CAMBRIDGE
International Education

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.

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	<u>‘List rule’ guidance</u> 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.

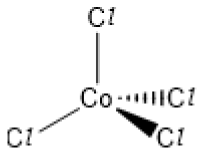
The annotations listed below were available to examiners marking this component in this series.

Annotations

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

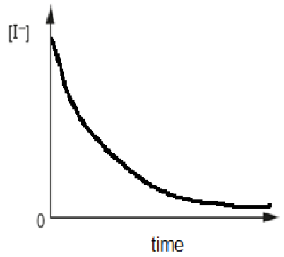
Annotation	Meaning
RE	Rounding error
REP	Repetition
SEEN	Blank page **or** part of script seen
SF	Error in number of significant figures
TE	Transcription error

Question	Answer	Marks
1(a)(i)	$Ca(NO_3)_2 \rightarrow CaO + 2NO_2 + ½O_2$[1]	**1**
1(a)(ii)	**M1:** temperature increases down the group **M2:** ionic radius **OR** size of cation / $M^{(2)+}$ **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 ÷ 103.6 = 3.214×10^{-3} **AND** moles of $Sr(OH)_2$ = 3.214×10^{-3} **OR** 9 / 2800 **M2:** moles of OH^- in 250 cm^3 = $3.214 \times 10^{-3} \times 2 = 6.429 \times 10^{-3}$ **AND** moles of OH^- in 1 dm^3 = $6.429 \times 10^{-3} \times 4 = 0.0257$ **M3:** $[H^+] = 1.00 \times 10^{-14} \div 0.0257 = 3.89 \times 10^{-13}$ **OR** pOH = –log[OH^-] = 1.59 **M4:** pH = –log(3.89×10^{-13}) = 12.41 must be to 2dp **OR** pH = 14 –1.59 = 12.41 must be 2 dp	**4**
2(a)(i)	**A** = $[Co(H_2O)_6]^{2+}$ pink **B** = $[Co(H_2O)_4(OH)_2]$ / $Co(OH)_2$ blue **C** = $[Co(NH_3)_6]^{2+}$ 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 HC*l*	**1**
2(b)(i)	• 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 any two [1] all three [2]	**2**

Question	Answer	Marks
2(b)(ii)		**1**
2(c)	**M1:** H_2O_2 acting as oxidising agent with $Mn(OH)_2$ / Mn^{2+} **M2:** $Mn^{2+} + H_2O_2 \rightarrow MnO_2 + 2H^+$ **AND** $E^{\ominus}_{cell} = +0.56$ **OR** $Mn(OH)_2 + H_2O_2 \rightarrow MnO_2 + 2H_2O$ **AND** $E^{\ominus}_{cell} = +0.92$ **M3:** H_2O_2 acting as reducing agent with MnO_2 **M4:** $MnO_2 + 2H^+ + H_2O_2 \rightarrow Mn^{2+} + 2H_2O + O_2$ **AND** $E^{\ominus}_{cell} = +0.54$	**4**
2(d)(i)	colourless to pale pink	**1**
2(d)(ii)	• moles MnO_4^- = 0.0500 × 18.60 / 1000 = 9.30×10^{-4} in 25.0 cm^3 • moles Fe^{2+} = 5 × 9.30×10^{-4} = 4.65×10^{-3} in 25.0 cm^3 • moles Fe^{2+} = 6 x 4.65×10^{-3} = 2.79×10^{-2}in 150.0 cm^3 **M1 / M2:** any two of the above bullets [1] all three [2] **OR** • moles MnO_4^- = 0.0500 × 18.60 / 1000 = 9.30×10^{-4} in 25.0 cm^3 • moles MnO_4^- = 6 × 9.30×10^{-4} = 5.58×10^{-3} in 150.0 cm^3 • moles Fe^{2+} = 5 × 5.58×10^{-3} = 2.79×10^{-2}in 150.0 cm^3 **M1 / M2:** any two of the above bullets [1] all three [2] **M3:** mass Fe = 55.8 × 2.79×10^{-2} = 1.55682 (g) in two tablets **M4:** mass Fe = 0.5 × 1.55682 = 0.77841 (g) in one tablet **AND** mass Fe = 7.7841×10^{-2} × 1000 = 778.4	**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:** $\Delta H^\circ_r = (3 \times -393.5) - ((-824.2) + (3 \times -110.5)) = -24.8$ (kJ mol^{-1}) **M2:** $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ **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 $x = 197.6 / 198$ (J K^{-1} mol^{-1}) min 3sf	**3**
3(d)	• (as temperature increases) the reaction is less feasible • as ΔG° 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**

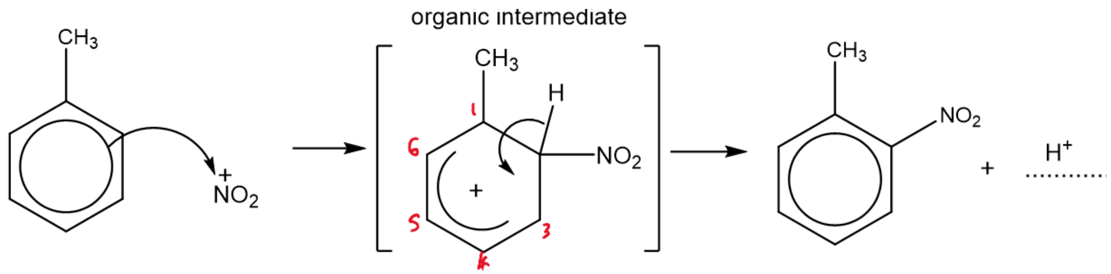
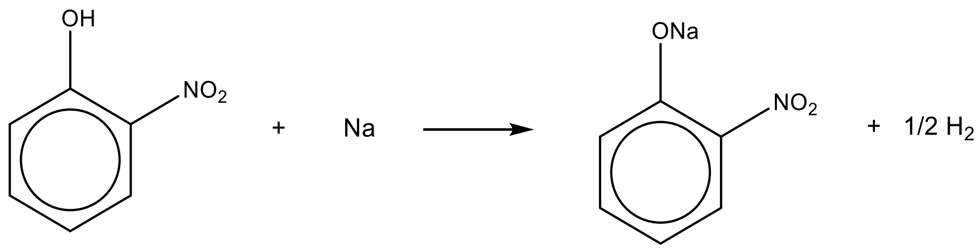
Question	Answer	Marks
4(a)(i)	the power/exponent to which a concentration **AND** of a reactant is raised in the rate equation	1
4(a)(ii)	<table><tr><td>the order of reaction with respect to [H⁺]</td><td>0</td></tr><tr><td>the order of reaction with respect to [I⁻]</td><td>1</td></tr><tr><td>the order of reaction with respect to [H₂O₂]</td><td>1</td></tr><tr><td>overall order of the reaction</td><td>2</td></tr></table> Any two [1] all three [2]	**2**

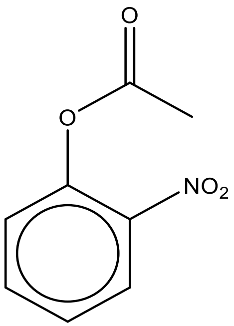
Question	Answer	Marks
4(a)(iii)	 negative gradient curve	**1**
4(b)(i)	rate = 4 × 4 = 16 times	**1**
4(b)(ii)	slowest step / slow step in the mechanism / multi-step reaction	**1**
4(b)(iii)	**M1:** step 1 $O_3 + NO_2 \rightarrow NO_3 + O_2$ **M2:** step 2 $NO_3 + NO_2 \rightarrow N_2O_5$ **AND** sum of step 1 and 2 is consistent with equation for reaction 2	**2**
4(c)(i)	Use of graph k = 12 × 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**

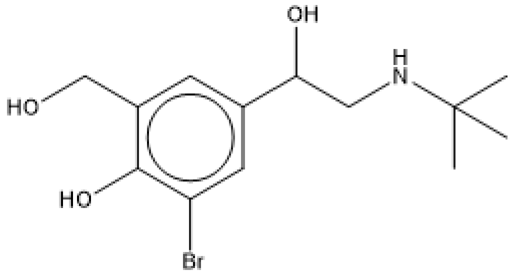
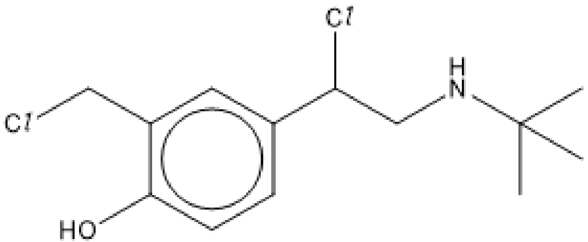
Question	Answer	Marks
5(a)(i)	acid I $HClO$ conjugate base of acid I ClO^- acid II H_2O conjugate base of acid II OH^-	**1**
(a)(ii)	**M1:** $[H^+] = 10^{-4.51} = 3.09 \times 10^{-5}$ **M2:** $[HClO] = (3.09 \times 10^{-5})^2 \div (3.70 \times 10^{-8}) = 0.0258$ min 2sf	**2**
(a)(iii)	$3\ HClO \rightarrow HClO_3 + 2\ HCl$	**1**

Question	Answer	Marks
(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(d)(i)	**M1:** Use of $[Ca^{2+}] = [PO_4^{3-}] = 1.14 \times 10^{-7}$ in the expression **OR** $K_{sp} = (3.42 \times 10^{-7})^3 \times (2.28 \times 10^{-7})^2$ **M2:** $K_{sp} = (3 \times 1.14 \times 10^{-7})^3 \times (2 \times 1.14 \times 10^{-7})^2$ $K_{sp} = 2.079 \times 10^{-33}$ **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**

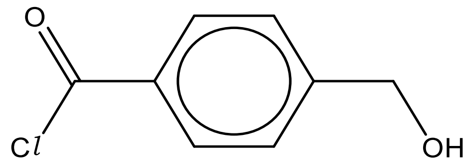
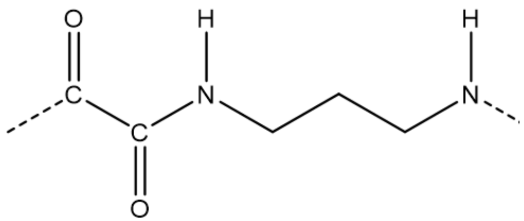
Question	Answer	Marks
6(a)(i)	$HNO_3 + H_2SO_4 \rightarrow NO_2^+ + HSO_4^- + H_2O$ **OR** $HNO_3 + 2H_2SO_4 \rightarrow NO_2^+ + 2HSO_4^- + H_3O^+$	**1**

Question	Answer	Marks
6(a)(ii)	 **M1:** curly arrow 1 from inside the hexagon to nitrogen of NO_2^+ **M2:** intermediate, usual rules for horseshoe and + charge **M3:** curly arrow 2 from C-H bond into hexagon **AND** H^+	3
6(b)	**M1:** p-orbital/lone pair from O / oxygen **AND** is delocalised / overlaps **AND** into the ring / π system **M2:** so electron density of the ring is increased **OR** polarises electrophiles / NO_2^+ better	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)	**M1:** 2-nitrophenol > phenol > water > ethanol **M2:** weakens O—H bond / anion stabilised **AND** proton/H^+ (more easily) lost / proton / H^+ (more easily) donated **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) **M4:** (for ethanol), positive inductive effect / electron donating of alkyl group	4
6(f)(i)	<table><tr><td>name of functional group</td><td>classification of functional group</td></tr><tr><td>alcohol / hydroxyl</td><td>primary</td></tr><tr><td>alcohol / hydroxyl</td><td>secondary</td></tr><tr><td>amine</td><td>secondary</td></tr></table> Any three correct [1] all six correct [2]	2

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

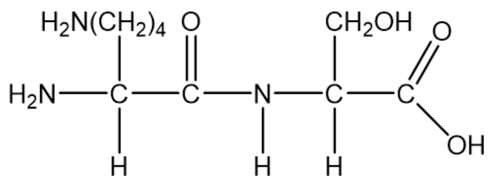
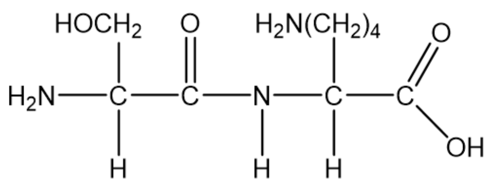
Question	Answer	Marks
7(a)	rotate the plane of polarised light equally in the opposite direction	1
7(b)(i)	**M1:** nitrogen / N can accept / bond to a proton / H^+ ion **OR** donation of lone pair/electrons on the nitrogen / N to a proton / H^+ ion **M2:** $CH_3CH(NH_2)CH_2CH_3 + H_2O \rightarrow CH_3CH(NH_3^+)CH_2CH_3 + OH^-$	2
7(b)(ii)	**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) **M2:** increase electron density on N **OR** make lone pair on N more available (to accept H^+)	2
7(b)(iii)	$(CH_3CH_2)_2NH + CH_3COOH \rightarrow (CH_3CH_2)_2NH_2^+ \ CH_3COO^-$	1

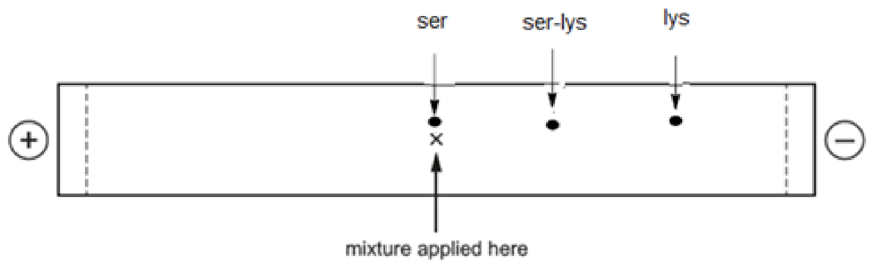
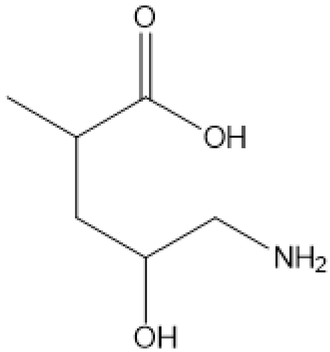
<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>7(b)(iii)</td><td>$(CH_3CH_2)_2NH + CH_3COOH \rightarrow (CH_3CH_2)_2NH_2^+\ CH_3COO^-$</td><td>1</td></tr>
<tr><td>7(b)(iv)</td><td>$(CH_3CH_2)_2NH + CH_3COCl \rightarrow CH_3CON(CH_2CH_3)_2 + HCl$</td><td>1</td></tr>
<tr><td>7(c)(i)</td><td>
<table>
<tr><td>monomer</td><td>type of polymerisation</td></tr>
<tr><td>CH_2CHCH_3COOH</td><td>addition</td></tr>
<tr><td></td><td>condensation</td></tr>
<tr><td>$CH_3CH(NH_2)COOH$</td><td>condensation</td></tr>
</table>
</td><td>1</td></tr>
<tr><td>7(c)(ii)</td><td>
M1: correct displayed amide linkage with an adjacent C=O (to CO) and $C(H_2)$ to NH

M2: rest of the structure correct (only one repeat unit) with continuation bonds</td><td>2</td></tr>
<tr><td>7(c)(iii)</td><td>they are chemically inert / difficult to hydrolyse / C-C bonds are non-polar</td><td>1</td></tr>
</table>

Question	Answer	Marks
8(a)	reference: TMS / tetramethylsilane / $(CH_3)_4Si$ **AND** solvent: D_2O / $CDCl_3$	1

Question	Answer	Marks
8(b)	six / 6 peaks	**1**
8(c)	<table><tr><td>chemical shift δ / ppm</td><td>splitting pattern</td><td>number of protons on adjacent carbon atoms</td><td>number of ^{1}H atoms responsible for the peak</td></tr><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></table> Any three [1] any six [2] any nine [3] all eleven [4]	**4**

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

Question	Answer	Marks
9(b)(ii)	 **M1:** correct relative positions of the spots drawn **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 **M3:** lys moves the furthest / fastest **AND** as it has the lower M_r / smaller size (than ser-lys)	3
9(c)(i)	**Q**, $C_6H_{13}NO_3$ 	1
9(c)(ii)	**M1:** step 1 aqueous **AND** HC*l* / H_2SO_4 **AND** heat / reflux[1] **M2:** step 2 conc. H_2SO_4 catalyst **AND** high temp / heat	2