Cambridge Assessment International Education

Cambridge International AS & A Level

CHEMISTRY **9701/41**

Paper 4 A Level Structured Questions **May/June 2021**

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 2021 series for most Cambridge IGCSE™, Cambridge International A and AS Level components and some Cambridge O Level components.

This document consists of **17** 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 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.

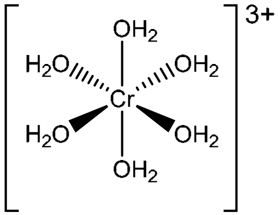
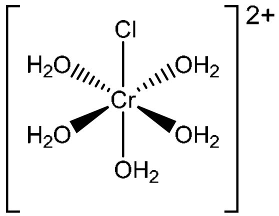
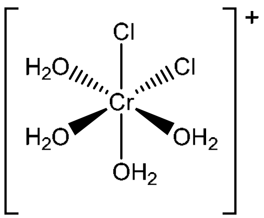
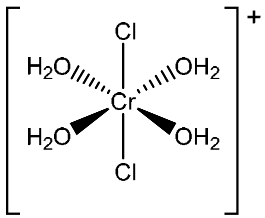
Science-Specific Marking Principles

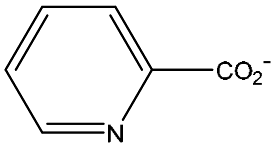
1	Examiners should consider the context and scientific use of any keywords when awarding marks. Although keywords may be present, marks should not be awarded if the keywords are used incorrectly.
2	The examiner should not choose between contradictory statements given in the same question part, and credit 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	<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	<u>Calculation specific guidance</u> 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	<u>Guidance for chemical equations</u> 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.

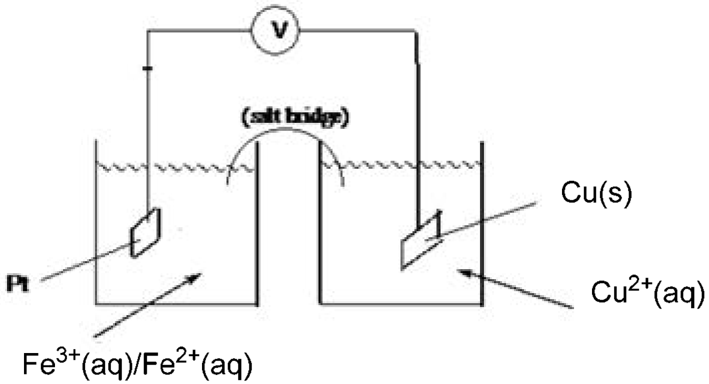
Question	Answer	Marks
1(a)	**M1:** increases down the group **M2:** radius / size of (cat)ion / M^{2+} increases **M3:** less polarisation / distortion of anion / hydroxide ion **/** hydroxide group / OH^- / OH	**3**
1(b)(i)	$Ca(OH)_2(s) \rightleftharpoons Ca^{2+}(aq) + 2OH^-(aq)$	**1**
1(b)(ii)	**M1:** $K_{sp} = [Ca^{2+}][OH^-]^2$ **OR** $K_{sp} = 4x^3$ **M2:** x = $\sqrt[3]{5.02 \times 10^{-6} / 4}$ = 0.0108 / 0.011 / 1.08×10^{-2} / 1.1×10^{-2} (mol dm^{-3}) min 2 sf	**2**
1(b)(iii)	less soluble / decreases due to the common ion effect **OR** decreases as equilibrium in **(b)(i)** has shifted to the left **OR** decreases as $[OH^-]$ increases causing $[Ca^{2+}][OH^-]^{(2)}$ to exceed its K_{sp}	**1**

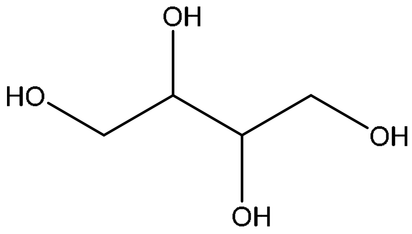
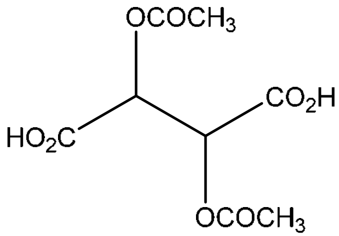
Question	Answer	Marks
2(a)	**M1:** (complexes have two sets of) d orbital(s) of different energy / d-d splitting occurs **OR** d orbital(s) / d (sub)-shell splits **OR** (inferred from a movement of an electron) from a lower d to higher d orbital **M2:** electron(s) promoted / excited **OR** electron(s) moves to higher (d–)orbital **OR** electron(s) jumps up (to d–orbital) / jumps to higher (d–orbital) **M3:** wavelength / frequency / light / photon / hν absorbed **OR** radiation / energy from <u>visible</u> (region) absorbed **M4:** colour seen is complementary (to colour absorbed) **OR** wavelength / frequency / colour / light not absorbed is transmitted / reflected / seen	**4**

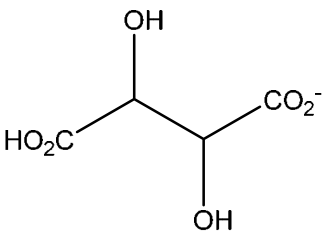
Question	Answer	Marks
2(b)(i)	**P**  **Q**  **R**  **S**  **M1:** All charges **M2:** One octahedral with correct 3D **M3:** All formulae **M4:** R is cis, S is trans	**4**
2(b)(ii)	dipoles cancel	**1**
2(c)(i)	**M1:** (a species) that donates <u>two</u> lone pairs / forms two coordinate bonds / two dative bonds **M2:** to a metal atom / metal ion	**2**

Question	Answer	Marks
2(c)(ii)	 structure of the picolinate anion ligand	**1**
2(c)(iii)	(coordination number) six **AND** (geometry around Cr) octahedral	**1**
2(d)(i)	$(NH_4)_2Cr_2O_7$ +6 Cr_2O_3 +3	**1**
2(d)(ii)	$(NH_4)_2Cr_2O_7 \rightarrow N_2 + Cr_2O_3 + 4H_2O$	**1**

Question	Answer	Marks
3(a)(i)	(an element) forming stable ion / ions / compound(s) / oxidation state(s) **AND** with partially filled / incomplete **AND** d orbitals / d subshell / d shell	**1**
3(a)(ii)	(melting point) higher **AND** (density) higher	**1**
3(b)(i)	**M1:** emf / potential difference / difference in electrode potential between two half-cells / two electrodes (in a cell) **M2:** (all solutions being) 1 mol dm^{-3} **AND either** 1 atm **OR** 298 K	**2**

Question	Answer	Marks
3(b)(ii)	salt bridge, voltmeter, Cu(s), Cu^{2+}(aq), Pt(s), Fe^{2+} and Fe^{3+}(aq) two for one mark, four for two marks, six for three marks 	3
3(c)(i)	**M1:** $2I^- + 2Fe^{3+} \rightarrow I_2 + 2Fe^{2+}$ **M2:** $S_2O_8^{2-} + 2Fe^{2+} \rightarrow 2SO_4^{2-} + 2Fe^{3+}$	2
3(c)(ii)	**M1:** I_2 / I^- +0.54 V **AND** Fe^{3+} / Fe^{2+} + 0.77 V **AND** $[Fe(CN)_6]^{3-} / [Fe(CN)_6]^{4-}$ +0.36 V **M2:** $E^\ominus$ of I_2 / I^- is more positive / greater than $E^\ominus$ of $[Fe(CN)_6]^{3-} / [Fe(CN)_6]^{4-}$ **OR** $E^\ominus_{cell}$ = –0.18 V so no reaction occurs **OR** $E^\ominus$ of Fe^{3+} / Fe^{2+} is more positive / greater than $E^\ominus$ of I_2 / I^- **OR** $E^\ominus_{cell}$ = 0.23 V so reaction occurs [1]	2
3(d)(i)	$S_2O_8^{2-}$ and tartrate ions are both negatively charged / both reactants same charge **AND** so repel each other **OR** have a high E_a	1
3(d)(ii)	$C_4H_4O_6^{2-} + 2H_2O \rightleftharpoons 2CO_2 + 2HCO_2^- + 6H^+ + 6e^-$	1

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>3(e)(i)</td><td>
<table>
<tr><td>reagent</td><td>structure of organic product</td><td>type of reaction</td></tr>
<tr><td>an excess of $LiAlH_4$</td><td>
</td><td>reduction</td></tr>
<tr><td>an excess of CH_3COCl</td><td>
</td><td>condensation</td></tr>
</table>

M1: product with $LiAlH_4$
M2: product with CH_3COCl
M3: both types of reaction
</td><td>3</td></tr>
<tr><td>3(e)(ii)</td><td>

$C_6H_5CH(NH_3^+)CH_3$
OR dianion of tartrate with two cations present</td><td>1</td></tr>
</table>

Question	Answer	Marks
4(a)(i)	**M1:** blue solid / blue ppt **M2:** $[Cu(H_2O)_6]^{2+}$ + $2OH^-$ $\rightarrow$ $Cu(OH)_2$ + $6H_2O$ **OR** $[Cu(H_2O)_6]^{2+}$ + $2OH^-$ $\rightarrow$ $Cu(OH)_2(H_2O)_4$ + $2H_2O$ **M3:** precipitation / acid-base	**3**
4(a)(ii)	**M1:** dark blue solution / deep blue solution **M2:** $[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4H_2O$ **M3:** ligand exchange / substitution / displacement / replacement	**3**
4(b)	**M1:** **X** $CuSO_4$ and **Y** Cu **M2:** *type of reaction* = redox / disproportionation	**2**

Question	Answer	Marks
5(a)	measure volume / amount of oxygen formed / mass lost / and time / against time / per unit time **OR** measure absorbance / transmission against time / per unit time	**1**
5(b)(i)	time taken for the concentration / mass / amount of a reactant to fall to half (its original value) / to halve	**1**
5(b)(ii)	$t_{1/2}$ = 150 s **AND** evidence on graph / paper of one half-life	**1**
5(b)(iii)	no change	**1**
5(c)(i)	**M1:** evidence on graph of tangent **AND** 4 to 5 $\times 10^{-4}$ **M2:** mol dm^{-3} s^{-1}	**2**

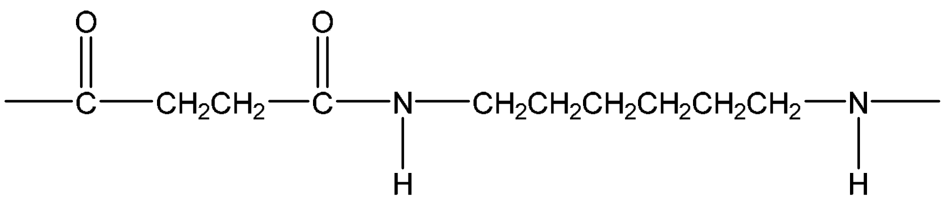
Question	Answer	Marks
5(c)(ii)	**(c)(i)** / 0.10 **AND** s^{-1}	**1**
5(d)	**M1:** $NO_2 + O_3 \rightarrow NO_3 + O_2$ **M2:** $NO_2 + NO_3 \rightarrow N_2O_5$	**2**

Question	Answer	Marks
6(a)	**M1:** ethanoic acid > butanoic acid > water > ethanol **M2:** a reason given in terms of an electron donating or an electron withdrawing group for one of: strengthening of O–H bond **OR** weakening of O–H bond **OR** stability of anion *Two out of the three alternatives M3, M4 and M5:* M3: <u>ethanol</u>: positive inductive effect / electron donating effect of ethyl / alkyl / R group M4: <u>butanoic acid</u>: positive inductive effect / electron donating effect of propyl / alkyl / R group M5: (either ethanoic or butanoic) <u>acid</u>: negative inductive effect of either C=O or carbonyl **OR** negative charge delocalised over COO^-	**4**
6(b)(i)	<table><tr><td></td><td>reagents and conditions</td><td>observed change</td></tr><tr><td>test 1</td><td>Tollen's reagent, warm **OR** Fehling's solution, warm</td><td>silver mirror (brick) red ppt / solid</td></tr><tr><td>test 2</td><td>acidified MnO_4^-, warm</td><td>decolourises **OR** bubbles</td></tr></table> **M1 / M2:** reagents and conditions × 2 **M3:** observations both correct	**3**

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>6(b)(ii)</td><td>
<table>
<tr><td>compound</td><td>number of peaks in proton NMR</td><td>number of peaks in carbon-13 NMR</td></tr>
<tr><td>HCO_2H</td><td>2</td><td>1</td></tr>
<tr><td>HO_2CCO_2H</td><td>1</td><td>1</td></tr>
<tr><td>$HO_2CCH_2CH_2CO_2H$</td><td>2</td><td>2</td></tr>
</table>
one mark for three, four or five correct
two marks for six correct</td><td>2</td></tr>
<tr><td>6(b)(iii)</td><td>OH peak disappears AND proton / H exchanges with deuterium</td><td>1</td></tr>
<tr><td>6(c)(i)</td><td>G = $HOCH_2CH_2CH_2CH_2OH$
H = $NCCH_2CH_2CH_2CH_2CN$</td><td>2</td></tr>
<tr><td>6(c)(ii)</td><td>M1: step 1 NaOH(aq) + heat

M2: step 2 acidified $KMnO_4$ + heat / acidified $K_2Cr_2O_7$ + heat

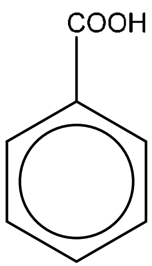
M3: step 3 CN^- / KCN / NaCN + heat

M4: step 4 $LiAlH_4$ ALLOW Na in ethanol or H_2 + Ni / Pd / Pt</td><td>4</td></tr>
<tr><td>6(d)</td><td>
M1: correct displayed amide linkage

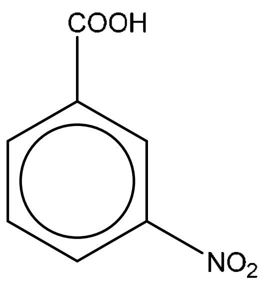
M2: the rest of the repeat unit correct including trailing bonds</td><td>2</td></tr>
</table>

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>7(a)(i)</td><td>

M



N



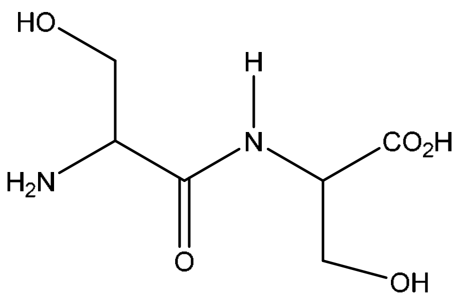
</td><td>2</td></tr>
<tr><td>7(a)(ii)</td><td>

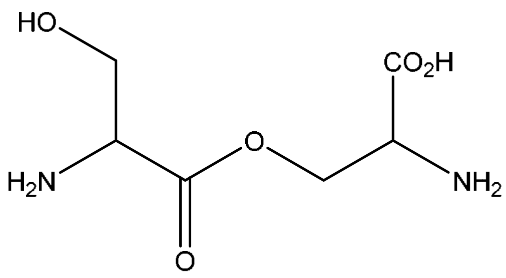
M1: step 1 hot $KMnO_4$ / MnO_4^-

M2: step 2 conc. H_2SO_4 and conc. HNO_3

M3: step 3 Sn and conc. HC*l* (heat)

</td><td>3</td></tr>
<tr><td>7(b)(i)</td><td>

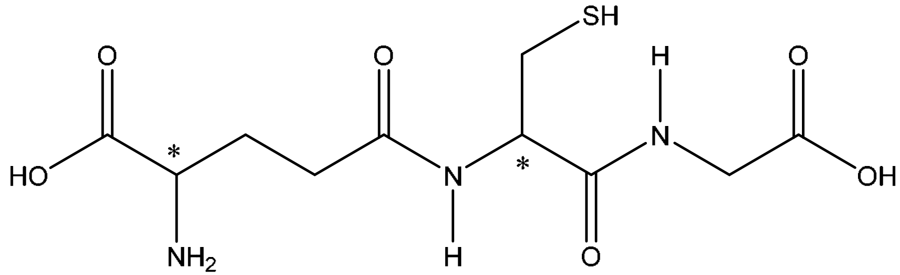
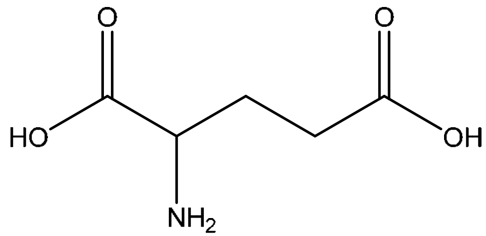
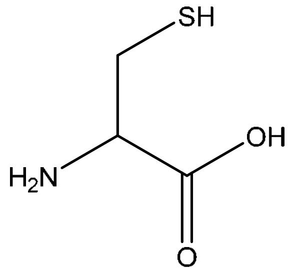
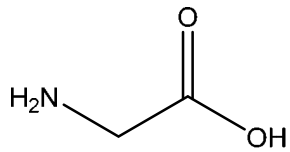




M1 / M2: each structure

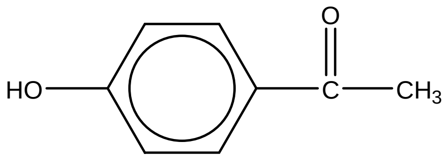
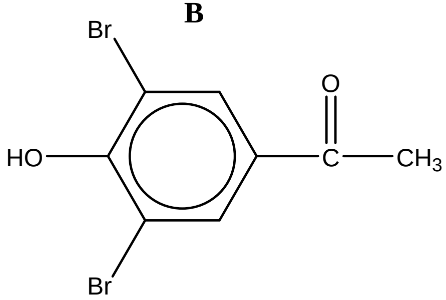
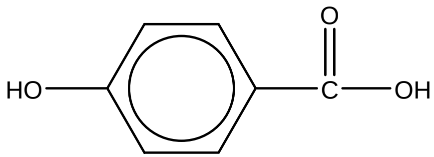
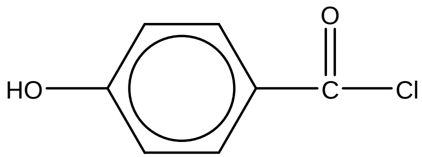
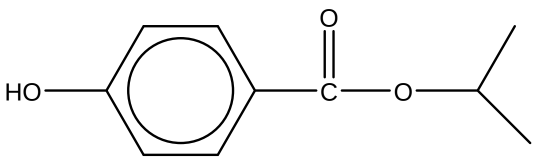
M3: both displayed linkage

</td><td>3</td></tr>
<tr><td>7(b)(ii)</td><td>
<table>
<tr><td>molecular formula</td><td>number of structural isomers formed</td></tr>
<tr><td>$C_9H_{19}N_3O_4$</td><td>4</td></tr>
</table>
</td><td>1</td></tr>
</table>

Question	Answer	Marks
7(c)(i)		**1**
7(c)(ii)	   one mark for two correct two marks for three correct	**2**

Question	Answer	Marks
8(a)(i)	**M1:** CH_3CO_2H and $CH_3CO_2^-$ **M2:** due to buffering action / acting as a buffer solution **M3:** CH_3CO_2H reacts with NaOH / OH^- (forming $CH_3CO_2^-$ and water) **OR** OH^- reacts with H^+ <u>and</u> equilibrium $CH_3CO_2H \rightleftharpoons CH_3CO_2^- + H^+$ shifts to the right	**3**
8(a)(ii)	identifying $CH_3CO_2^-$ is present (with water) at the equivalence point **OR** $CH_3CO_2^-$ react with water forming OH^- **OR** titrating a weak acid with a strong base	**1**

Question	Answer	Marks
8(b)	**M1:** moles MnO_4^- = 0.025 × 0.0201 = 5.025 × 10^{-4} moles V^{2+} = 5.025 × 10^{-4} × 5 / 3 = 8.375 × 10^{-4} **M2:** moles VO_3^- = 8.375 × 10^{-4} mass of NH_4VO_3 = 116.9 × 8.375 × 10^{-4} = 0.0979 g **M3:** % Purity of NH_4VO_3 = 100 × 0.0979 / 0.15 = 65.3 must be 3 sf	**3**

Question	Answer	Marks
9(a)	**A**  **B**  **C** CHI_3 **D**  **E**  **F**  one mark for each structure	**6**