkmark$ $\Delta H = \text{«}6649 - 7312 \text{ =» } -663 \text{ «kJ mol}^{-1}\text{» (correct calculation: reactants-products)} \checkmark$	Award [3] for correct final answer. Award [2 max] for +663 «kJ mol⁻¹». Accept breaking and remaking all the other bonds.	3
3.	(d)	(ii)	bond enthalpy values are averages / not specific to this reaction OR bond enthalpies apply to gases but this reaction involves liquids OR the second set of data was specific to the reaction. $\checkmark$		1
3.	(d)	(iii)	$-4 = \Delta H_{\text{f}}^{\ominus} (\text{ester}) + (-286) - (-278 + (-484)) \text{ «kJ mol}^{-1}\text{»} \checkmark$ $\text{«} -4 + 286 - 278 - 484 \text{ =» } -480 \text{ «kJ mol}^{-1}\text{»} \checkmark$	Award [2] for the correct final answer. M1 for the correct expression or rearrangement. Award [1] for +480 «kJ mol⁻¹ »	2
3.	(d)	(iv)	$\text{«} 70 + 259 - (161 + 160) \text{ =» } 8 \text{ «J K}^{-1} \text{ mol}^{-1}\text{»} \checkmark$		1

3.	(d)	(v)	conversion to common units ✓ «$\Delta G^\theta = -4 \text{ kJ mol}^{-1} - 298 \text{ K} \times 0.008 \text{ kJ K}^{-1}\text{mol}^{-1}$» $-6.4 \text{ «kJ mol}^{-1}\text{»}$ ✓	<i>M1 is for conversion to common units M2 is for correct value.</i> <i>Award [2] for correct final answer.</i> <i>If $-10 \text{ J K}^{-1} \text{ mol}^{-1}$ is used, the answer will be $-1.0 \text{ «kJ mol}^{-1}\text{»}$.</i>	2
3.	(d)	(vi)	the $-T\Delta S$ expression becomes more negative / so Gibbs energy/ΔG becomes more negative ✓ increase in spontaneity «as temperature is increased»✓	<i>Accept feasibility in place of spontaneity.</i> <i>If $-10 \text{ J K}^{-1} \text{ mol}^{-1}$ is used, the answer will be opposite (decrease in spontaneity,</i> <i>$-T\Delta S$ becomes more positive, ΔG becomes less negative).</i> <i>Do not accept “spontaneous” without reference to increases.</i>	2

3.	(d)	(vii)	 shape of graph lines correct. AND finishing at the same rate. ✓ top line identified as forward reaction. AND lower line identified as reverse reaction. ✓	Accept straight lines from the starting points to the equilibrium rate. Do not accept “reactants / products” or formulas for “forward / reverse”	2
3.	(d)	(viii)	«$\ln K = -6400\text{J mol}^{-1} / -8.31\text{J K}^{-1}\text{mol}^{-1} \times 333\text{K}$» 2.313 ✓ «$e^{2.313}$» 10.10 ✓	Award [2] for correct final answer. Award [1] max for $K=1.00$ for either -6.4 or -8.5. If -8.5 kJ mol^{-1} is used answer is 21.58.	2

3.	(e)	(i)	«moles of» ethanol «at equilibrium» = 0.2 «moles of» ethyl ethanoate «at equilibrium» = 0.4 «moles of» water «at equilibrium» = 0.4 ✓ $\frac{0.4^2}{0.2^2} \checkmark$ «0.16» 4.0✓ «0.04»	<i>Award [3] for correct final answer.</i> <i>M1 can be awarded for a correct expression for M2.</i>	3
3.	(e)	(ii)	«the value of K in (e)(i) is too low and» insufficient time was given for equilibrium to be reached. ✓		1
3.	(e)	(iii)	reaction quotient / Q ✓		1

3.	(f)	(i)	 correct shape curve starting at the origin, without touching the x axis at high energy. ✓ (E_a) catalysed < (E_a) uncatalysed on x axis. ✓		2
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3.	(f)	(ii)	 curve with peak higher AND to left AND decreasing at lower KE and labelled. ✓	Accept the correct label on either or both curves. Do not award mark if line crosses x axis or rises above the 60 C curve at high energy.	1
3.	(g)		$\frac{88.12 \text{ g mol}^{-1}}{2 \times 30.08 \text{ g mol}^{-1} + 70.90 \text{ g mol}^{-1} + \frac{3}{2} \times 32.00 \text{ g mol}^{-1}} \times 100$ 49.21% ✓	Award [2] for correct final answer.	2

Question			Answers	Notes	Total
4.	(a)	(i)	Peak 1 wavenumber: 1700 – 1750 «cm⁻¹» AND bond: C=O/carbonyl ✓ Peak 2 wavenumber: 1050 – 1410 «cm⁻¹» AND bond: C–O ✓	Allow word descriptions for the bonds i.e “carbon oxygen double bond”. Accept any order. Accept any value in the given range.	2
4.	(a)	(ii)	3200 - 3600 «cm⁻¹» AND 2500 – 3000 «cm⁻¹» AND «hydrogen bonded» O–H✓		1
4.	(b)	(i)	70 / (102 – 32) ✓ the rest of the formula/ C₅H₁₀O₂ ✓	Any calculation that demonstrates 2 O atoms present for M1 Award [2] for correct final formula, allow any representation of the structure.	2
4.	(b)	(ii)	$\begin{array}{c} \text{O} \\ \\ \text{CH}_3 - \text{CH}_2 - \text{C} - \text{O} - \text{CH}_2 - \text{CH}_3 \end{array}$ CH₃—CH₂—C(=O)—O—CH₂—CH₃ / ethyl propanoate / CH₃CH₂COOCH₂CH₃ ✓	Allow any correct structural representation of the ester.	1

Question			Answers	Notes	Total
5.	(a)	(i)	$2\text{NiO}(\text{OH})(\text{s}) + 2\text{H}_2\text{O}(\text{l}) + \text{Cd}(\text{s}) \rightarrow \text{Cd}(\text{OH})_2(\text{s}) + 2\text{Ni}(\text{OH})_2(\text{s}) \checkmark$	Accept equilibrium arrows	1
5.	(a)	(ii)	salt bridge✓ Voltmeter✓ ions «in solutions» AND electrodes correctly labelled ✓	Ignore any electron flow or standard conditions. Salt bridge must be in contact with the solutions for M1 Wires must be connected for M2	3
5.	(a)	(iii)	0.92 «V» ✓	.	1

5.	(b)	«$\Delta G^\theta = -nFE^\theta_{\text{cell}}$» $-570300 = -1 \times 96500 \times E^\theta_{\text{cell}}$ ✓ «$E^\theta_{\text{cell}} = 5.91 \text{ V}$» ✓ «half cells» $\frac{1}{2}\text{F}_2 + \text{e}^- \rightleftharpoons \text{F}^-$ AND $\text{Li} \rightleftharpoons \text{Li}^+ + \text{e}^-$ ✓	Award [3] if correct half cells identified and evidence of a calculation seen. M1 conversion to J and correct value of n. M2 5.91V. Accept named half cells for M3 Accept cell notation for M3	3																				
5.	(c)	<table border="1"> <thead> <tr> <th></th><th colspan="2">Direction of movement</th><th colspan="2">Place of movement</th></tr> <tr> <th>Species</th><th>Towards cathode</th><th>Towards anode</th><th>In the wires</th><th>Through the electrolytes</th></tr> </thead> <tbody> <tr> <td>electrons</td><td>✓</td><td></td><td>✓</td><td></td></tr> <tr> <td>Cr²⁺ ions</td><td>✓</td><td></td><td></td><td>✓</td></tr> </tbody> </table> ✓✓		Direction of movement		Place of movement		Species	Towards cathode	Towards anode	In the wires	Through the electrolytes	electrons	✓		✓		Cr ²⁺ ions	✓			✓	Any two correct ticks for [1] .	2
	Direction of movement		Place of movement																					
Species	Towards cathode	Towards anode	In the wires	Through the electrolytes																				
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