Cambridge Assessment International Education

Cambridge International AS & A Level

CHEMISTRY **9701/41**

Paper 4 A Level Structured Questions **May/June 2023**

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 2023 series for most Cambridge IGCSE, Cambridge International A and AS Level and Cambridge Pre-U components, and some Cambridge O Level components.

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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 descriptors 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

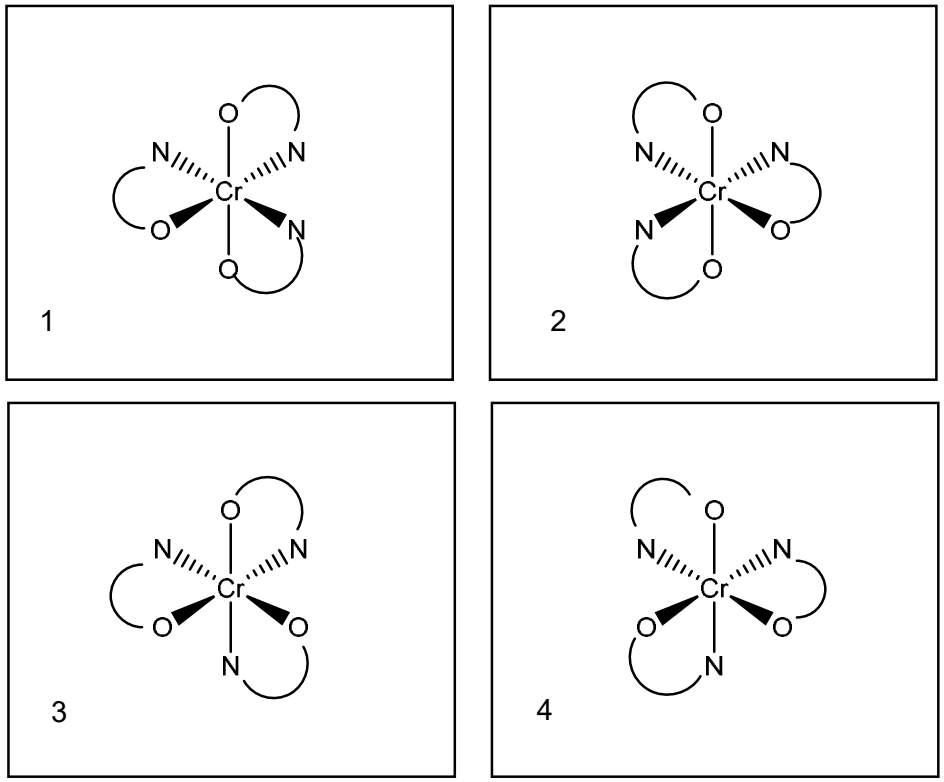
Multiples / fractions of coefficients used in chemical equations are acceptable unless stated otherwise in the mark scheme.

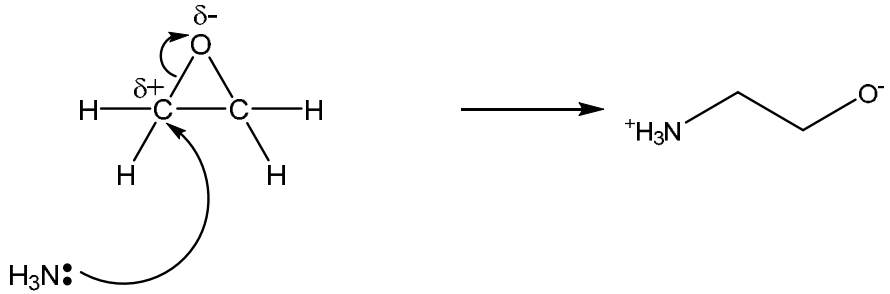
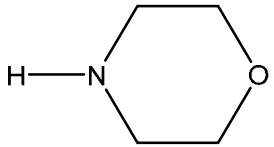
State symbols given in an equation should be ignored unless asked for in the question or stated otherwise in the mark scheme.

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>1(a)</td><td>M1 increases (down the group)
M2 radius / size of (cat)ion / M^{2+} increases
M3 less polarisation / distortion of anion / nitrate ion / NO_3^- OR less weakening of N–O / N=O (bond)</td><td>3</td></tr>
<tr><td>1(b)</td><td>$Cu(NO_3)_2 \rightarrow CuO + 2NO_2 + ½O_2$</td><td>1</td></tr>
<tr><td>1(c)</td><td><table><tr><th>copper-containing species</th><th>formula of copper-containing species formed</th><th>colour copper-containing formed</th></tr><tr><td>A</td><td>$[Cu(H_2O)_6]^{2+}$</td><td>(pale) blue</td></tr><tr><td>B</td><td>$Cu(H_2O)_4(OH)_2$ or $Cu(OH)_2$</td><td>(pale) blue</td></tr><tr><td>C</td><td>$[Cu(NH_3)_4(H_2O)_2]^{2+}$</td><td>dark blue</td></tr><tr><td>D</td><td>$CuCl_4^{2-}$</td><td>yellow</td></tr></table>Two correct for one mark, four correct for two marks, six correct for three marks, eight correct for four marks.</td><td>4</td></tr>
<tr><td>1(d)(i)</td><td>M1 (a species) that donates more than two lone pairs
M2 to form dative / coordinate bonds to a metal atom or ion</td><td>2</td></tr>
<tr><td>1(d)(ii)</td><td>six atoms circled, 2N and 4O from different CO_2^-</td><td>1</td></tr>
<tr><td>1(d)(iii)</td><td>the number of co-ordinate bonds being formed by the metal ion</td><td>1</td></tr>
<tr><td>1(d)(iv)</td><td>ligand exchange</td><td>1</td></tr>
<tr><td>1(d)(v)</td><td>$[FeEDTA]^-$ > $[CrEDTA]^-$ > $[PbEDTA]^{2-}$
highest conc^n lowest conc^n AND K_{stab} of $[FeEDTA]^-$ is highest</td><td>1</td></tr>
</table>

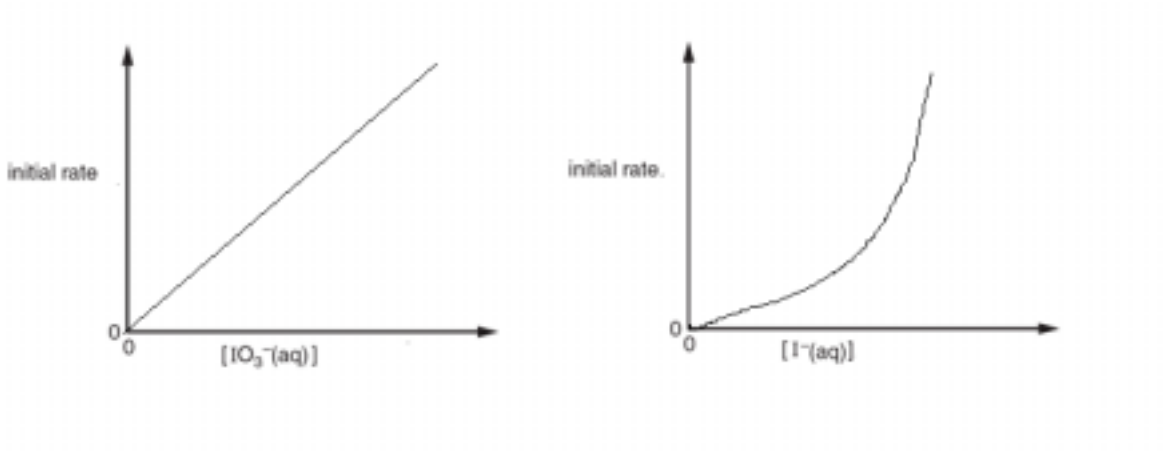
Question	Answer	Marks
1(e)	**M1** moles of Cr^{3+} = 2.096×10^{-4} in 25.0 cm^3) **M2** moles of Cr^{3+} = 8.384×10^{-4} (in 100.0 cm^3) moles of $Cr_2(SO_4)_3 \bullet nH_2O$ = $8.384 \times 10^{-4} / 2 = 4.192 \times 10^{-4}$ **M3** M_r of $Cr_2(SO_4)_3 \bullet nH_2O$ = $0.2550 / 4.192 \times 10^{-4}$ = 608.3 n = (608.3 – 392.3) / 18 = 12	**3**
1(f)	**M1** ΔE is different **M2** different frequency (of light) is absorbed	**2**

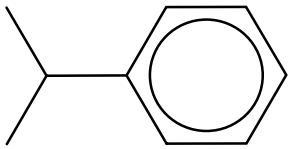
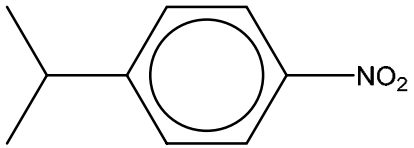
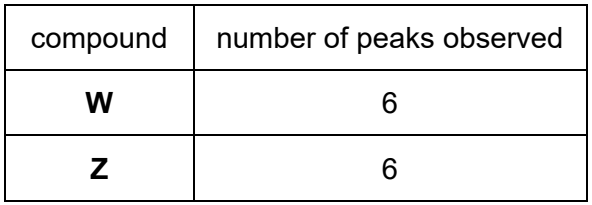
Question	Answer	Marks
2(a)	geometrical / cis-trans **AND** optical	**1**
2(b)	square planar	**1**

Question	Answer	Marks
2(c)	 Two correct for one mark, three correct for two marks, four correct for three marks.	**3**

Question	Answer	Marks
2(d)(i)	 **M1** two correct curly arrows **M2** correct dipole **M3** correct structure of intermediate	**3**
2(d)(ii)	use an excess of ammonia **OR** limiting amount of oxirane	**1**
2(d)(iii)	 **M1** **M2** elimination / dehydration / condensation	**2**

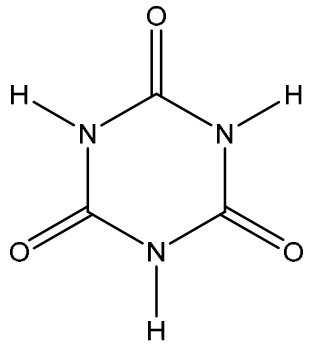
Question	Answer	Marks
3(a)(i)	the power to which the concentration of a reactant is raised in the rate equation	**1**

Question	Answer	Marks
3(a)(ii)	<table><tr><td>the order of reaction with respect to $[IO_3^-]$</td><td>1</td></tr><tr><td>the order of reaction with respect to $[H^+]$</td><td>2</td></tr><tr><td>the order of reaction with respect to $[I^-]$</td><td>2</td></tr><tr><td>the overall order of reaction</td><td>5</td></tr></table> All correct for one mark	**1**
3(a)(iii)		**1**
3(a)(iv)	**M1** k = rate / $[I^-]^2[IO_3^-][H^+]^2$ = $(4.20 \times 10^{-2})/(0.025^2 \times 0.04 \times 0.015^2) = 7.47 \times 10^6$ **M2** units = $mol^{-4}\,dm^{12}\,min^{-1}$	**2**
3(a)(v)	$0.0709 = k \times 0.12 \times [H^+]^2 \times 0.0125^2$ $[H^+] = 2.25 \times 10^{-2}$	**1**
3(a)(vi)	$x = 10^2 / 1 = 100$	**1**
3(b)	**M1** step 1 $Fe^{3+} + I^- \rightarrow FeI^{2+}$ **M2** step 2 $FeI^{2+} + I^- \rightarrow Fe^{2+} + I_2^-$ **OR** $FeI^{2+} + I^- \rightarrow FeI_2^+$ **AND** slowest step = step 2 **M3** step 3 $Fe^{3+} + I_2^- \rightarrow Fe^{2+} + I_2$ **OR** $FeI_2^+ + Fe^{3+} \rightarrow 2Fe^{2+} + I_2$	**3**

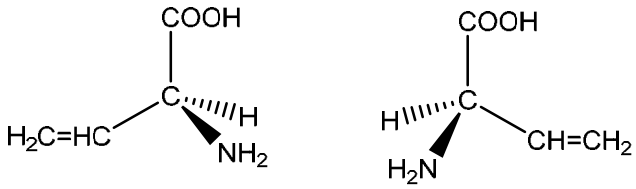
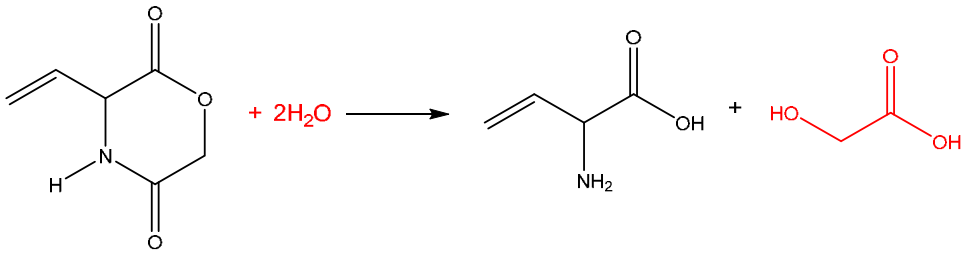
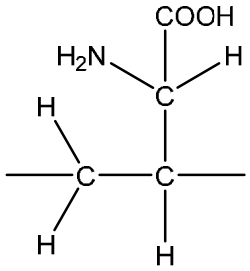
Question	Answer	Marks
4(a)	**M1** bond angle = 120° **AND** carbons are sp^2 **M2** σ bonds are formed by end-on-end / head on / head to head / linear overlap of orbitals **M3** π bonds are formed by sideways / lateral overlap of p orbitals	**3**
4(b)(i)	**X**  [1] **Y**  [1]	**2**
4(b)(ii)	**M1** step 1 $(CH_3)_2CHBr$ and $FeBr_3$ / $AlBr_3$ **M2** step 2 conc HNO_3 and conc H_2SO_4 **M3** step 3 Sn and conc HCl	**3**
4(c)	3,4,5-trimethylphenylamine	**1**
4(d)	 Both correct for one mark	**1**

compound	number of peaks observed
W	6
Z	6

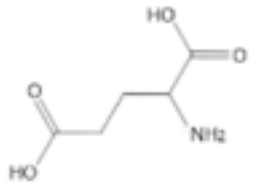
Question	Answer	Marks
5(a)(i)	palladium, platinum and rhodium / Pt, Pd, Rh	**1**
5(a)(ii)	a catalyst in a different state / phase to the reactants / substrate	**1**
5(b)(i)	measure / degree of disorder / randomness of a system **OR** the number of possible arrangements of the particles and the energy in a system	**1**

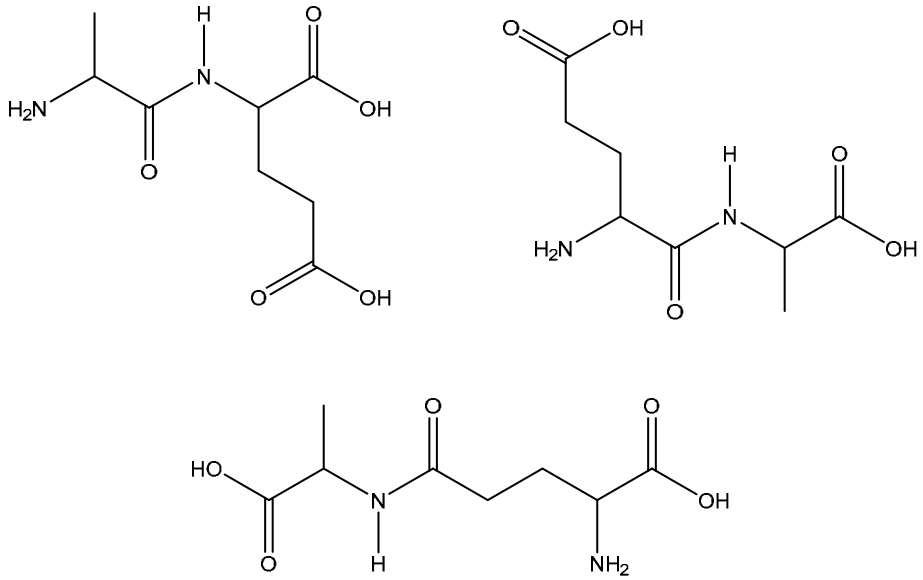
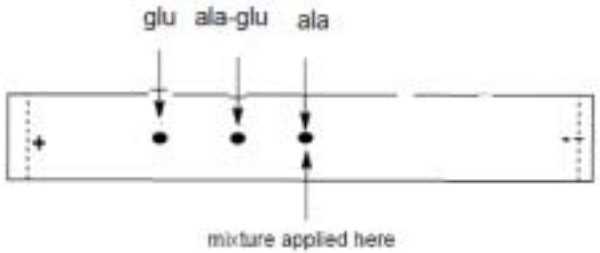
Question	Answer	Marks
5(b)(ii)	**M1** $\Delta S^{\ominus}$ = (192.8) + 213.8 – 238.2 – 188.8 $\Delta S^{\ominus}$ = -20.4 (J K^{-1} mol^{-1}) **M2** $\Delta H^{\ominus}$ = (–45.9) + (–393.5) – (–101.7) – (–241.8) $\Delta H^{\ominus}$ = -95.9 (kJ mol^{-1}) **M3** $\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$ **M4** $\Delta G^{\ominus}$ = –95.9 – (298 × –0.0204) = –89.8 (kJ mol^{-1})	**4**
5(c)	$4(NH_2)_2CO + 6NO_2 \rightarrow 7N_2 + 8H_2O + 4CO_2$	**1**
5(d)		**1**
5(e)(i)	pK_a = –log K_a **AND** pH = –log $[H^+]$	**1**
5(e)(ii)	**M1** $[H^+] = \sqrt{0.120 \times 2.00 \times 10^{-4}} = 4.89(317) \times 10^{-3}$ **M2** pH = 2.31	**2**
5(e)(iii)	% ionisation = $4.89 \times 10^{-3}/0.12 \times 100$ = 4.1%	**1**

Question	Answer	Marks
6(a)(i)	carboxylic acid, amine, alkene Two correct for one mark, three correct for two marks	**2**

Question	Answer	Marks
6(a)(ii)	 optical Two correct for one mark, three correct for two marks.	**2**
6(b)(i)		**1**
6(b)(ii)	hydrolysis	**1**
6(c)(i)		**1**

Question	Answer	Marks
6(c)(ii)	**M1** amide linkage displayed correctly **M2** rest of the structure correct	**2**
6(c)(iii)	condensation polymers can be hydrolysed	**1**

Question	Answer	Marks
7(a)	**M1** diethylamine > ethylamine > ethanamide explanation **M2** basicity linked to ability of lone pair on N to accept a proton / H^+ **M3** electron donating ethyl group increases electron density on N / makes lone pair more available for donation **M4** lone pair of electrons on N is delocalised into C=O group	**4**
7(b)(i)	**M1** resists change in pH **M2** when a **small** amount of acid or alkali is added	**2**
7(b)(ii)	**M1** $H_2NCH(CH_3)COOH + H^+ \rightarrow H_3N^+CH(CH_3)COOH$ **M2** $H_2NCH(CH_3)COOH + OH^- \rightarrow H_2NCH(CH_3)COO^- + H_2O$	**2**
7(c)(i)		**1**

Question	Answer	Marks
7(c)(ii)	 **M1** displayed peptide bond (between two amino acids) **M2** rest of the structure correct	**2**
7(d)	 **M1** relative positions of the spots drawn **M2** Ala is a zwitterion / neutral / at its isoelectric point (at pH 6) **OR** ala-glu **AND** glu are negatively charged **M3** glu has lower M_r **OR** ala-glu has higher M_r	**3**

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>7(e)(i)</td><td>
<table>
<tr><th>chemical shift (δ)</th><th>splitting pattern</th><th>number of ^{1}H atoms responsible for the peak</th><th>number of protons on the adjacent carbon(s)</th></tr>
<tr><td>1.4</td><td>doublet</td><td>3</td><td>1</td></tr>
<tr><td>3.5</td><td>singlet</td><td>3</td><td>0</td></tr>
<tr><td>4.0</td><td>quartet</td><td>1</td><td>3</td></tr>
</table>
Three correct for one mark, six correct for two marks, nine correct for three marks.
</td><td>3</td></tr>
<tr><td>7(e)(ii)</td><td>one extra peak for NH_2 group seen in $CDCl_3$, AND H exchanged for D in D_2O</td><td>1</td></tr>
</table>

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>8(a)</td><td>
<table>
<tr><th>energy change</th><th>always positive</th><th>always negative</th><th>either negative or positive</th></tr>
<tr><td>lattice energy</td><td></td><td>✓</td><td></td></tr>
<tr><td>enthalpy of hydration</td><td></td><td>✓</td><td></td></tr>
<tr><td>enthalpy of solution</td><td></td><td></td><td>✓</td></tr>
</table>
All correct for one mark
</td><td>1</td></tr>
<tr><td>8(b)</td><td>The energy / enthalpy change when 1 mole of gaseous ions is dissolved in water</td><td>1</td></tr>
<tr><td>8(c)(i)</td><td>M1 use of correct six numbers only
682.8 178.2 590 1145 111.9 324.6
M2 2× used correctly with Br (2 × 111.9 and 2 × 324.6)
M3 correct signs and evaluation to give –2170.6 kJ mol^{-1}</td><td>3</td></tr>
</table>

Question	Answer	Marks
8(c)(ii)	**M1** use of correct three numbers only 2170.6 103.1 and 1579 **M2** correct signs & evaluation –347 kJ mol^{-1}	**2**
8(c)(iii)	**M1** Br^- has a smaller ionic radius **M2** Br^- has stronger attractive forces with water molecules	**2**