CAMBRIDGE
International Education

Cambridge International AS & A Level

CHEMISTRY **9701/41**

Paper 4 A Level Structured Questions **October/November 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 October/November 2025 series for most Cambridge IGCSE, Cambridge International A and AS Level components, and some Cambridge O Level components.

This document consists of **19** printed pages.

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

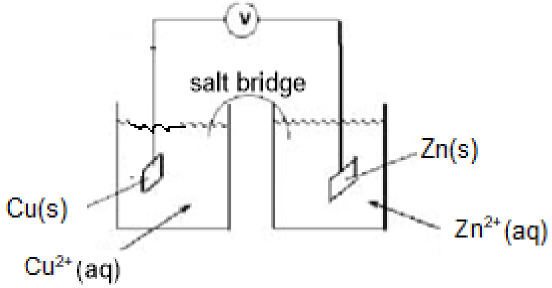
Annotation	Meaning
✓	Correct point or mark awarded
✗	Incorrect point or mark not awarded
?	Unclear
^	Information missing or insufficient for credit
BOD	Benefit of the doubt given
CON	Contradiction in response otherwise markworthy, mark not given
●	Part of the correct answer has been seen. Full credit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

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

Question	Answer	Marks
1(a)(i)	$Sr(HCO_3)_2 \rightarrow SrCO_3 + CO_2 + H_2O$	**1**
1(a)(ii)	**M1**: radius of cation / M^{2+} increases **OR** charge density of cation / M^{2+} decreases **M2**: less polarisation / less distortion of the anion / carbonate ion	**2**
1(b)	**M1**: least soluble $CaF_2 < SrF_2 < BaF_2$ most soluble **M2**: ΔH_{latt} and ΔH_{hyd} both become less exothermic / less negative **M3**: ΔH_{hyd} changes less / becomes less exothermic by a smaller extent **OR** ΔH_{latt} changes more / becomes less exothermic by a larger extent **M4**: ΔH_{sol} becomes more exothermic / more negative	**4**
1(c)(i)	enthalpy change when one mole of gaseous ions dissolve in water to form a solution	**1**
1(c)(ii)	**M1**: ionic radii **AND** ionic charge **M2**: (ionic) radii increase / charge density decreases **AND** ΔH_{hyd} decreases/less exothermic **AND** less attraction between water molecules and (gaseous) ions **OR** as ionic charge increases / charge density increases **AND** ΔH_{hyd} increases/more exothermic **AND** more attraction between water molecules and (gaseous) ions	**2**
1(d)	**M1**: use of –2957 / –1926 / –505 **AND** 2 × (–505) **M2**: correct signs and evaluation ΔH_{sol} of $MgF_2(s) = -1926 + (2 \times -505) - (-2957) = (+)21\ kJ\ mol^{-1}$	**2**
1(e)(i)	**M1:** $K_{sp} = [Hg_2^{2+}]\,[F^-]^2$ **M2:** units = $mol^3\ dm^{-9}$	**2**
1(e)(ii)	$K_{sp} = 2^2 \times (9.20 \times 10^{-3})^3 = \mathbf{3.11 \times 10^{-6}}$ min 2sf	**1**

Question	Answer	Marks
2(a)	the (3)d and (4)s sub-shells / orbitals / electrons are close / similar in energy	**1**
2(b)	species or ion formed by a central metal atom/ion **AND** surrounded by/bonded to (one or more) ligands	**1**
2(c)(i)	NaOH / $OH^-(aq)$ **AND** precipitation / ligand exchange / deprotonation / acid–base	**1**
2(c)(ii)	**M1**: $Fe(H_2O)_4(OH)_2$ is oxidised (from + 2 to + 3 on standing) **M2**: $E^\ominus$ of $Fe(H_2O)_3(OH)_3$ is more negative than $E^\ominus$ of O_2 **OR** $E^\ominus_{cell} = 0.40 - (-0.56) = (+)0.96$ V **M3**: $4Fe(H_2O)_4(OH)_2 + O_2 \rightarrow 4Fe(H_2O)_3(OH)_3 + 2H_2O$	**3**
2(d)	$\Delta G^\ominus = -2 \times 1.67 \times 96\,500 = -322\,310$ J mol^{-1} **M1:** $\Delta G^\ominus = -nE^\ominus_{cell}F$ **AND** n = 2 **OR** $-2 \times 1.67 \times 96\,500$ **M2:** $\Delta G^\ominus = -322.3$ kJ mol^{-1}	**2**

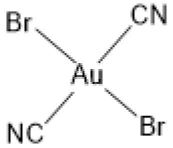
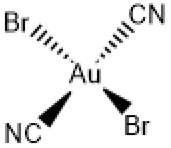
Question	Answer	Marks
3(a)	heterogeneous **AND** MnO_2 is in a different state / phase to the reactants / H_2O_2	1
3(b)(i)	**M1:** (expt 2 and 3) $[I^-] \times 2$ initial rate × 2 so 1st order wrt $[I^-]$ **M2:** (expt 1 and 2) $[I^-] \times 2$, $[H_2O_2] \times 0.5$ initial rate × 1 so 1st order wrt $[H_2O_2]$ **OR** (expt 1 and 4) $[I^-] \times 4$ initial rate × 4 **AND** $[H^+] \times 4$ so zero order wrt $[H^+]$ **OR** (expt 1 and 3) $[I^-] \times 4$, $[H_2O_2] \times 0.5$ initial rate × 2 so 1st order wrt $[H_2O_2]$ **M3:** (expt 1 and 4) $[I^-]$ x 4 , $[H^+] \times 4$ initial rate × 4 so zero order wrt $[H^+]$ **OR** (expt 3 and 4) $[H_2O_2] \times 2$ initial rate × 2**AND** $[H^+]$ x 4 so zero order wrt $[H^+]$ **OR** (expt 3 and 4) $[H_2O_2] \times 2$, $[H^+] \times 4$ initial rate × 2 so 1st order wrt $[H_2O_2]$ **M4:** rate = $k\,[H_2O_2]\,[I^-]$ **OR** rate = $k\,[H_2O_2]\,[I^-]\,[H^+]^0$	4
3(b)(ii)	**M1:** $k = 2.42 \times 10^{-3} \div (0.045 \times 0.030) = 1.79$ min 2sf **M2:** units = $dm^3\ mol^{-1}\ s^{-1}$	2
3(c)(i)	**M1:** calculation of one $t_{1/2}$ = 60 s ± 5 s **M2:** two $t_{1/2}$ calculated that are constant	2
3(c)(ii)	$k = \ln 2 \div 60 = 0.0116$ **OR** $k = 0.693 \div 60 = 0.0116$ min 2sf	1
3(d)	increases k and increases the rate of reaction	1
4(a)	**M1:** potential difference / voltage / EMF **AND** between two half-cells / two electrodes (in a cell) **M2:** (at concentration of) 1 mol dm^{-3} **AND** (pressure of) 1 atm / 101 kPa **AND** (temperature of) 298 K / 25 °C	2

Question	Answer	Marks
4(b)(i)	 **M1**: salt bridge labelled **AND** voltmeter / V **AND** wire to electrode and liquid level shown [complete circuit] **M2**: Cu(s) **AND** Cu^{2+}(aq) **M3**: Zn(s) **AND** Zn^{2+}(aq)	**3**
4(b)(ii)	ions **AND** electrons	**1**
4(b)(iii)	**M1**: Nernst equation $E = E^{\ominus} + (0.059/z)\log(Zn^{2+}/Zn)$ **M2**: $E = –0.76 + (0.059 / 2)\log(0.25) = –0.778$ V **OR** $E = –0.76 + (8.31 \times 298) / (96\,500 \times 2)\ln(0.25) = –0.778$ V min 2sf	**2**
4(c)(i)	(from) +4 (to) +3	**1**
4(c)(ii)	$Zn + 2MnO_2 \rightarrow ZnO + Mn_2O_3$	**1**
4(c)(iii)	$E^{\ominus}(MnO_2 / Mn_2O_3) = 1.47 – 1.28 = (+)0.19$ V	**1**

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>5(a)</td><td>
<table>
<tr><th rowspan="2">species</th><th colspan="2">number of unpaired electrons</th></tr>
<tr><th>3d</th><th>4s</th></tr>
<tr><td>Cu</td><td>0</td><td>1</td></tr>
<tr><td>Cu^{2+}</td><td>1</td><td>0</td></tr>
</table>
</td><td>1</td></tr>
<tr><td>5(b)</td><td>• five 3d orbitals (lines, boxes) in the isolated Cu^{2+} ion of the same energy
• splitting: three higher and two lower d orbitals
• energy of all five d orbitals in complex higher than all d orbitals in isolated ion

any two [1], all three [2]</td><td>2</td></tr>
<tr><td>5(c)</td><td>M1: more than one (stable) oxidation state / exist in variable oxidation states

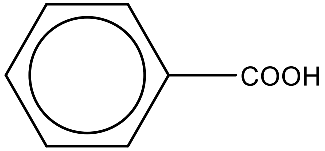
M2: vacant / empty (d) orbitals are energetically accessible
OR vacant / empty (d) orbitals can form dative bonds with ligands</td><td>2</td></tr>
<tr><td>5(d)</td><td>
<table>
<tr><th>metal ion</th><th>coordination number</th><th>formula of complex ion</th><th>charge of complex ion</th></tr>
<tr><td>Ag^+</td><td>2</td><td>$Ag(CN)_2$</td><td>1–</td></tr>
<tr><td>Fe^{2+}</td><td>6</td><td>$Fe(CN)_6$</td><td>4–</td></tr>
</table>
each row [1]</td><td>2</td></tr>
</table>

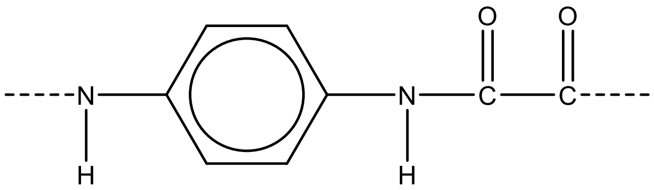
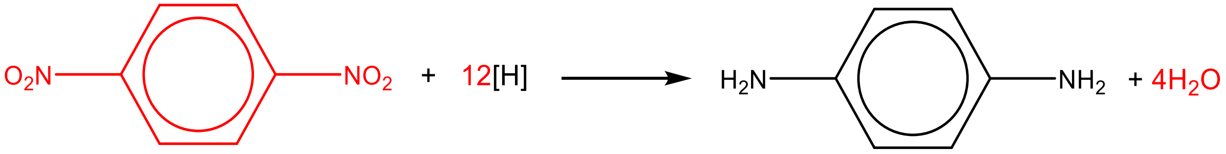
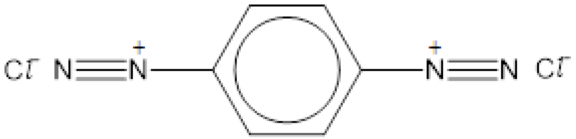
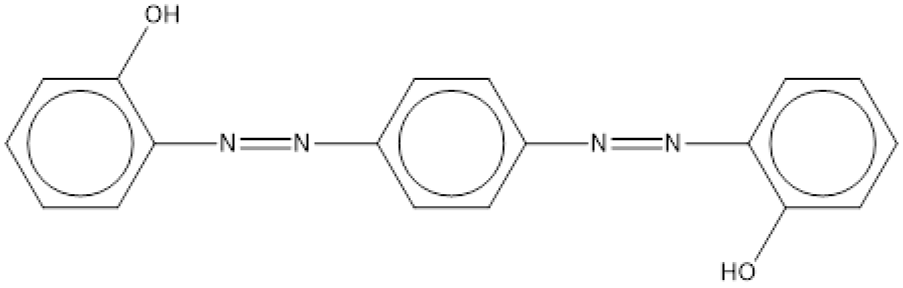
Question	Answer	Marks
5(e)	**M1:**  **OR**  **M2:** (shape) square planar **AND** (bond angle) 180°	**2**
5(f)(i)	**M1**: moles MnO_4^- = 0.075 × 0.0225 = 1.6875×10^{-3} **M2:** moles V^{2+} = 5 / 3 × 1.6875×10^{-3} = 2.8125×10^{-3} **M3:** mass V = 50.9 × 2.8125×10^{-3} = 0.143 g % of V = 0.143 / 0.250 × 100 = 57.3 min 2sf	**3**
5(f)(ii)	$2VO_3^- + 3Zn + 12H^+ \rightarrow 2V^{2+} + 3Zn^{2+} + 6H_2O$ **M1:** 2 : 3 ratio on both sides **M2:** rest of the equation correct	**2**

Question	Answer	Marks
6(a)(i)	**M1:** (R_f value) is distance moved by a component / spot / solute **AND** divided by distance moved by solvent **OR** (R_f value) is the ratio of distance moved by a component / spot / solute **AND** by distance moved by solvent **M2:** (retention time) is (the time) between injection and detection (of a component)	**2**

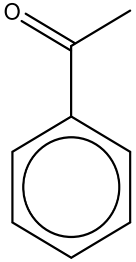
<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>6(a)(ii)</td><td>thin-layer chromatography: polar solvent OR non-polar solvent OR named solvent

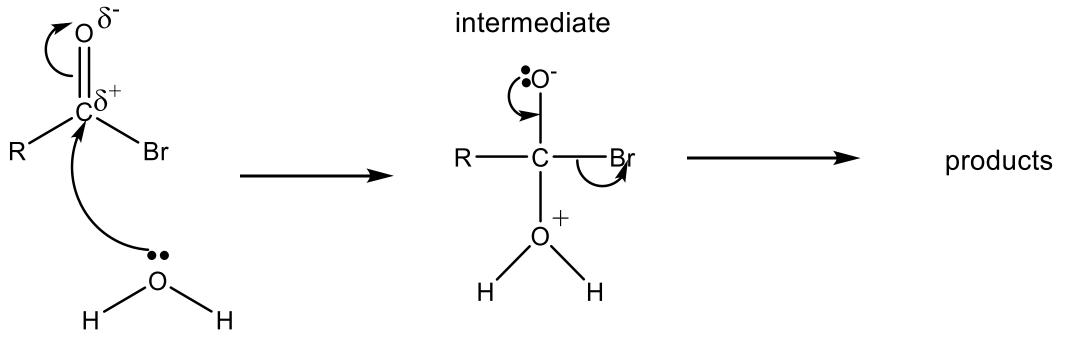
gas-liquid chromatography: non-volatile liquid OR high boiling point liquid</td><td>1</td></tr>
<tr><td>6(b)</td><td>A is more soluble in the mobile phase OR A has less adsorption to the stationary phase</td><td>1</td></tr>
<tr><td>6(c)(i)</td><td><table><tr><th>compound</th><th>number of peaks observed</th></tr><tr><td>Y</td><td>2</td></tr><tr><td>Z</td><td>2</td></tr></table></td><td>1</td></tr>
<tr><td>6(c)(ii)</td><td>M1: Y (two) singlet(s)
M2: Z triplet AND quartet</td><td>2</td></tr>
</table>

Question	Answer	Marks
7(a)	**M1:** $ClCH_2COOH$ $BrCH_2COOH$ CH_3COOH CH_3CH_2OH most acidic least acidic **M2:** electron withdrawing groups / electronegative groups / negative inductive effect **AND** weakens O–H bond / more stable anion **OR** electron donating groups / positive inductive effect **AND** strengthens O-H bond / less stable anion **M3 M4:** • chlorine is more electron-withdrawing / electronegative than bromine (related to XCH_2COOH) • electron withdrawing of C=O / negative inductive effect of C=O (related to COOH) • positive inductive effect / electron donating of alkyl / ethyl / R group (related to ROH) any two [1], all three [2]	4
7(b)	**M1:**  **M2:** CO_2	2

Question	Answer	Marks
7(c)(i)	 **M1**: correct displayed amide bond with C=O, (C_6H_5)–N and (C–)C=O **M2**: rest of the structure correct with continuation bonds	**2**
7(c)(ii)		**1**
7(d)(i)	**M1:**  **M2:** 	**2**

Question	Answer	Marks
7(d)(ii)	HNO_2 (and HCl) **AND** ⩽10 °C **OR** $NaNO_2$ **AND** HCl **AND** ⩽10 °C	1

Question	Answer	Marks
8(a)(i)	NO_2 group directs to 3 (and 5) / meta position **AND** due to being an electron-withdrawing / electronegative group	1
8(a)(ii)	$HNO_3 + H_2SO_4 \rightarrow NO_2^+ + HSO_4^- + H_2O$ **OR** $HNO_3 + 2H_2SO_4 \rightarrow NO_2^+ + 2HSO_4^- + H_3O^+$	1
8(b)(i)		1
8(b)(ii)	**M1:** (reaction 1) ethanoyl chloride / CH_3COCl **AND** $AlCl_3$ **M2:** (reaction 2) 2-bromopropane / $(CH_3)_2CHBr$ **AND** $FeBr_3$	2
8(c)	**M1:** with C_6H_5Br no change / no precipitate **AND** with $C_6H_5CH_2Br$ cream precipitate in C_6H_5Br **M2:** lone pair / p-orbital on Br delocalised / overlaps with ring / π system **M3:** C–Br bond stronger / has partially double bond character	3

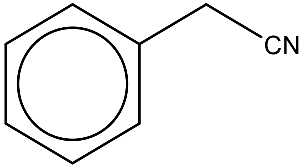
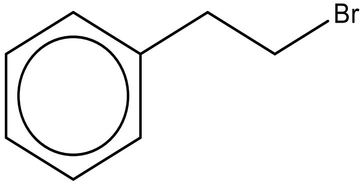
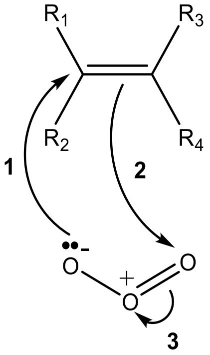
<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>8(d)(i)</td><td>(nucleophilic) addition–elimination</td><td>1</td></tr>
<tr><td>8(d)(ii)</td><td>

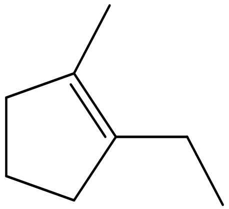
M1 M2:
• lone pair on O
• curly arrow from (lone pair) O (in H_2O) to C (of C=O)
• correct dipole on C=O
• curly arrow from the C=O bond to O atom
any two [1], all four [2]

M3: correct intermediate

M4: curly arrow from (lone pair on) $O^{(-)}$ to C–O bond AND curly arrow from C–Br to Br</td><td>4</td></tr>
</table>

Question	Answer	Marks
9(a)	**M1:** (basicity linked to) ability of lone pair / p-orbital to **AND** accept / coordinate with a proton / H^+ **M2:** (lone pair of) electrons on N is delocalised into C=O group (and make amides neutral)	2

Question	Answer	Marks
9(b)(i)	**M1: M**  **M2: N** 	**2**
9(b)(ii)	$LiAlH_4$	**1**
9(c)	ketone / carbonyl **AND** secondary / 2°	**1**
9(d)(i)	 curly arrow 1: from O lone pair to C atom (in C=C) curly arrow 2: from C=C bond to the right-hand O atom in O=O curly arrow 3: from O=O bond to O^+	**2**

Question	Answer	Marks
9(d)(ii)		**1**