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**CHEMISTRY**

**9701/42**

Paper 4 A Level Structured Questions

**October/November 2016**

MARK SCHEME

Maximum Mark: 100

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**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.

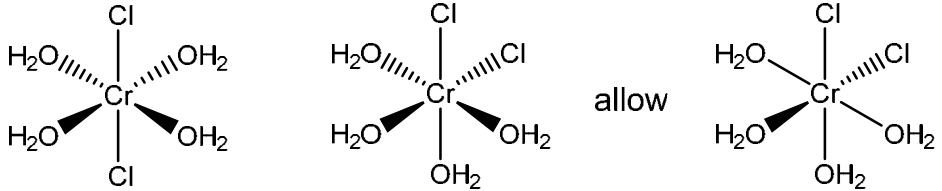
Cambridge will not enter into discussions about these mark schemes.

Cambridge is publishing the mark schemes for the October/November 2016 series for most Cambridge IGCSE<sup>®</sup>, Cambridge International A and AS Level components and some Cambridge O Level components.

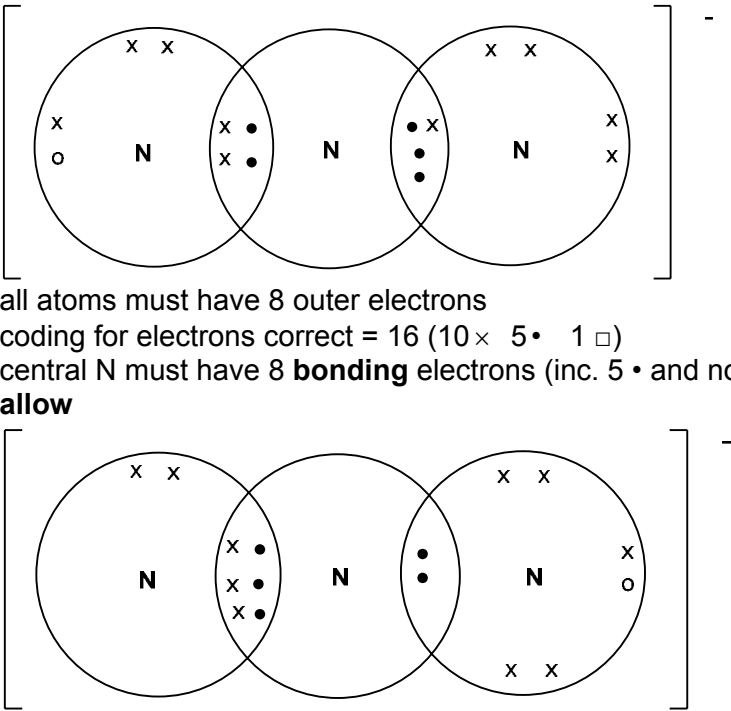
Page 2	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – October/November 2016	9701	42

Question	Answer	Marks									
1(a)	(an element) forming (one or more stable) <b>ions</b> with <b>incomplete d subshell</b> [1]	1 1									
1(b)(i)	<table border="1"> <thead> <tr> <th></th> <th>co-ordination number</th> <th>oxidation number</th> </tr> </thead> <tbody> <tr> <td><math>[\text{Ni}(\text{CN})_2(\text{NH}_3)_2]</math></td> <td>4</td> <td>+2</td> </tr> <tr> <td><math>[\text{CrCl}_2(\text{H}_2\text{O})_4]^+</math></td> <td>6</td> <td>+3</td> </tr> </tbody> </table>		co-ordination number	oxidation number	$[\text{Ni}(\text{CN})_2(\text{NH}_3)_2]$	4	+2	$[\text{CrCl}_2(\text{H}_2\text{O})_4]^+$	6	+3	2
	co-ordination number	oxidation number									
$[\text{Ni}(\text{CN})_2(\text{NH}_3)_2]$	4	+2									
$[\text{CrCl}_2(\text{H}_2\text{O})_4]^+$	6	+3									
1(b)(ii)	dative (covalent)/co-ordinate	1 1									
1(b)(iii)	<p>correct diagram of <math>[\text{Ni}(\text{CN})_2(\text{NH}_3)_2]</math></p> <p>square planar or tetrahedral</p>	1 1 2									
1(c)(i)	(concentrated) hydrochloric acid / soluble chloride ion	1 1									
1(c)(ii)	<b>ligand</b> exchange / substitution	1 1									
1(d)(i)	cis-trans (isomerism) / geometric(al)	1 1									

<b>Page 3</b>	<b>Mark Scheme</b>	<b>Syllabus</b>	<b>Paper</b>
	<b>Cambridge International AS/A Level – October/November 2016</b>	<b>9701</b>	<b>42</b>

Question	Answer	Marks
1(d)(ii)	<p>one 3D isomer one correct isomer other isomer correct in 3D</p> 	<p>1 1 1</p> <p style="text-align: center;"><b>3</b></p>
	<b>Total:</b>	<b>12</b>

Page 4	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – October/November 2016	9701	42

Question	Answer	Marks
2(a)	$\text{NaN}_3 \rightarrow \text{Na} + 1.5\text{N}_2$	1 1
2(b)	 <p>all atoms must have 8 outer electrons coding for electrons correct = 16 (10 × 5 • 1 □) central N must have 8 <b>bonding</b> electrons (inc. 5 • and no non-bonded electrons) <b>allow</b></p>	1 1 1  3
2(c)(i)	(energy change) when <b>1 mole</b> of an (ionic) <b>compound is formed</b> or (energy change) when <b>1 mole</b> of an <u>ionic</u> solid/lattice/crystal <b>is formed</b> (from)  <b>gas</b> (phase) ions / gaseous ions (under standard conditions)	1  1  2
2(c)(ii)	<b>forming</b> an (ionic) bond	1  1

<b>Page 5</b>	<b>Mark Scheme</b>	<b>Syllabus</b>	<b>Paper</b>
	<b>Cambridge International AS/A Level – October/November 2016</b>	<b>9701</b>	<b>42</b>

<b>Question</b>	<b>Answer</b>	<b>Marks</b>
2(c)(iii)	use of $\Delta H_{f1}$ 494 (kJ mol <sup>-1</sup> ) $\Delta H_f^\ominus = +107+494+142-732$ $\Delta H_f^\ominus = +11$ (kJ mol <sup>-1</sup> )	1 1 1 <b>3</b>
2(c)(iv)	(ionic) radius / size of Na <sup>+</sup> is smaller (so stronger attraction to azide ion) <b>OR</b> ionic radius increases down the group	1 <b>1</b>
	<b>Total:</b>	<b>11</b>

<b>Question</b>	<b>Answer</b>	<b>Mark</b>
3(a)	Fe [Ar] 3d <sup>6</sup> 4s <sup>2</sup> Fe <sup>3+</sup> [Ar] 3d <sup>5</sup>	1 1 <b>2</b>
3(b)(i)	(catalyst is in) the same phase / state as the reactants	1 <b>1</b>
3(b)(ii)	$S_2O_8^{2-} + 2I^- \rightarrow 2SO_4^{2-} + I_2$	1 <b>1</b>
3(b)(iii)	(two) negatively-charged species <b>repel</b> each other	1 <b>1</b>
3(b)(iv)	Equation 1: $2Fe^{3+} + 2I^- \rightarrow 2Fe^{2+} + I_2$ Equation 2: $S_2O_8^{2-} + 2Fe^{2+} \rightarrow 2SO_4^{2-} + 2Fe^{3+}$	1 1 <b>2</b>

<b>Page 6</b>	<b>Mark Scheme</b>	<b>Syllabus</b>	<b>Paper</b>
	<b>Cambridge International AS/A Level – October/November 2016</b>	<b>9701</b>	<b>42</b>

<b>Question</b>	<b>Answer</b>	<b>Marks</b>
3(c)(i)	(entropy is a measure / degree of the) disorder of a <b>system / substance</b>	1 <b>1</b>
3(c)(ii)	$\Delta S^\ominus = (2 \times 27) + (3 \times 214) - (90) - (3 \times 198)$ <b>OR</b> $696 - 684$ $\Delta S^\ominus = (+) 12 \text{ (J K}^{-1} \text{ mol}^{-1}\text{)}$	1 1 <b>2</b>
3(c)(iii)	$\Delta G^\ominus = -43.6 - (298 \times 12 / 1000)$ $\Delta G^\ominus = -47.2 \text{ (kJ mol}^{-1}\text{)}$	1 1 <b>2</b>
3(c)(iv)	high $E_a$ <b>and</b> to speed up the rate	1 <b>1</b>
	<b>Total:</b>	<b>13</b>

<b>Page 7</b>	<b>Mark Scheme</b>	<b>Syllabus</b>	<b>Paper</b>
	<b>Cambridge International AS/A Level – October/November 2016</b>	<b>9701</b>	<b>42</b>

<b>Question</b>	<b>Answer</b>	<b>Marks</b>
4(a)	<p>d orbitals split into lower <b>and</b> upper orbitals</p> <p>light/photon absorbed</p> <p><b>electron(s)</b> promoted / excited / jumps up to (higher) (d-) orbital <b>or</b>  <b>electron(s)</b> moves / jumps (from lower (d-)) to higher (d-) orbital</p>	<p>1</p> <p>1</p> <p>1</p> <p><b>3</b></p>
4(b)(i)	<p><math>\text{Cu} + 4\text{HNO}_3 \rightarrow \text{Cu}(\text{NO}_3)_2 + 2\text{NO}_2 + 2\text{H}_2\text{O}</math></p> <p>or ionic <math>\text{Cu} + 4\text{H}^+ + 2\text{NO}_3^- \rightarrow \text{Cu}^{2+} + 2\text{NO}_2 + 2\text{H}_2\text{O}</math></p> <p>correct species correct balancing</p>	<p>1</p> <p>1</p> <p><b>2</b></p>
4(b)(ii)	<p>moles <math>\text{S}_2\text{O}_3^{2-} = 0.1 \times 22.4 / 1000 = \mathbf{2.24 \times 10^{-3}}</math></p> <p>moles of <math>\text{Cu}^{2+}</math> in <math>25 \text{ cm}^3 = \mathbf{2.24 \times 10^{-3}}</math></p> <p>moles of <math>\text{Cu}^{2+}</math> in <math>250 \text{ cm}^3 = 2.24 \times 10^{-2}</math></p> <p>mass of <math>\text{Cu} = 2.24 \times 10^{-2} \times 63.5 = 1.4224 \text{ g}</math></p> <p><math>\% \text{ Cu} = 1.42 / 1.75 \times 100 = \mathbf{81.1}</math> or <math>\mathbf{81.3\%}</math></p>	<p>1</p> <p>1</p> <p>1</p> <p>1</p> <p><b>4</b></p>
	<b>Total:</b>	<b>9</b>

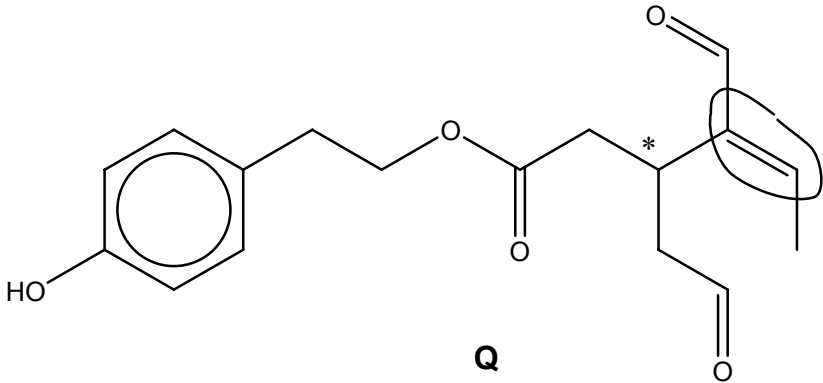
<b>Page 8</b>	<b>Mark Scheme</b>	<b>Syllabus</b>	<b>Paper</b>
	<b>Cambridge International AS/A Level – October/November 2016</b>	<b>9701</b>	<b>42</b>

<b>Question</b>	<b>Answer</b>	<b>Marks</b>
5(a)	$K_a = \frac{[\text{HPO}_4^{2-}][\text{H}_3\text{O}^+]}{[\text{H}_2\text{PO}_4^-]}$	1 <b>1</b>
5(b)(i)	a solution that resists changes in pH when <b>small</b> amounts of acid and base / alkali are added	1 1 <b>2</b>
5(b)(ii)	addition of acid: $\text{H}^+ + \text{HPO}_4^{2-} \rightarrow \text{H}_2\text{PO}_4^-$ <b>OR</b> $\text{H}^+ + \text{H}_2\text{PO}_4^- \rightarrow \text{H}_3\text{PO}_4$ addition of base: $\text{HO}^- + \text{H}_2\text{PO}_4^- \rightarrow \text{HPO}_4^{2-} + \text{H}_2\text{O}$ <b>OR</b> $\text{OH}^- + \text{HPO}_4^{2-} \rightarrow \text{H}_2\text{O} + \text{PO}_4^{3-}$	1 1 <b>2</b>
5(c)	$[\text{H}^+] = 10^{-7.4} = 3.98 \times 10^{-8}$ $[\text{HPO}_4^{2-}] / [\text{H}_2\text{PO}_4^-] = K_a / [\text{H}^+]$ $([\text{HPO}_4^{2-}] / [\text{H}_2\text{PO}_4^-]) = 6.31 \times 10^{-8} / 3.98 \times 10^{-8} = \mathbf{1.58-1.6}$	1 1 1 <b>3</b>
5(d)(i)	$\text{HCl} + \text{H}_2\text{PO}_4^- \rightarrow \text{H}_3\text{PO}_4 + \text{Cl}^-$ <b>OR</b> $\text{H}^+ + \text{H}_2\text{PO}_4^- \rightarrow \text{H}_3\text{PO}_4$ <b>OR</b> $\text{H}_2\text{O} + \text{H}_2\text{PO}_4^- \rightarrow \text{H}_3\text{PO}_4 + \text{OH}^-$	1 <b>1</b>

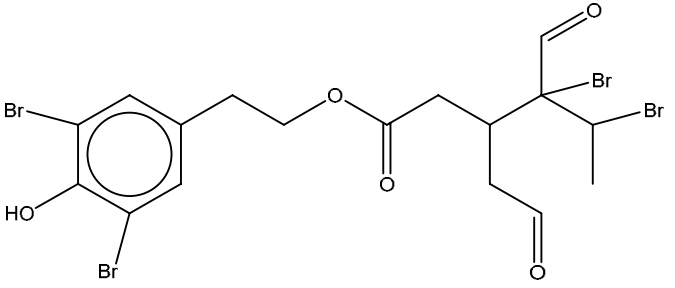
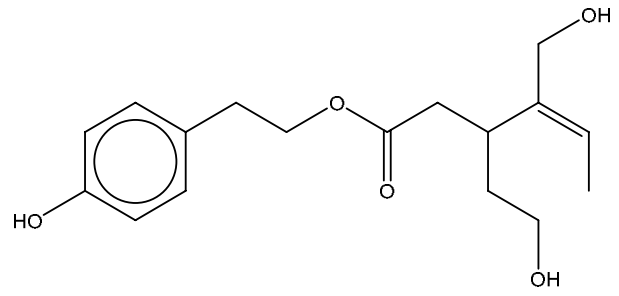


Page 9	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – October/November 2016	9701	42

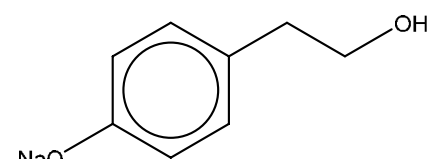
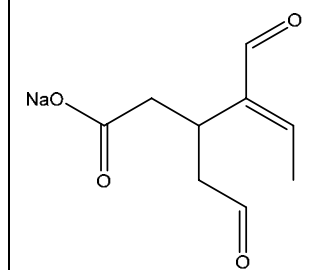
Question	Answer	Marks
5(d)(ii)	$\text{NaOH} + \text{HPO}_4^{2-} \rightarrow \text{PO}_4^{3-} + \text{H}_2\text{O} + \text{Na}^+$ OR $\text{OH}^- + \text{HPO}_4^{2-} \rightarrow \text{PO}_4^{3-} + \text{H}_2\text{O}$ OR $\text{H}_2\text{O} + \text{HPO}_4^{2-} \rightarrow \text{PO}_4^{3-} + \text{H}_3\text{O}^+$	1 1
	Total:	10

Question	Answer	Marks
6(a)	 <p style="text-align: center;">Q</p>	1
6(b)(i)	<b>ratio</b> of the <b>concentration</b> of a solute in the (two immiscible) solvents/liquids at equilibrium	1 1 2
6(b)(ii)	$K_{\text{partition}} = (0.06 / 40) / (0.25 - 0.06 / 10)$ or reversed ratio: $K_{\text{partition}} = (0.25 - 0.06 / 10) / (0.06 / 40)$ $K_{\text{partition}} = \mathbf{0.079}$ (0.0789) <span style="margin-left: 200px;"><math>K_{\text{partition}} = 12.7/13.0</math></span>	1 1 2

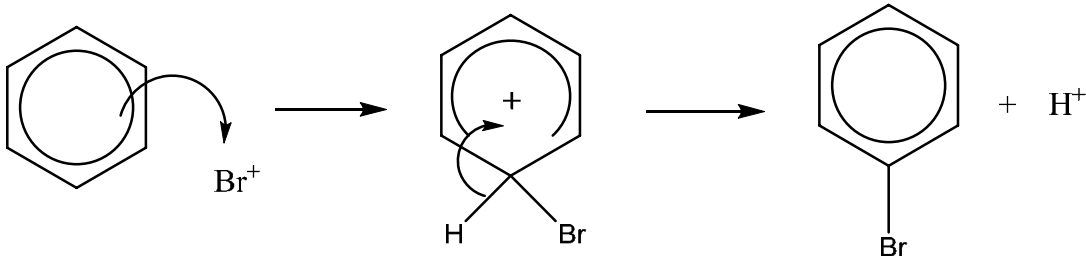
Page 10	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – October/November 2016	9701	42

Question	Answer			Marks
6(c)	reagent	structure of product(s)	type of reaction	1 1
	excess Br <sub>2</sub> (aq)	 <p>addition of bromine to alkene 2×Br substituted in phenol at positions <b>2</b> and <b>6</b></p>	(electrophilic) substitution  or  (electrophilic) addition	
NaBH <sub>4</sub>		reduction  (allow nucleophilic addition)	1	

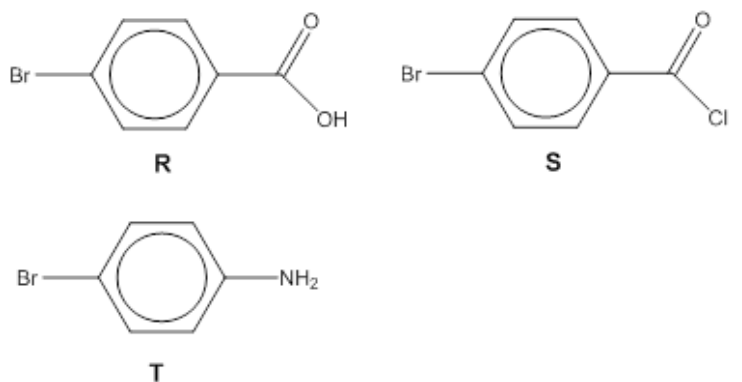
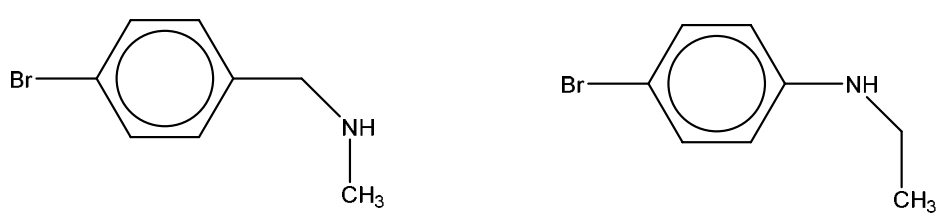
Page 11	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – October/November 2016	9701	42

Question	Answer		Marks
	<p>excess hot NaOH(aq)</p> 	 <p>hydrolysis</p>	<p>1+1</p>
	all three reaction types		1
6(d)	mixture of (two) <b>optical/stereo isomers</b> formed		1
	<b>Total:</b>		<b>12</b>

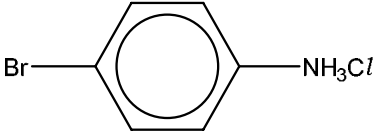
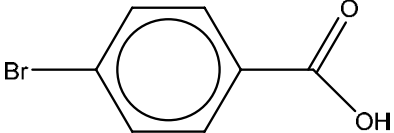
Page 12	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – October/November 2016	9701	42

Question	Answer	Marks
7(a)(i)	electrophilic substitution	1 <b>1</b>
7(a)(ii)	$(\text{Br}_2 + \text{A}/\text{Br}_3) \rightarrow \text{Br}^+ + \text{A}/\text{Br}_4^-$  <p>curly arrow from ring system to <math>\text{Br}^+</math>  correct intermediate  curly arrow from C–H bond into ring and loss of <math>\text{H}^+</math></p>	1  1 1 <b>4</b>
7(b)	<b>both</b> amide	1 <b>1</b>
7(c)(i)	step 1, $\text{A}/\text{Br}_3$ <b>and</b> $\text{CH}_3\text{Br}$ <b>OR</b> other suitable halogen instead of Br step 2, $\text{KMnO}_4$ or potassium manganate(VII) step 3, conc. $\text{H}_2\text{SO}_4$ <b>and</b> conc. $\text{HNO}_3$ step 4. Sn <b>and</b> (conc.) $\text{HCl}$ (heat)	1 1 1 1 <b>4</b>

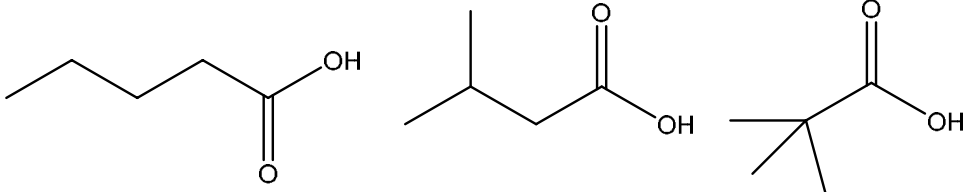
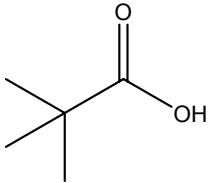
Page 13	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – October/November 2016	9701	42

Question	Answer	Marks
7(c)(ii)	 <p style="text-align: center;">R                      S</p> <p style="text-align: center;">T</p>	<p>1 mark for each correct structure</p> <p><b>3</b></p>
7(d)(i)		<p>1 mark for each correct structure</p> <p><b>2</b></p>
7(d)(ii)	reduction	<p>1</p> <p><b>1</b></p>

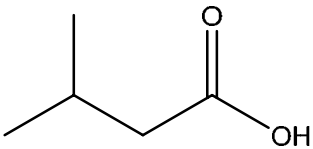
Page 14	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – October/November 2016	9701	42

Question	Answer	Marks
7(e)(i)	 $\text{CH}_3\text{COOH}$ (or ionic)	   1 mark for each correct structure   <b>2</b>
7(e)(ii)		   <b>1</b>
7(e)(iii)	(precipitate) compound is less polar / more non-polar / non-ionic resulting in less hydrogen bonding to water	   <b>1</b>
	<b>Total:</b>	<b>20</b>

Page 15	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – October/November 2016	9701	42

Question	Answer	Marks												
8(a)	$102 \times 0.314 = 32$ ( <b>32.028</b> ) ( $102 - 32 = 70$ ) <b>and</b> $(12 \times 5) + (1 \times 10) = 70$ <b>OR</b> F contains $\text{CO}_2\text{H} = 45$ so $102 - 45 = 57$ so $\text{C}_4\text{H}_9$	1 <b>1</b>												
8(b)(i)	 <p>2 correct = 1 mark 3 correct = 2 marks</p>	<b>2</b>												
8(b)(ii)	2-methyl butanoic acid	1 <b>1</b>												
8(c)(i)		1 <b>1</b>												
8(c)(ii)	<table border="1"> <thead> <tr> <th><math>\delta/\text{ppm}</math></th> <th>environment of the carbon atom</th> <th>hybridisation of the carbon atom</th> </tr> </thead> <tbody> <tr> <td>27</td> <td>alkyl/<math>\text{CH}_3</math></td> <td><math>\text{sp}^3</math></td> </tr> <tr> <td>41</td> <td>next to carboxyl/<math>(\text{CH}_3)_3\text{C}</math></td> <td><math>\text{sp}^3</math></td> </tr> <tr> <td>179</td> <td>carboxyl/<math>\text{CO}_2\text{H}</math></td> <td><math>\text{sp}^2</math></td> </tr> </tbody> </table>	$\delta/\text{ppm}$	environment of the carbon atom	hybridisation of the carbon atom	27	alkyl/ $\text{CH}_3$	$\text{sp}^3$	41	next to carboxyl/ $(\text{CH}_3)_3\text{C}$	$\text{sp}^3$	179	carboxyl/ $\text{CO}_2\text{H}$	$\text{sp}^2$	<b>2</b>
$\delta/\text{ppm}$	environment of the carbon atom	hybridisation of the carbon atom												
27	alkyl/ $\text{CH}_3$	$\text{sp}^3$												
41	next to carboxyl/ $(\text{CH}_3)_3\text{C}$	$\text{sp}^3$												
179	carboxyl/ $\text{CO}_2\text{H}$	$\text{sp}^2$												

Page 16	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – October/November 2016	9701	42

Question	Answer				Marks
8(d)(i)	$\delta/\text{ppm}$	type of proton	number of protons	splitting	4
	0.9	alkane / CH / CH <sub>3</sub>	6	doublet	
	1.6	alkane / CH	1	<b>[multiplet]</b>	
	2.4	alkyl next to C = O / CH <sub>(2)</sub> CO / CH	2	doublet	
	11.5	OH / CO <sub>2</sub> H / carboxylic acid	1	singlet	
8(d)(ii)					1
8(e)	CDCl <sub>3</sub> <b>OR</b> D <sub>2</sub> O, DMSO, CD <sub>2</sub> Cl <sub>2</sub> , CCl <sub>4</sub>				1
	<b>Total</b>				<b>13</b>