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**CHEMISTRY**

**9701/41**

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.

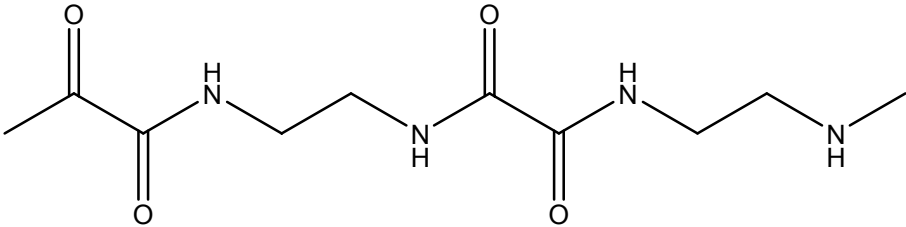
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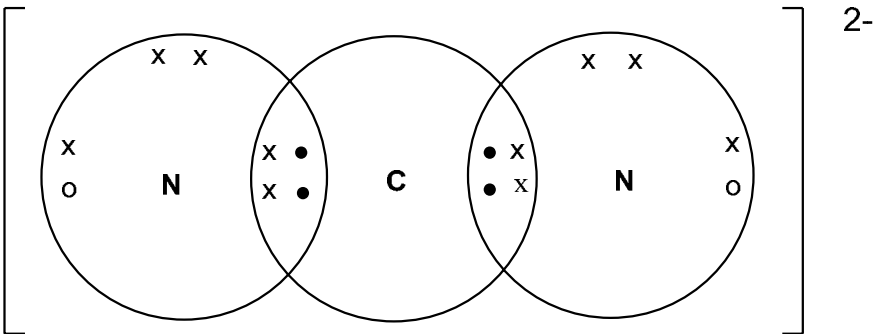
<b>Page 2</b>	<b>Mark Scheme</b>	<b>Syllabus</b>	<b>Paper</b>
	<b>Cambridge International AS/A Level – October/November 2016</b>	<b>9701</b>	<b>41</b>

<b>Question</b>	<b>Answer</b>	<b>Mark</b>
1(a)	Cu [Ar] 3d <sup>10</sup> 4s <sup>1</sup> Cu <sup>2+</sup> [Ar] 3d <sup>9</sup> (4s <sup>0</sup> )	1 1 <b>2</b>
1(b)(i)	<b>ligand</b> exchange / replacement / displacement / substitution	1 <b>1</b>
1(b)(ii)	[Cu(H <sub>2</sub> O) <sub>6</sub> ] <sup>2+</sup> blue <b>and</b> [CuCl <sub>4</sub> ] <sup>2-</sup> yellow <b>OR</b> yellow / green <b>OR</b> green / yellow	1 <b>1</b>
1(b)(iii)	tetrahedral	1 <b>1</b>
1(b)(iv)	$K_{\text{stab}} = \frac{[\text{CuCl}_4^{2-}]}{[\text{Cu}(\text{H}_2\text{O})_6^{2+}][\text{Cl}]^4}$	1 <b>1</b>
1(c)(i)	a species that contains <b>two lone pairs</b> that (each) form a co-ordinate / dative bond <b>OR</b> are donated (to a metal ion / atom)	1 1 <b>2</b>
1(c)(ii)	equilibrium 2 lies more to the RHS / favours forward reaction more	1 <b>1</b>
1(d)(i)	<b>optical</b>	1 <b>1</b>
1(d)(ii)	3D correct for octahedral one correct structure with 3D second correct with 3D	1 1 1

Page 3	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – October/November 2016	9701	41

Question	Answer	Mark
		<b>3</b>
1(e)(i)	lone pair receive / accepts a proton / H <sup>+</sup>	1 1 <b>2</b>
1(e)(ii)	H <sub>2</sub> NCH <sub>2</sub> CH <sub>2</sub> NH <sub>2</sub> + 2HCl → ClH <sub>3</sub> NCH <sub>2</sub> CH <sub>2</sub> NH <sub>3</sub> Cl <b>OR</b> H <sub>2</sub> NCH <sub>2</sub> CH <sub>2</sub> NH <sub>2</sub> + 2H <sup>+</sup> → H <sub>3</sub> N <sup>+</sup> CH <sub>2</sub> CH <sub>2</sub> N <sup>+</sup> H <sub>3</sub>	1 <b>1</b>
1(f)(i)	amide bond, displayed or –CONH–  rest of the molecule with continuation bonds  	1 1 <b>2</b>
1(f)(ii)	condensation / addition – elimination	1 <b>1</b>
1(f)(iii)	any named polyalkene / eg polyethene, PVC <b>allow</b> Bakelite or Kevlar	1 <b>1</b>
	<b>Total:</b>	<b>20</b>

Page 4	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – October/November 2016	9701	41

Question	Answer	Mark
2(a)	solid remains	1 <b>1</b>
2(b)	stability increases (down the group) as size / radius of (metal) <b>ion</b> / <b>M<sup>2+</sup></b> increases so polarisation / distortion of anion / carbonate ion decreases	1 1 1 <b>3</b>
2(c)(i)		<b>2</b>
2(c)(ii)	$\text{CaCN}_2 + 3\text{H}_2\text{O} \rightarrow \text{CaCO}_3 + 2\text{NH}_3$ $\text{CaCO}_3$ correct equation	1 1 <b>2</b>
	<b>Total:</b>	<b>8</b>

<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>41</b>

<b>Question</b>	<b>Answer</b>	<b>Mark</b>
3(a)(i)	(entropy) increases/is positive <b>and</b> H <sub>2</sub> /gas is formed	1 <b>1</b>
3(a)(ii)	(entropy) increases/is positive <b>and</b> (KCl (aq)) solution has (free) moving/mobile ions/aqueous ions	1 <b>1</b>
3(a)(iii)	(entropy) decreases/is negative <b>and</b> decrease in <b>gas</b>	1 <b>1</b>
3(b)(i)	$\Delta S^\circ = 26.9 + 214 - 65.7 = (+) 175.2 \text{ (J K}^{-1} \text{ mol}^{-1}\text{)}$ $\Delta G^\circ = 117 - (298 \times 175.2 / 1000)$ <b>OR</b> $\Delta G^\circ = 117\,000 - (298 \times 175.2)$ $\Delta G^\circ = +64.8 \text{ (kJ mol}^{-1}\text{)}$	1 1 1 <b>3</b>
3(b)(ii)	T $\Delta S$ is more positive than $\Delta H$ /T $\Delta S$ increases/–T $\Delta S$ more negative <b>and</b> $\Delta G$ is negative/decrease/less positive	1 <b>1</b>
3(c)	use of $\Delta G = 0$ or $\frac{T\Delta S}{\Delta H} = 1$ $T = 130 / (316 / 1000) = \mathbf{410 / 411 / 412 / 411.4}$ (K)	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>41</b>

<b>Question</b>	<b>Answer</b>	<b>Mark</b>
3(d)	hydration enthalpy and lattice energy <b>both</b> more endothermic / more positive / less exothermic / less negative (down the group)	1
	$\Delta H_{\text{hyd}}$ decreases more / faster <b>and</b> $\Delta H_{\text{sol}}$ becomes (more) endothermic / (more) positive / less exothermic / less negative	1
		<b>2</b>
	<b>Total:</b>	<b>11</b>

<b>Question</b>	<b>Answer</b>	<b>Mark</b>
4(a)	(an element) forming one or more (stable) <b>ions</b> or <b>compounds</b> or <b>oxidation states</b> with <b>partially filled / incomplete d orbitals</b>	1
4(b)(i)	<b>A</b> $\text{Co(OH)}_2$ <b>OR</b> $\text{Co(H}_2\text{O)}_4(\text{OH})_2$ <b>B</b> $[\text{CoCl}_4]^{2-}$ <b>C</b> $[\text{Co(NH}_3)_6]^{2+}$ <b>OR</b> $[\text{Co(NH}_3)_6]^{3+}$ two correct = 1 mark three correct = 2 marks	<b>2</b>
4(b)(ii)	$[\text{Co(H}_2\text{O)}_6]^{2+}$ pink solution of <b>B</b> blue solution of <b>C</b> brown/yellow/orange	

<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>41</b>

<b>Question</b>	<b>Answer</b>	<b>Mark</b>
	two correct = 1 mark three correct = 2 marks	<b>2</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>41</b>

<b>Question</b>	<b>Answer</b>	<b>Mark</b>							
4(c)	(emf / potential / $E$ ) of an <b>electrode OR a half-cell</b> compared to / connected to <b>(S)HE</b> which can be called a "hydrogen half-cell"  at concentration of $1 \text{ mol dm}^{-3}$ <b>and</b> pressure of 1 atm (or in Pa) <b>OR</b> 298 K	1  1	<b>2</b>						
4(d)(i)	<table border="1"> <tr> <td>half-cell</td> <td>electrode</td> </tr> <tr> <td><math>\text{Co}^{2+} / \text{Co}</math></td> <td>Co / cobalt</td> </tr> <tr> <td><math>\text{Fe}^{3+} / \text{Fe}^{2+}</math></td> <td>Pt / carbon / graphite</td> </tr> </table>	half-cell	electrode	$\text{Co}^{2+} / \text{Co}$	Co / cobalt	$\text{Fe}^{3+} / \text{Fe}^{2+}$	Pt / carbon / graphite	1	<b>1</b>
half-cell	electrode								
$\text{Co}^{2+} / \text{Co}$	Co / cobalt								
$\text{Fe}^{3+} / \text{Fe}^{2+}$	Pt / carbon / graphite								
4(d)(ii)	$\text{Co} + 2\text{Fe}^{3+} \rightarrow \text{Co}^{2+} + 2\text{Fe}^{2+}$	1	<b>1</b>						
4(d)(iii)	$E_{\text{cell}}^{\ominus} = 0.77 - (-0.28) = (+ \text{ or } -) 1.05 \text{ (V)}$	1	<b>1</b>						
4(e)(i)	$E_{\text{electrode}} = -0.28 + (0.059 / 2) \log [0.05] = \mathbf{-0.32 / -0.318 \text{ (V)}}$	1	<b>1</b>						
4(e)(ii)	more positive	1	<b>1</b>						
4(f)	$4\text{Fe}^{3+} + \text{V} + \text{H}_2\text{O} \rightarrow \text{VO}^{2+} + 4\text{Fe}^{2+} + 2\text{H}^+$  $\text{VO}^{2+}$ correct equation	1  1							



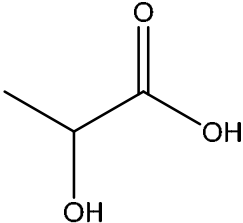
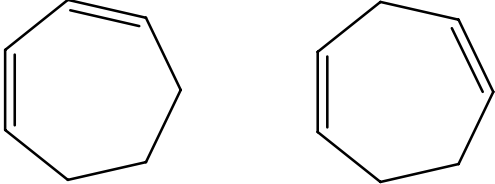
<b>Page 9</b>	<b>Mark Scheme</b>	<b>Syllabus</b>	<b>Paper</b>
	<b>Cambridge International AS/A Level – October/November 2016</b>	<b>9701</b>	<b>41</b>

<b>Question</b>	<b>Answer</b>	<b>Mark</b>
		<b>2</b>
	<b>Total:</b>	<b>14</b>

Page 10	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – October/November 2016	9701	41

Question	Answer				Mark																
5(a)(i)	$(100/22.1) \times (0.7/1.1)$ or $\frac{100 \times 0.7}{22.1 \times 1.1}$ or 2.87/2.88/2.9 3 carbon atoms				1 1 <b>2</b>																
5(a)(ii)	C <sub>3</sub> H <sub>6</sub> O <sub>3</sub>				1 <b>1</b>																
5(b)	<table border="1"> <thead> <tr> <th>absorption / cm<sup>-1</sup></th> <th>appearance of the peak</th> <th>type of bond</th> <th>functional group</th> </tr> </thead> <tbody> <tr> <td>3350</td> <td>broad and strong</td> <td>OH or O–H</td> <td>alcohol / ROH</td> </tr> <tr> <td>2680</td> <td>very broad and strong</td> <td>OH or O–H</td> <td>(carboxylic) acid / CO<sub>2</sub>H</td> </tr> <tr> <td>1725</td> <td>strong</td> <td>C=O</td> <td>(carboxylic) acid / CO<sub>2</sub>H</td> </tr> </tbody> </table>				absorption / cm <sup>-1</sup>	appearance of the peak	type of bond	functional group	3350	broad and strong	OH or O–H	alcohol / ROH	2680	very broad and strong	OH or O–H	(carboxylic) acid / CO <sub>2</sub> H	1725	strong	C=O	(carboxylic) acid / CO <sub>2</sub> H	<b>2</b>
absorption / cm <sup>-1</sup>	appearance of the peak	type of bond	functional group																		
3350	broad and strong	OH or O–H	alcohol / ROH																		
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1725	strong	C=O	(carboxylic) acid / CO <sub>2</sub> H																		

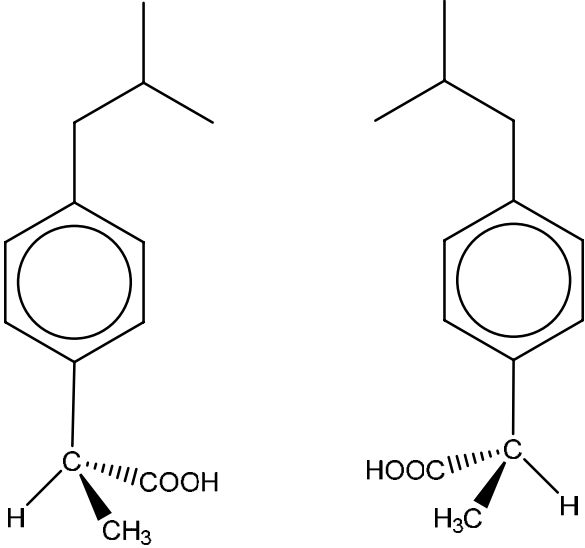
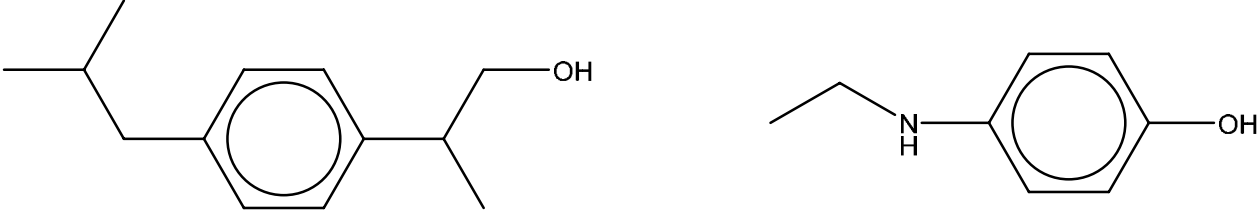
Page 11	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – October/November 2016	9701	41

Question	Answer			Mark															
5(c)(i)	<table border="1"> <thead> <tr> <th><math>\delta</math>/ppm</th> <th>type of proton</th> <th>relative peak area</th> </tr> </thead> <tbody> <tr> <td>1.4</td> <td>-CH<sub>3</sub> or -CH<sub>2</sub> or -CH or alkane</td> <td>3</td> </tr> <tr> <td>3.9</td> <td>-OCH or -OCH<sub>2</sub> or -OCH<sub>3</sub> or CH or alkyl next to electronegative atom / oxygen</td> <td>1</td> </tr> <tr> <td>4.7</td> <td>-OH or alcohol</td> <td>1</td> </tr> <tr> <td>12.9</td> <td>-OH or -CO<sub>2</sub>H or carboxylic acid</td> <td>1</td> </tr> </tbody> </table>	$\delta$ /ppm	type of proton	relative peak area	1.4	-CH <sub>3</sub> or -CH <sub>2</sub> or -CH or alkane	3	3.9	-OCH or -OCH <sub>2</sub> or -OCH <sub>3</sub> or CH or alkyl next to electronegative atom / oxygen	1	4.7	-OH or alcohol	1	12.9	-OH or -CO <sub>2</sub> H or carboxylic acid	1			<b>4</b>
$\delta$ /ppm	type of proton	relative peak area																	
1.4	-CH <sub>3</sub> or -CH <sub>2</sub> or -CH or alkane	3																	
3.9	-OCH or -OCH <sub>2</sub> or -OCH <sub>3</sub> or CH or alkyl next to electronegative atom / oxygen	1																	
4.7	-OH or alcohol	1																	
12.9	-OH or -CO <sub>2</sub> H or carboxylic acid	1																	
5(c)(ii)	doublet <b>and</b> 1 / one H / proton on neighbouring <b>OR</b> adjacent carbon			1 <b>1</b>															
5(c)(iii)	4.7 <b>and</b> 12.9 <b>OR</b> -OH <b>and</b> -CO <sub>2</sub> H			1 <b>1</b>															
5(c)(iv)				1 <b>1</b>															
5(d)(i)	 both required for 1 mark			1 <b>1</b>															

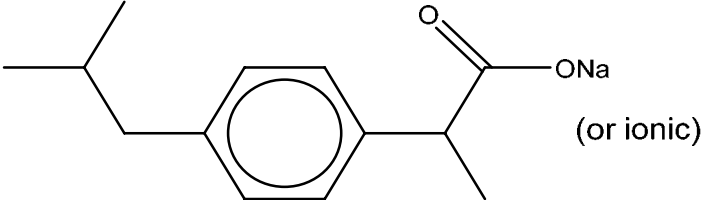
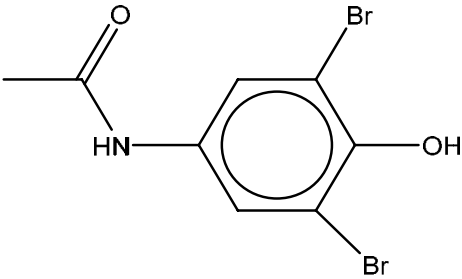
Page 12	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – October/November 2016	9701	41

Question	Answer	Mark						
5(d)(ii)	<table border="1"> <tr> <td>isomer</td> <td>number of peaks</td> </tr> <tr> <td><b>P</b></td> <td>4</td> </tr> <tr> <td><b>Q</b></td> <td>4</td> </tr> </table>	isomer	number of peaks	<b>P</b>	4	<b>Q</b>	4	1
	isomer	number of peaks						
	<b>P</b>	4						
	<b>Q</b>	4						
		1						
		<b>2</b>						
	<b>Total:</b>	<b>15</b>						

Question	Answer	Mark
6(a)	ibuprofen: carboxylic acid / carboxyl paracetamol: phenol and amide any two = 1 mark all three = 2 marks	<b>2</b>
6(b)(i)	(chiral centre is a) carbon <b>OR</b> atom that has four different groups / atoms / species attached to it	1 <b>1</b>

Question	Answer	Mark
6(b)(ii)	 <p>one correct isomer second diagram shows second isomer</p>	<p>1 1 <b>2</b></p>
6(c)	 <p>with ibuprofen with paracetamol</p>	<p>1 1 <b>2</b></p>

Page 14	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – October/November 2016	9701	41

Question	Answer	Mark
6(d)(i)	(reagent <b>D</b> ) $\text{Na}_2\text{CO}_3$ / any carbonate (reagent <b>E</b> ) $\text{Cl}_2/\text{Br}_2$	1 1 <b>2</b>
6(d)(ii)	 (or ionic)	1 <b>1</b>
6(d)(iii)		1 <b>1</b>
6(e)(i)	$\text{CH}_3\text{COCl} + \text{AlCl}_3 \rightarrow \text{CH}_3\text{CO}^+ + \text{AlCl}_4^-$	1 <b>1</b>

Question	Answer	Mark
6(e)(ii)	<p>curly arrow from ring system to <math>\text{CH}_3\text{CO}^+</math></p> <p>correct intermediate</p> <p>curly arrow from C–H bond into ring</p>	<p>1</p> <p>1</p> <p>1</p> <p><b>3</b></p>
6(e)(iii)	electrophilic substitution	1
	<b>Total:</b>	<b>16</b>

Page 16	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – October/November 2016	9701	41

Question	Answer	Mark
7(a)	moles of thiosulfate = $0.1 \times 20.8 / 1000 = 2.08 \times 10^{-3}$ moles of $\text{ClO}^-$ in $25 \text{ cm}^3$ portion = $2.08 \times 10^{-3} / 2 = 1.04 \times 10^{-3}$ (moles of $\text{ClO}^-$ in $250 \text{ cm}^3 = 1.04 \times 10^{-2}$ ) concentration of $\text{ClO}^- = 1.04 \times 10^{-2} / (10 / 1000) = 1.04 \text{ (mol dm}^{-3}\text{)}$	1 1 1 <b>3</b>
7(b)(i)	starch	1 <b>1</b>
7(b)(ii)	blue <b>OR</b> black to colourless	1 <b>1</b>
7(b)(iii)	towards/ close to the end-point of the titration/when the solution goes yellow	1 <b>1</b>
7(c)	moles of $\text{O}_2 = 82 / 24\,000 = 3.42 \times 10^{-3} = \text{moles } \text{ClO}^- \text{ ions}$ concentration of $\text{ClO}^- = 3.42 \times 10^{-3} / (5 / 1000) = 0.68 / 0.683 / 0.684 \text{ (mol dm}^{-3}\text{)}$	1 1 <b>2</b>
7(d)(i)	$K_c = \frac{[\text{C}_3\text{H}_3\text{N}_3\text{O}_3][\text{HClO}_3]^3}{[\text{C}_3\text{Cl}_3\text{N}_3\text{O}_3][\text{H}_2\text{O}]^3}$	1 <b>1</b>
7(d)(ii)	(position of eqm) moves to the right/ forward reaction predominates/ more $\text{HClO}$ made (as $[\text{HClO}]$ decreases) no effect on $K_c$	1 1 <b>2</b>



Page 17	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – October/November 2016	9701	41

Question	Answer	Mark
7(d)(iii)	$2\text{HClO} \rightarrow 2\text{HCl} + \text{O}_2$ <b>OR</b> $2\text{HClO} \rightarrow \text{H}_2 + \text{Cl}_2 + \text{O}_2$	<p>1</p> <p><b>1</b></p>
7(e)(i)	addition of acid: $\text{H}^+ + \text{HCO}_3^- \rightarrow \text{H}_2\text{CO}_3$ <b>OR</b> $\text{H}^+ + \text{HCO}_3^- \rightarrow \text{H}_2\text{O} + \text{CO}_2$  addition of base: $\text{OH}^- + \text{H}_2\text{CO}_3 \rightarrow \text{HCO}_3^- + \text{H}_2\text{O}$ <b>OR</b> $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$ <b>and</b> position of eqm moves to the right <b>OR</b> $\text{OH}^- + \text{HCO}_3^- \rightarrow \text{CO}_3^{2-} + \text{H}_2\text{O}$	<p>1</p> <p>1</p> <p><b>2</b></p>
7(e)(ii)	$K_a = \frac{[\text{H}^+][\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]}$ $[\text{H}^+] = (7.94 \times 10^{-7}) \times 1/9.5 = 8.36 \times 10^{-8}$ $\text{pH} = -\log[\text{H}^+] = \mathbf{7.08}$	<p>1</p> <p>1</p> <p><b>2</b></p>
	<b>Total:</b>	<b>16</b>