

Cambridge International AS & A Level

CHEMISTRY

9701/42

Paper 4 A Level Structured Questions

May/June 2025

MARK SCHEME

Maximum Mark: 100

Published

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

Mark schemes should be read in conjunction with the question paper and the Principal Examiner Report for Teachers.

Cambridge International will not enter into discussions about these mark schemes.

Cambridge International is publishing the mark schemes for the May/June 2025 series for most Cambridge IGCSE, Cambridge International A and AS Level components, and some Cambridge O Level components.

This document consists of **18** printed pages.

PUBLISHED**Generic Marking Principles**

These general marking principles must be applied by all examiners when marking candidate answers. They should be applied alongside the specific content of the mark scheme or generic level descriptions for a question. Each question paper and mark scheme will also comply with these marking principles.

GENERIC MARKING PRINCIPLE 1:

Marks must be awarded in line with:

- the specific content of the mark scheme or the generic level descriptors for the question
- the specific skills defined in the mark scheme or in the generic level descriptors for the question
- the standard of response required by a candidate as exemplified by the standardisation scripts.

GENERIC MARKING PRINCIPLE 2:

Marks awarded are always **whole marks** (not half marks, or other fractions).

GENERIC MARKING PRINCIPLE 3:

Marks must be awarded **positively**:

- marks are awarded for correct/valid answers, as defined in the mark scheme. However, credit is given for valid answers which go beyond the scope of the syllabus and mark scheme, referring to your Team Leader as appropriate
- marks are awarded when candidates clearly demonstrate what they know and can do
- marks are not deducted for errors
- marks are not deducted for omissions
- answers should only be judged on the quality of spelling, punctuation and grammar when these features are specifically assessed by the question as indicated by the mark scheme. The meaning, however, should be unambiguous.

GENERIC MARKING PRINCIPLE 4:

Rules must be applied consistently, e.g. in situations where candidates have not followed instructions or in the application of generic level descriptors.

GENERIC MARKING PRINCIPLE 5:

Marks should be awarded using the full range of marks defined in the mark scheme for the question (however; the use of the full mark range may be limited according to the quality of the candidate responses seen).

GENERIC MARKING PRINCIPLE 6:

Marks awarded are based solely on the requirements as defined in the mark scheme. Marks should not be awarded with grade thresholds or grade descriptors in mind.

Science-Specific Marking Principles

1 Examiners should consider the context and scientific use of any keywords when awarding marks. Although keywords may be present, marks should not be awarded if the keywords are used incorrectly.

2 The examiner should not choose between contradictory statements given in the same question part, and credit should not be awarded for any correct statement that is contradicted within the same question part. Wrong science that is irrelevant to the question should be ignored.

3 Although spellings do not have to be correct, spellings of syllabus terms must allow for clear and unambiguous separation from other syllabus terms with which they may be confused (e.g. ethane / ethene, glucagon / glycogen, refraction / reflection).

4 The error carried forward (ecf) principle should be applied, where appropriate. If an incorrect answer is subsequently used in a scientifically correct way, the candidate should be awarded these subsequent marking points. Further guidance will be included in the mark scheme where necessary and any exceptions to this general principle will be noted.

5 'List rule' guidance

For questions that require *n* responses (e.g. State **two** reasons ...):

- The response should be read as continuous prose, even when numbered answer spaces are provided.
- Any response marked *ignore* in the mark scheme should not count towards *n*.
- Incorrect responses should not be awarded credit but will still count towards *n*.
- Read the entire response to check for any responses that contradict those that would otherwise be credited. Credit should **not** be awarded for any responses that are contradicted within the rest of the response. Where two responses contradict one another, this should be treated as a single incorrect response.
- Non-contradictory responses after the first *n* responses may be ignored even if they include incorrect science.

6 Calculation specific guidance

Correct answers to calculations should be given full credit even if there is no working or incorrect working, **unless** the question states 'show your working'.

For questions in which the number of significant figures required is not stated, credit should be awarded for correct answers when rounded by the examiner to the number of significant figures given in the mark scheme. This may not apply to measured values.

For answers given in standard form (e.g. $a \times 10^n$) in which the convention of restricting the value of the coefficient (a) to a value between 1 and 10 is not followed, credit may still be awarded if the answer can be converted to the answer given in the mark scheme.

Unless a separate mark is given for a unit, a missing or incorrect unit will normally mean that the final calculation mark is not awarded. Exceptions to this general principle will be noted in the mark scheme.

7 Guidance for chemical equations

Multiples / fractions of coefficients used in chemical equations are acceptable unless stated otherwise in the mark scheme.

State symbols given in an equation should be ignored unless asked for in the question or stated otherwise in the mark scheme.

Annotations guidance for centres

Examiners use a system of annotations as a shorthand for communicating their marking decisions to one another. Examiners are trained during the standardisation process on how and when to use annotations. The purpose of annotations is to inform the standardisation and monitoring processes and guide the supervising examiners when they are checking the work of examiners within their team. The meaning of annotations and how they are used is specific to each component and is understood by all examiners who mark the component.

We publish annotations in our mark schemes to help centres understand the annotations they may see on copies of scripts. Note that there may not be a direct correlation between the number of annotations on a script and the mark awarded. Similarly, the use of an annotation may not be an indication of the quality of the response.

The annotations listed below were available to examiners marking this component in this series.

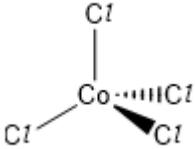
Annotations

Annotation	Meaning
	Correct point or mark awarded
	Incorrect point or mark not awarded
	Unclear
	Information missing or insufficient for credit
	Benefit of the doubt given
	Contradiction in response otherwise markworthy, mark not given
	Part of the correct answer has been seen. Full credit has not been awarded.
	Error carried forward applied
	Incorrect or insufficient point ignored while marking the rest of the response
	Benefit of the doubt not applied in this instance

Annotation	Meaning
RE	Rounding error
REP	Repetition
SEEN	Blank page or part of script seen
SF	Error in number of significant figures
TE	Transcription error

Question	Answer	Marks
1(a)(i)	$\text{Ca}(\text{NO}_3)_2 \rightarrow \text{CaO} + 2\text{NO}_2 + \frac{1}{2}\text{O}_2$ [1]	1
1(a)(ii)	M1: temperature increases down the group M2: ionic radius OR size of cation / $\text{M}^{(2)+}$ AND increases M3: less polarisation / less distortion AND of anion / nitrate ion OR less weakening of NO bond / harder to break NO bond	3
1(b)	M1: moles of SrO = $0.333 \div 103.6 = 3.214 \times 10^{-3}$ AND moles of $\text{Sr}(\text{OH})_2 = 3.214 \times 10^{-3}$ OR 9 / 2800 M2: moles of OH^- in $250 \text{ cm}^3 = 3.214 \times 10^{-3} \times 2 = 6.429 \times 10^{-3}$ AND moles of OH^- in $1 \text{ dm}^3 = 6.429 \times 10^{-3} \times 4 = 0.0257$ M3: $[\text{H}^+] = 1.00 \times 10^{-14} \div 0.0257 = 3.89 \times 10^{-13}$ OR $\text{pOH} = -\log[\text{OH}^-] = 1.59$ M4: $\text{pH} = -\log(3.89 \times 10^{-13}) = 12.41$ must be to 2dp OR $\text{pH} = 14 - 1.59 = 12.41$ must be 2 dp	4

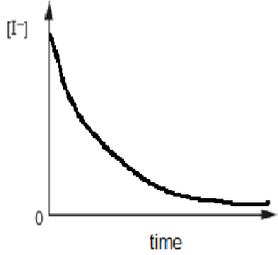
Question	Answer	Marks
2(a)(i)	A = $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ pink B = $[\text{Co}(\text{H}_2\text{O})_4(\text{OH})_2] / \text{Co}(\text{OH})_2$ blue C = $[\text{Co}(\text{NH}_3)_6]^{2+}$ straw / yellow-brown B = precipitation / deprotonation / acid-base C = ligand exchange Any two [1] any four [2] any six [3] all eight [4]	4
2(a)(ii)	concentrated HCl	1

Question	Answer	Marks
2(b)(i)	<ul style="list-style-type: none"> • five (3d) orbitals (lines, boxes) in the isolated Co^{2+} ion of same energy • splitting three higher and two lower d orbitals • energy of all d orbitals in the complex clearly higher than all d orbitals in isolated ion <p>any two [1] all three [2]</p>	2
2(b)(ii)		1
2(c)	<p>M1: H_2O_2 acting as oxidising agent with $\text{Mn}(\text{OH})_2 / \text{Mn}^{2+}$</p> <p>M2: $\text{Mn}^{2+} + \text{H}_2\text{O}_2 \rightarrow \text{MnO}_2 + 2\text{H}^+$ AND $E^\ominus_{\text{cell}} = +0.56$ OR $\text{Mn}(\text{OH})_2 + \text{H}_2\text{O}_2 \rightarrow \text{MnO}_2 + 2\text{H}_2\text{O}$ AND $E^\ominus_{\text{cell}} = +0.92$</p> <p>M3: H_2O_2 acting as reducing agent with MnO_2</p> <p>M4: $\text{MnO}_2 + 2\text{H}^+ + \text{H}_2\text{O}_2 \rightarrow \text{Mn}^{2+} + 2\text{H}_2\text{O} + \text{O}_2$ AND $E^\ominus_{\text{cell}} = +0.54$</p>	4
2(d)(i)	colourless to pale pink	1

Question	Answer	Marks
2(d)(ii)	<ul style="list-style-type: none"> • moles $\text{MnO}_4^- = 0.0500 \times 18.60 / 1000 = 9.30 \times 10^{-4}$ in 25.0 cm^3 • moles $\text{Fe}^{2+} = 5 \times 9.30 \times 10^{-4} = 4.65 \times 10^{-3}$ in 25.0 cm^3 • moles $\text{Fe}^{2+} = 6 \times 4.65 \times 10^{-3} = 2.79 \times 10^{-2}$ in 150.0 cm^3 <p>M1 / M2: any two of the above bullets [1] all three [2]</p> <p>OR</p> <ul style="list-style-type: none"> • moles $\text{MnO}_4^- = 0.0500 \times 18.60 / 1000 = 9.30 \times 10^{-4}$ in 25.0 cm^3 • moles $\text{MnO}_4^- = 6 \times 9.30 \times 10^{-4} = 5.58 \times 10^{-3}$ in 150.0 cm^3 • moles $\text{Fe}^{2+} = 5 \times 5.58 \times 10^{-3} = 2.79 \times 10^{-2}$ in 150.0 cm^3 <p>M1 / M2: any two of the above bullets [1] all three [2]</p> <p>M3: mass Fe = $55.8 \times 2.79 \times 10^{-2} = 1.55682$ (g) in two tablets</p> <p>M4: mass Fe = $0.5 \times 1.55682 = 0.77841$ (g) in one tablet AND mass Fe = $7.7841 \times 10^{-2} \times 1000 = 778.4$</p>	4

Question	Answer	Marks
3(a)(i)	number of possible arrangements of particles/molecules AND energy in a system	1
3(b)(i)	T_1 melting OR solid to liquid T_2 boiling OR liquid to gas	1
3(b)(ii)	change in disorder from a liquid to a gas is much bigger than solid to liquid OR change in intermolecular distance between liquid & gas is much bigger than solid to liquid	1
3(c)	M1: $\Delta H^\ominus_r = (3 \times -393.5) - ((-824.2) + (3 \times -110.5)) = -24.8 \text{ (kJ mol}^{-1}\text{)}$ M2: $\Delta G^\ominus = \Delta H^\ominus - T\Delta S^\ominus$ AND $T = 723$ used M3: $(24800 - 36200) \div 723 = - [3 \times 213.8 + 2 \times 27.3] - (87.4) - (3x)$ $-15.8 = -608.6 + 3x$, so $3x = 592.8$, so $x = 197.6 / 198 \text{ (J K}^{-1} \text{ mol}^{-1}\text{)}$ min 3sf	3
3(d)	<ul style="list-style-type: none"> (as temperature increases) the reaction is less feasible as ΔG^\ominus becomes less negative / (more) positive due to $T\Delta S$ becoming more negative / $-T\Delta S$ (becoming more) positive M1 / M2: any two of the above bullets [1] all three [2]	2

Question	Answer	Marks								
4(a)(i)	the power/exponent to which a concentration AND of a reactant is raised in the rate equation	1								
4(a)(ii)	<table border="1" style="margin-left: 20px;"> <tbody> <tr> <td>the order of reaction with respect to $[H^+]$</td> <td style="text-align: center;">0</td> </tr> <tr> <td>the order of reaction with respect to $[I^-]$</td> <td style="text-align: center;">1</td> </tr> <tr> <td>the order of reaction with respect to $[H_2O_2]$</td> <td style="text-align: center;">1</td> </tr> <tr> <td>overall order of the reaction</td> <td style="text-align: center;">2</td> </tr> </tbody> </table> <p>Any two [1] all three [2]</p>	the order of reaction with respect to $[H^+]$	0	the order of reaction with respect to $[I^-]$	1	the order of reaction with respect to $[H_2O_2]$	1	overall order of the reaction	2	2
the order of reaction with respect to $[H^+]$	0									
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the order of reaction with respect to $[H_2O_2]$	1									
overall order of the reaction	2									

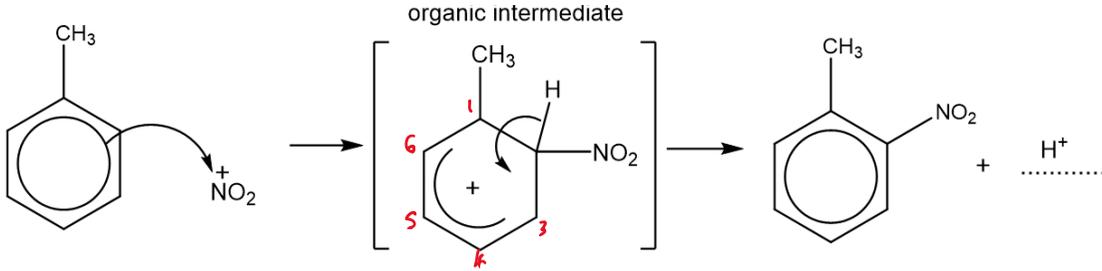
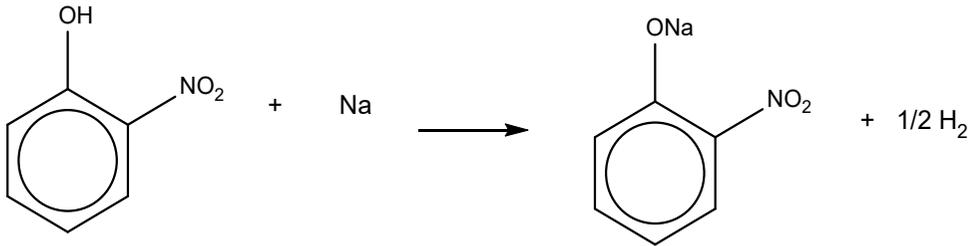
Question	Answer	Marks
4(a)(iii)	 <p>negative gradient curve</p>	1
4(b)(i)	rate = $4 \times 4 = 16$ times	1
4(b)(ii)	slowest step / slow step in the mechanism / multi-step reaction	1
4(b)(iii)	<p>M1: step 1 $\text{O}_3 + \text{NO}_2 \rightarrow \text{NO}_3 + \text{O}_2$</p> <p>M2: step 2 $\text{NO}_3 + \text{NO}_2 \rightarrow \text{N}_2\text{O}_5$ AND sum of step 1 and 2 is consistent with equation for reaction 2</p>	2
4(c)(i)	Use of graph $k = 12 \times 10^{-4} / 0.04 = 0.03$	1
4(c)(ii)	$k = 0.693 / t_{1/2}$ $t_{1/2} = 0.693 / 0.030 = 23.1$ (s) min 2sf	1

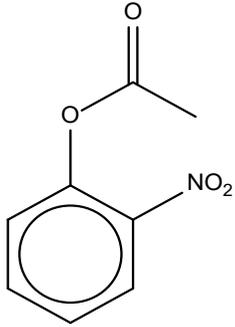
Question	Answer	Marks
5(a)(i)	acid I HClO conjugate base of acid I ClO^- acid II H_2O conjugate base of acid II OH^-	1
5(a)(ii)	<p>M1: $[\text{H}^+] = 10^{-4.51} = 3.09 \times 10^{-5}$</p> <p>M2: $[\text{HClO}] = (3.09 \times 10^{-5})^2 \div (3.70 \times 10^{-8}) = 0.0258$ min 2sf</p>	2
5(a)(iii)	$3 \text{HClO} \rightarrow \text{HClO}_3 + 2 \text{HCl}$	1

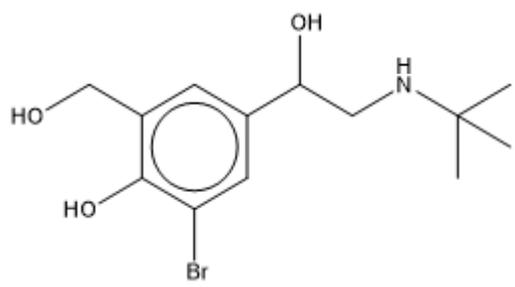
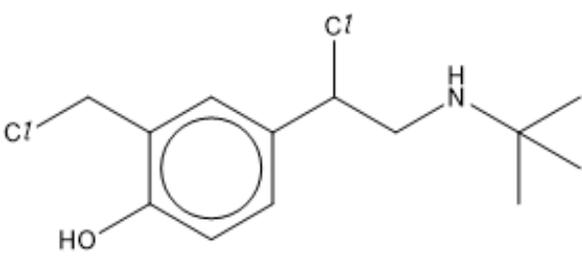
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Question	Answer	Marks
5(b)(i)	(a solution that) resists / minimises changes pH AND when small amounts of acid / H ⁺ and base / OH ⁻ are added to it	1
5(b)(ii)	hydroxide ions / NaOH / OH ⁻ AND it reacts with the acid to form the conjugate base / ethanoate ions OR ethanoate ions / sodium ethanoate AND as it is the conjugate base (of ethanoic acid)	1
5(c)	addition of acid M1: H ₂ PO ₄ ⁻ + H ⁺ → H ₃ PO ₄ addition of alkali M2: H ₂ PO ₄ ⁻ + OH ⁻ → HPO ₄ ²⁻ + H ₂ O	2
5(d)(i)	M1: Use of [Ca ²⁺] = [PO ₄ ³⁻] = 1.14 × 10 ⁻⁷ in the expression OR K _{sp} = (3.42 × 10 ⁻⁷) ³ × (2.28 × 10 ⁻⁷) ² M2: K _{sp} = (3 × 1.14 × 10 ⁻⁷) ³ × (2 × 1.14 × 10 ⁻⁷) ² K _{sp} = 2.079 × 10 ⁻³³ OR 2.08 × 10 ⁻³³ OR 2.1 × 10 ⁻³³ min 2sf M3: units = mol ⁵ dm ⁻¹⁵	3
5(d)(ii)	solubility decreases AND due to the common ion effect	1

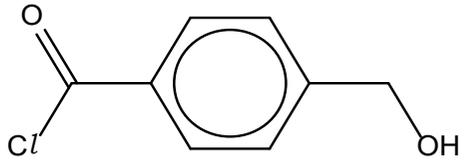
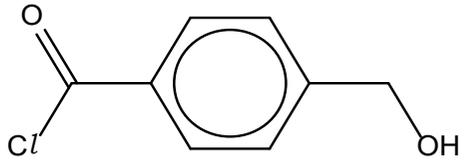
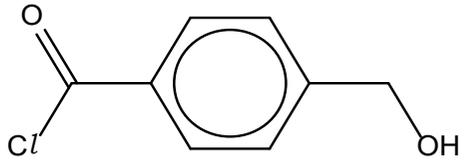
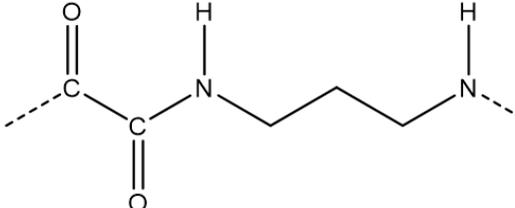
Question	Answer	Marks
6(a)(i)	HNO ₃ + H ₂ SO ₄ → NO ₂ ⁺ + HSO ₄ ⁻ + H ₂ O OR HNO ₃ + 2H ₂ SO ₄ → NO ₂ ⁺ + 2HSO ₄ ⁻ + H ₃ O ⁺	1

Question	Answer	Marks
6(a)(ii)	 <p>organic intermediate</p> <p>M1: curly arrow 1 from inside the hexagon to nitrogen of NO_2^+</p> <p>M2: intermediate, usual rules for horseshoe and + charge</p> <p>M3: curly arrow 2 from C-H bond into hexagon AND H^+</p>	3
6(b)	<p>M1: p-orbital/lone pair from O / oxygen AND is delocalised / overlaps AND into the ring / π system</p> <p>M2: so electron density of the ring is increased OR polarises electrophiles / NO_2^+ better</p>	2
6(c)		1
6(d)(i)	(hot) tin / Sn AND concentrated AND HCl	1
6(d)(ii)	reduction	1

Question	Answer	Marks								
6(d)(iii)		1								
6(d)(iv)	(nucleophilic) addition – elimination	1								
6(e)	<p>M1: 2-nitrophenol > phenol > water > ethanol</p> <p>M2: weakens O—H bond / anion stabilised AND proton/H⁺ (more easily) lost / proton / H⁺ (more easily) donated</p> <p>M3: (for 2-nitrophenol / phenol), a p-orbital / lone pair from O / oxygen AND is delocalised / overlaps AND into the ring / π system (and increases electron density in the ring)</p> <p>M4: (for ethanol), positive inductive effect / electron donating of alkyl group</p>	4								
6(f)(i)	<table border="1" data-bbox="338 983 1173 1249"> <thead> <tr> <th data-bbox="338 983 719 1050">name of functional group</th> <th data-bbox="719 983 1173 1050">classification of functional group</th> </tr> </thead> <tbody> <tr> <td data-bbox="338 1050 719 1117">alcohol / hydroxyl</td> <td data-bbox="719 1050 1173 1117">primary</td> </tr> <tr> <td data-bbox="338 1117 719 1184">alcohol / hydroxyl</td> <td data-bbox="719 1117 1173 1184">secondary</td> </tr> <tr> <td data-bbox="338 1184 719 1249">amine</td> <td data-bbox="719 1184 1173 1249">secondary</td> </tr> </tbody> </table> <p data-bbox="338 1281 842 1318">Any three correct [1] all six correct [2]</p>	name of functional group	classification of functional group	alcohol / hydroxyl	primary	alcohol / hydroxyl	secondary	amine	secondary	2
name of functional group	classification of functional group									
alcohol / hydroxyl	primary									
alcohol / hydroxyl	secondary									
amine	secondary									

Question	Answer	Marks
6(f)(ii)		1
6(f)(iii)		1

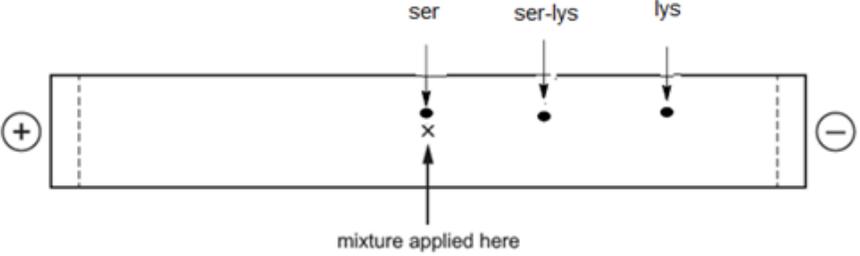
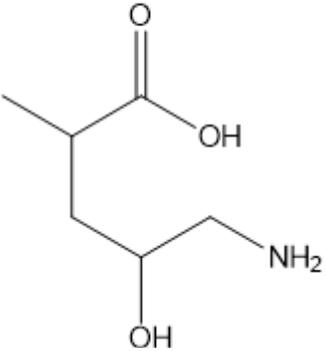
Question	Answer	Marks
7(a)	rotate the plane of polarised light equally in the opposite direction	1
7(b)(i)	<p>M1: nitrogen / N can accept / bond to a proton / H⁺ ion OR donation of lone pair/electrons on the nitrogen / N to a proton / H⁺ ion</p> <p>M2: CH₃CH(NH₂)CH₂CH₃ + H₂O → CH₃CH(NH₃⁺)CH₂CH₃ + OH⁻</p>	2
7(b)(ii)	<p>M1: more electron donating alkyl / ethyl group on N / NH (in diethylamine) OR two electron donating alkyl / R / alkane / ethyl group on N / NH (in diethylamine)</p> <p>M2: increase electron density on N OR make lone pair on N more available (to accept H⁺)</p>	2
7(b)(iii)	(CH ₃ CH ₂) ₂ NH + CH ₃ COOH → (CH ₃ CH ₂) ₂ NH ₂ ⁺ CH ₃ COO ⁻	1

Question	Answer	Marks								
7(b)(iii)	$(\text{CH}_3\text{CH}_2)_2\text{NH} + \text{CH}_3\text{COOH} \rightarrow (\text{CH}_3\text{CH}_2)_2\text{NH}_2^+ \text{CH}_3\text{COO}^-$	1								
7(b)(iv)	$(\text{CH}_3\text{CH}_2)_2\text{NH} + \text{CH}_3\text{COCl} \rightarrow \text{CH}_3\text{CON}(\text{CH}_2\text{CH}_3)_2 + \text{HCl}$	1								
7(c)(i)	<table border="1"> <tbody> <tr> <td>monomer</td> <td>type of polymerisation</td> </tr> <tr> <td>$\text{CH}_2\text{CHCH}_3\text{COOH}$</td> <td>addition</td> </tr> <tr> <td></td> <td>condensation</td> </tr> <tr> <td>$\text{CH}_3\text{CH}(\text{NH}_2)\text{COOH}$</td> <td>condensation</td> </tr> </tbody> </table>	monomer	type of polymerisation	$\text{CH}_2\text{CHCH}_3\text{COOH}$	addition		condensation	$\text{CH}_3\text{CH}(\text{NH}_2)\text{COOH}$	condensation	1
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	condensation									
$\text{CH}_3\text{CH}(\text{NH}_2)\text{COOH}$	condensation									
7(c)(ii)	 <p>M1: correct displayed amide linkage with an adjacent C=O (to CO) and C(H₂) to NH</p> <p>M2: rest of the structure correct (only one repeat unit) with continuation bonds</p>	2								
7(c)(iii)	they are chemically inert / difficult to hydrolyse / C-C bonds are non-polar	1								

Question	Answer	Marks
8(a)	reference: TMS / tetramethylsilane / $(\text{CH}_3)_4\text{Si}$ AND solvent: D_2O / CDCl_3	1

Question	Answer				Marks																				
8(b)	six / 6 peaks				1																				
8(c)	<table border="1"> <thead> <tr> <th>chemical shift δ / ppm</th> <th>splitting pattern</th> <th>number of protons on adjacent carbon atoms</th> <th>number of ^1H atoms responsible for the peak</th> </tr> </thead> <tbody> <tr> <td>1.10</td> <td>triplet</td> <td>2</td> <td>3</td> </tr> <tr> <td>1.50</td> <td>doublet</td> <td>1</td> <td>6</td> </tr> <tr> <td>2.45</td> <td>quartet / quadruplet</td> <td>3</td> <td>2</td> </tr> <tr> <td>3.75</td> <td>multiplet</td> <td>6</td> <td>1</td> </tr> </tbody> </table>				chemical shift δ / ppm	splitting pattern	number of protons on adjacent carbon atoms	number of ^1H atoms responsible for the peak	1.10	triplet	2	3	1.50	doublet	1	6	2.45	quartet / quadruplet	3	2	3.75	multiplet	6	1	4
chemical shift δ / ppm	splitting pattern	number of protons on adjacent carbon atoms	number of ^1H atoms responsible for the peak																						
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2.45	quartet / quadruplet	3	2																						
3.75	multiplet	6	1																						
Any three [1] any six [2] any nine [3] all eleven [4]																									

Question	Answer	Marks
9(a)	<p>M1: correct displayed peptide bond with an adjacent C(H) (to CO) and C(H) to NH</p> <p>M2: rest of the dipeptide correct</p>	2
9(b)(i)	pH at which a molecule has no overall charge / no net charge	1

Question	Answer	Marks
9(b)(ii)	 <p>M1: correct relative positions of the spots drawn</p> <p>M2: ser not moved AND as it is a zwitterion / neutral OR ser-lys / lys AND move towards negative (pole) as they are positively charged</p> <p>M3: lys moves the furthest / fastest AND as it has the lower M_r / smaller size (than ser-lys)</p>	3
9(c)(i)	<p>Q, $C_6H_{13}NO_3$</p> 	1
9(c)(ii)	<p>step 1 M1: aqueous AND HCl / H_2SO_4 AND heat / reflux[1]</p> <p>step 2 M2: conc. H_2SO_4 catalyst AND high temp / heat</p>	2