Acids, Bases and pH
Answers

Q	Part	Sub Part	Marking Guidance		Mark	Comments
5	(a)	(i)	$-\log[H^+]$		1	penalise missing [ ] here **and not elsewhere**
5	(a)	(ii)	$[H^+][OH^-]$		1	
5	(b)	(i)	$[H^+] = 2.34 \times 10^{-7}$ pH = 6.63 *Penalise fewer than 3 sig figs but allow more than 2 dp*		1 1	
5	(b)	(ii)	$[H^+] = [OH^-]$		1	
5	(b)	(iii)	$[H^+] = K_w/[OH^-]$ $(= 5.48 \times 10^{-14} / 0.140) = 3.91 \times 10^{-13}$ pH = 12.4(1) *Penalise fewer than 3 sig figs but allow more than 3 sfs* *For values above 10, allow 3sfs - do not insist on 2 dp.* *For values below 1, allow 2dp – do not insist on 3 sig figs*	M1 M2 M3	1 1 1	if upside down or CE, allow M3 only for correct use of their $[H^+]$ not 12.40 (AE from 12.407)
			Not allow pH = 14 – pOH but can award M3 only for pH = 13.1(46) Can award all three marks if $pK_w = 13.26$ is used			

5	(c)		mol NaOH = mol OH^- = $(30\times10^{-3}) \times 0.20 = 6.0 \times 10^{-3}$	M1	1	mark for answer
			mol H_2SO_4 = $(25\times10^{-3}) \times 0.15 = 3.75\times10^{-3}$	M2	1	mark for answer
			mol H^+ = $(25\times10^{-3}) \times 0.15 \times 2 = 7.5\times10^{-3}$ OR XS mol H_2SO_4 = 0.75×10^{-3}	M3	1	if factor of 2 missed or used wrongly, CE - lose M3 and next mark gained. In this case they must then use K_w to score any more. see examples below
			XS mol H^+ = 1.5×10^{-3}	M4	1	
			$[H^+]$ = $(1.5\times10^{-3}) \times (1000/55) = 0.0273$	M5	1	if no use or wrong use of volume, lose M5 and M6 except if 1000 missed AE -1 (pH = 4.56)
			pH = 1.56 *Penalise fewer than 3 sig figs but allow more than 3 sfs* *For values above 10, allow 3sfs - do not insist on 2 dp.* *For values below 1, allow 2dp – do not insist on 3 sig figs*	M6	1	

5	(d)	(i)	$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]}$	Must have all 3 brackets but don't penalize ( ) see note to Q5(a)(i)	1	not HA This mark could score in (d) (ii)

5	(d)	(ii)	$K_a = \frac{[H^+]^2}{[CH_3COOH]}$ or with numbers or $[H^+] = [CH_3COO^-]$		1	allow HA here This mark could score in (d) (i)
			$[H^+]$ =($\sqrt{(1.74\times10^{-5} \times 0.136)} = \sqrt{(2.366\times10^{-6}} =) 1.54\times10^{-3}$		1	mark for answer if 1.5×10^{-3} penalise here if miss √ but it is shown, AE -1 so allow 2 for pH = 5.63
			pH = 2.81 can give three marks here for (d)(ii) *Do not insist on 2 dp* *Penalise fewer than 3 sig figs but allow more than 3 sfs* *For values below 1, allow 2dp – do not insist on 3 sig figs*		1	allow pH = 2.82 conseq

Question	Part	Sub part		Mark	Comments
2	(a)	(i)	$-\log[H^+]$	1	or $\log 1/[H^+]$ penalise ( )
2	(a)	(ii)	$[H^+] = 0.56$ $[H_2SO_4] = ½ \times 0.56 = 0.28$	1 1	mark for the answer; allow 2dp or more
2	(b)	(i)	$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$ ***OR*** $CH_3COOH + OH^- \rightarrow CH_3COO^- + H_2O$	1	Allow CH_3CO_2H etc
2	(b)	(ii)	mol acid = $(25.0 \times 10^{-3}) \times 0.41 = 1.025 \times 10^{-2}$ or 1.03×10^{-2} [NaOH] = $1.025 \times 10^{-2} / 22.6 \times 10^{-3} = 0.45(4)$ ***OR*** [NaOH] = $1.03 \times 10^{-2} / 22.6 \times 10^{-3} = 0.456$ or 0.46	1 1	 mark for answer if not 0.454 look back for error
2	(b)	(iii)	cresol purple	1	
2	(b)	(iv)	NaOH reacts with <u>carbon dioxide</u> (in the air)	1	
2	(c)	(i)	$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]}$ allow molecular formulae or minor slip in formulae	1	penalise ( ) allow H_3O^+ not allow HA etc

2	(c)	(ii)	$K_a = \frac{[H^+]^2}{[CH_3COOH]}$ or with numbers $[H^+] = (\sqrt{(1.74 \times 10^{-5} \times 0.410)} = \sqrt{(7.13 \times 10^{-6})}) = 2.67 \times 10^{-3}$ pH = 2.57 can give three ticks here for (c)(ii) penalise decimal places < 2 >	1 1 1	allow HA etc here This can be scored in part(c)(i) but doesn't score there. mark for 2.67×10^{-3} or 2.7×10^{-3} either gives 2.57 pH mark conseq on their $[H^+]$ so 5.15 gets 2 marks where square root not taken

2	(c)	(iii)	**M1** mol OH^- = $(10.0 \times 10^{-3}) \times 0.10 = 1.0 \times 10^{-3}$ **M2** orig mol HA = $(25.0 \times 10^{-3}) \times 0.41 = 0.01025$ or 1.025×10^{-2} or 1.03×10^{-2} **M3** mol <u>HA</u> in buffer = orig mol HA – mol OH^- = 0.00925 or 0.0093 **M4** mol A^- in buffer = mol OH^- = 1.0×10^{-3} **M5** $[H^+] = (\frac{Ka \times [CH_3COOH]}{[CH_3COO^-]} =)$ $\frac{(1.74 \times 10^{-5})(0.00925)}{0.0010}$ or $\frac{(1.74 \times 10^{-5})(0.00930)}{0.0010}$ $(= 1.61 \times 10^{-4}$ or $1.62 \times 10^{-4})$ **M6** pH = 3.79 can give six ticks for 3.79 NB Unlike Qu 2(c)(ii), this pH mark is NOT awarded conseq to their $[H^+]$ unless following AE	1 1 1 1 1 1	If no subtraction or other wrong chemistry the max score is 3 for M1, M2 and M4 If A^- is wrong, max 3 for M1, M2 and M3 or use of pH = pKa – log [HA]/ $[A^-]$ Mark is for insertion of correct numbers in correct expression for $[H^+]$ if [HA]/[A^-] upside down lose M5 & M6 If wrong method e.g. $[H^+]^2/[HA]$ max 3 for M1, M2 and M3 Some may calculate concentrations [HA] = 0.264 and $[A^-]$ = 0.0286 and rounding this to 0.029 gives pH = 3.80 (which is OK) BEWARE: using 0.01025 wrongly instead of 0.00925 gives pH = 3.75 (this gets 3 for M1, M2 & M4)

Question	Marking Guidance	Mark	Comments
1(a)	C A D	1 1 1	
1(b)(i)	Bromocresol green	1	Allow wrong spellings
1(b)(ii)	Purple to yellow	1	Must have both colours: Purple start – yellow finish

Question	Marking Guidance	Mark	Comments
2(a)(i)	$-\log[H^+]$	1	penalise missing [ ] here **and not elsewhere**
2(a)(ii)	$[H^+][OH^-]$	1	Allow ( ) brackets, but must have charges
2(a)(iii)	Mark independently from a(ii) $[H^+] = 10^{-13.72} = 1.905 \times 10^{-14}$ $K_w = 1.905 \times 10^{-14} \times 0.154 = = (2.93 - 2.94) \times 10^{-15}$	 1 1	 If wrong no further mark
2(b)(i)	$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]}$	1	Must have charges and all brackets, allow ( ) Acid/salt shown must be CH_3COOH not HA and correct formulae needed
2(b)(ii)	**In pH values penalise fewer than 3 sig figs each time but allow more than 2 dp** **For values above 10, allow 3sfs - do not insist on 2 dp**		
	$K_a = \frac{[H^+]^2}{[CH_3COOH]}$ $([H^+]^2 = 1.75 \times 10^{-5} \times 0.154 = 2.695 \times 10^{-6} = 2.70 \times 10^{-6})$ $[H^+] = 1.64 \times 10^{-3}$ pH = 2.78 or 2.79	1 1 1	Allow HA If √ shown but not done gets pH = 5.57 (scores 2) Allow mark for pH conseq to their $[H^+]$ **here only**

2(c)(i)	**In pH values penalise fewer than 3 sig figs each time but allow more than 2 dp** **For values above 10, allow 3sfs - do not insist on 2 dp**		
	M1 Initially mol OH^- = (10 × 10^{-3}) × 0.154 **and** mol HA = (20 ×10^{-3}) × 0.154 **or** mol OH^- = 1.54 × 10^{-3} **and** mol HA = 3.08 × 10^{-3}	1	
	M2 $[H^+] = K_a \frac{[CH_3COOH]}{[CH_3COO^-]}$ or with numbers	1	Allow Henderson Hasselbach $pH = pK_a + \log \frac{[CH_3COO^-]}{[CH_3COOH]}$
	M3 mol ethanoic acid left = (mol ethanoate ions) = 1.54 × 10^{-3} $K_a = [H^+]$ **or** $pH = pK_a$ scores **M1**, **M2** and **M3**	1	If either mol acid in mixture or mol salt wrong - max 2 for M1 and M2 Any mention of $[H^+]^2$ - max 2 for M1 and M3
	M4 pH (= - log 1.75 × 10^{-5}) = 4.76 or 4.757	1	Not 4.75
	If no subtraction (so mol ethanoic acid in buffer = original mol) pH = 4.46 scores 2 for M1 and M2 If $[H^+]^2$ used, pH = 3.02 scores 2 for M1 and M3		

2(c)(ii)	**In pH values penalise fewer than 3 sig figs each time but allow more than 2 dp** **For values above 10, allow 3sfs - do not insist on 2 dp**		
	M1 XS mol KOH (= $(20\times10^{-3}) \times 0.154$) = 3.08×10^{-3}	1	If no subtraction: max 1 for correct use of volume No subtraction and no use of volume scores zero If wrong subtraction or wrong moles Can only score **M2** and **M3** for process
	M2 $[OH^-]$ = $3.08 \times 10^{-3} \times \frac{10^3}{60}$ = 0.0513(3)	1	Mark for dividing their answer to **M1** by correct volume (method mark) If no volume or wrong volume or multiplied by volume, max 2 for **M1** and **M3** process
	M3 $[H^+]$ = $\frac{10^{-14}}{0.05133}$ (= 1.948×10^{-13} to 1.95×10^{-13}) **or** pOH = 1.29	1	Mark for K_w divided by their answer to **M2** If pOH route, give one mark for 14 – pOH
	M4 pH = 12.7(1)	1	Allow 3sf but not 12.70
	If no subtraction and no use of volume (pH = 11.79 scores zero) If no subtraction, max 1 for correct use of volume, ($60cm^3$) (pH = 13.01 scores 1) If volume not used, pH = 11.49 (gets 2) If multiplied by vol , pH = 10.27 (gets 2)		

Question	Marking Guidance	Mark	Comments
2(a)(i)	$-\log[H^+]$ or $\log 1/[H^+]$	1	penalise missing square brackets here only
2(a)(ii)	0.81	1	2dp required, no other answer allowed
2(a)(iii)	**M1** mol $H^+ = 1.54 \times 10^{-3}$	1	if wrong no further mark if 1.5×10^{-3} allow M1 but not M2 for 2.82
	M2 pH = 2.81	1	allow more than 2dp but not fewer
2(b)	**M1** $[H^+] = 3.31 \times 10^{-3}$	1	
	M2 $K_a = \frac{[H^+][X^-]}{[HX]}$ or $\frac{[H^+]^2}{[HX]}$ or using numbers	1	do not penalise ( ) or one or more missing [ ]
	M3 $[HX] = \frac{[H^+]^2}{K_a} = \frac{(3.31\times10^{-3})^2}{4.83\times10^{-5}}$	1	allow conseq on their $[H^+]^2/(4.83 \times 10^{-5})$ (AE) if upside down, no further marks after M2
	M4 [HX] = 0.227	1	allow 0.225 – 0.23
2(c)	**M1** extra/added OH^- removed by reaction with H^+ or the acid	1	
	M2 correct discussion of equm shift i.e. $HX \rightleftharpoons H^+ + X^-$ moves to right	1	
	OR		
	ratio $\frac{[HX]}{[X^-]}$ remains almost constant		

2(d)(i)	**M1** mol HY = $(50\times10^{-3}) \times 0.428 = 0.0214$	**OR** $[Y^-] = .0236 \times \frac{1000}{50} = 0.472$	1	mark for answer
	M2 $[H^+] = 1.35\times10^{-5} \times \frac{0.0214}{0.0236}$ **OR** $1.35\times10^{-5} = [H^+] \times \frac{0.0236}{0.0214}$	**OR** $[H^+] = 1.35\times10^{-5} \times \frac{0.428}{0.472}$ **OR** $1.35\times10^{-5} = [H^+] \times \frac{0.472}{0.428}$	1	must be numbers not just rearrangement of Ka expression If either HY value or Y^- value wrong, (apart from AE -1) lose M2 and M3
	M3 $[H^+] = 1.22\times10^{-5}$		1	mark for answer
	M4 pH = 4.91		1	allow more than 2dp but not fewer **allow M4 for correct pH calculation using their $[H^+]$ (this applies in 2(d)(i) only)**
	If Henderson Hasselbalch equation used:			**If Henderson Hasselbalch equation used:**
	M1 mol HY = $(50\times10^{-3}) \times 0.428 = 0.0214$	**OR** $[Y^-] = .0236 \times \frac{1000}{50} = 0.472$	1	mark for answer
	M2 p*K*a = 4.87		1	
	M3 $\log(\frac{0.0214}{0.0236}) = -0.043$	$\log(\frac{0.428}{0.472}) = -0.043$	1	If either HY value or Y^- value wrong, (apart from AE-1) lose M3 and M4
	M4 pH = 4.87 – (– 0.043) = 4.91		1	allow more than 2dp but not fewer

2(d)(ii)				Can score full marks for correct consequential use of their HY and Y^- values from d(i)
	M1 Mol HY after adding NaOH = $0.0214 - 5.0 \times 10^{-4} = 0.0209$		1	AE in subtraction loses just M1 If wrong initial mol HY (i.e. not conseq to part d(i)) or no subtraction or subtraction of wrong amount, lose M1 and M3
	M2 Mol Y^- after adding NaOH = $0.0236 + 5.0 \times 10^{-4} = 0.0241$		1	AE in addition loses just M2 If wrong mol Y^- (i.e. not conseq to part d(i)) or no addition or addition of wrong amount lose M2 and next mark gained
	M3 $[H^+] = 1.35 \times 10^{-5} \times \frac{0.0209}{0.0241}$ $(= 1.17 \times 10^{-5})$	if convert to concentrations $[H^+] = 1.35 \times 10^{-5} \times \frac{0.418}{0.482}$ $(= 1.17 \times 10^{-5})$	1	if HY/Y^- upside down, no further marks
	M4 pH = 4.93		1	allow more than 2dp but not fewer NOT allow M4 for correct pH calculation using their $[H^+]$ (this allowance applies in 2(d)(i) only)

	If Henderson Hasselbalch equation used:		**If Henderson Hasselbalch equation used:** Can score full marks for correct consequential use of their HY and Y^- values from d(i)
	M1 Mol HY after adding NaOH = $0.0214 - 5.0 \times 10^{-4} = 0.0209$	1	AE in subtraction loses just M1 If wrong initial mol HY (i.e. not conseq to part d(i)) or no subtraction or subtraction of wrong amount lose M1 and M3
	M2 Mol Y^- after adding NaOH = $0.0236 + 5.0 \times 10^{-4} = 0.0241$	1	AE in addition loses just M2 If wrong mol Y^- (i.e. not conseq to part d(i)) or no addition or addition of wrong amount lose M2 and next mark gained
	M3 $\log\left(\frac{0.0209}{0.0241}\right) = -0.062$	1	if HY/Y^- upside down, no further marks
	M4 pH = $4.87 - (-0.062) = 4.93$	1	allow more than 2dp but not fewer

Question		Marking Guidance	Mark	Additional Guidance
3(a)		Proton donor or H^+ donor	1	Allow donator
3(b)(i)		B B	1	Both need to be correct to score the mark
3(b)(ii)		A A	1	Both need to be correct to score the mark
3(b)(iii)		B A	1	Both need to be correct to score the mark
3(c)	M1	$[H^+] = 10^{-1.25}$ OR 0.05623	1	
	M2	mol HCl = $(25 \times 10^{-3}) \times 0.0850$ (= 2.125×10^{-3})	1	Mark for Working
	M3	vol (= $\frac{2.125 \times 10^{-3}}{0.05623}$) = 0.0378 dm^3 or 37.8 cm^3 allow 0.0375 – 0.038 dm^3 or 37.5 –38 cm^3	1	Units and answer tied Lose M3 if total given as (25+ 37.8) = 62.8 cm^3 Ignore "vol added = 12.8cm^3" after correct answer
3(d)(i)		4.52	1	Must be 2dp
3(d)(ii)		$K_a = \frac{[H^+][X^-]}{[HX]}$ ignore = $\frac{[H^+]^2}{[HX]}$ but this may score M1 in d(iii)	1	Must have all brackets but allow ( ) Allow HA etc **NO** mark for 10^{-pKa}
3(d)(iii)		M1 $K_a = \frac{[H^+]^2}{[HX]}$ or with numbers	1	Allow $[H^+] = \sqrt{(Ka \times [HA])}$ for M1
		M2 $[H^+] = (\sqrt{(3.01 \times 10^{-5} \times 0.174)} = \sqrt{(5.24 \times 10^{-6})})$ $= 2.29 \times 10^{-3} - 2.3 \times 10^{-3}$	1	Mark for <u>answer</u> **Allow 1 for correct pH from their wrong $[H^+]$**
		M3 pH = 2.64 (allow more than 2dp but not fewer)	1	If square root forgotten, pH = 5.28 scores 2 for M1 and M3

3(e)	M1	mol OH^- = $(10.0 \times 10^{-3}) \times 0.125 = 1.25 \times 10^{-3}$	1	Mark for answer
	M2	orig mol HX = $(15.0 \times 10^{-3}) \times 0.174 = 2.61 \times 10^{-3}$	1	Mark for answer
	M3	mol HX in buffer = orig mol HX – mol OH^- = $2.61 \times 10^{-3} - 1.25 \times 10^{-3} = 1.36 \times 10^{-3}$ ($[HX] = 1.36 \times 10^{-3}/25 \times 10^{-3} = 0.0544$)	1	Mark for answer Allow conseq on their (M2 – M1) If no subtraction, max 3 for M1, M2 & M4 (pH = 4.20) If $[H^+] = [X^-]$ & √ used, max 3 for M1, M2 & M3 (pH = 2.89)
	M4	mol X^- in buffer = mol OH^- = 1.25×10^{-3} ($[X^-] = 1.25 \times 10^{-3}/25 \times 10^{-3} = 0.05$)	1	May be scored in M5 expression
	M5	$[H^+]$ $\left(= \frac{Ka \times [HX]}{[X^-]}\right)$ $= \frac{3.01\times10^{-5} \times 1.36\times10^{-3}}{1.25\times10^{-3}}$ OR $\frac{3.01\times10^{-5} \times 0.0544}{0.05}$ $(= 3.27 \times 10^{-5})$	1	If use $K_a = \frac{[H^+]^2}{[HX]}$ no further marks If either value of HX or X^- used wrongly or expression upside down, no further marks
	M6	pH = 4.48 or 4.49 (allow more than 2dp but not fewer)	1	Do **not** allow M6 for correct calculation of pH using their $[H^+]$ - this only applies in 3d(iii) - apart from earlier AE

Question	Marking Guidance		Mark	Comments
3(a)	Proton acceptor		1	
3(b)(i)	$CH_3CH_2NH_2 + H_2O \rightarrow CH_3CH_2NH_3^+ + OH^-$		1	allow eq with or without $\rightleftharpoons$ allow $C_2H_5NH_2$ and $C_2H_5NH_3^+$ (plus can be on N or H or 3) allow RHS as $C_2H_5NH_3OH$
3(b)(ii)	Mark independently of 3b(i) reaction/equilibrium lies to left or low $[OH^-]$ ***OR*** little OH^- formed ***OR*** little ethylamine has reacted		1	Allow Ethylamine is only partly/slightly dissociated OR Ethylamine is only partly/slightly ionized Ignore "not fully dissociated" or "not fully ionized" Ignore reference to ionisation or dissociation of water
3(c)	Ethylamine alkyl group is electron releasing/donating ***OR*** alkyl group has (positive) inductive effect increases electron density on $N(H_2)$ ***OR*** increased availability of lp ***OR*** increases ability of lp (to accept H(+))	M1 M2 M3	1 1 1	If wrong no marks in 3c Mark M3 is independent of M2

3(d)	$CH_3CH_2NH_3Cl$ allow name (ethylammonium chloride or ethylamine hydrochloride) or other halide for Cl	1	Or any amine hydrochloride or a strong **organic** acid **NOT** NH_4Cl

3(e)	Mark independently of 3(d) Extra H^+ reacts with ethylamine or OH^- ***OR*** $CH_3CH_2NH_2 + H^+ \rightarrow CH_3CH_2NH_3^+$ ***OR*** $H^+ + OH^- \rightarrow H_2O$ Equilibrium shifts to RHS ***OR*** ratio $[CH_3CH_2NH_3^+]/[CH_3CH_2NH_2]$ remains almost constant	 1 1	 Or makes reference to Equilibrium (in 3(b)(i)) with amine on LHS

Question	Marking Guidance		Mark	Comments
4(a)	$[H^+]$ = 0.0170	M1	1	
	pH = 1.77	M2	1	2 dp **Allow M2 for correct pH calculation from their wrong $[H^+]$ for this pH calculation only**
4(b)(i)	$K_a = \frac{[H^+][X^-]}{[HX]}$ Ignore $K_a = \frac{[H^+]^2}{[HX]}$		1	Penalize missing [ ] here **and not elsewhere** Allow HA instead of HX
4(b)(ii)	$[H^+] = 10^{-2.79}$ OR $1.6218\ldots \times 10^{-3}$	M1	1	If $[H^+]$ wrong, can only score M2
	$K_a = \frac{[H^+]^2}{[HX]}$ OR $\frac{[1.62 \times 10^{-3}]^2}{[0.0850]}$	M2	1	Allow HA instead of HX
	$K_a = 3.09 \times 10^{-5}$ 3sfs min (allow 3.10×10^{-5} if 1.6218 rounded to 1.622) Ignore units	M3	1	If [HX] used as $(0.0850 - 1.62 \times 10^{-3})$ this gives $K_a = 3.15 \times 10^{-5}$ $(0.0016)^2/0.085 = 3.01 \times 10^{-5}$ scores 2 for AE

4(c)	mol OH^- (= $(38.2 \times 10^{-3}) \times 0.550$) = $2.10(1) \times 10^{-2}$ or 0.0210(1) mol H^+ (= $(25.0 \times 10^{-3}) \times 0.620$) = 1.55×10^{-2} or 0.0155 excess mol OH^- = $5.5(1) \times 10^{-3}$	M1 M2 M3	1 1 1	Mark for answer Mark for answer Allow conseq for M1 – M2 **If wrong method** e.g. no subtraction or use of √ **can only score max of M1, M2, M3 and M4**.
	$[[OH^-] = 5.51 \times 10^{-3} \times \frac{10^3}{63.2}$ [= 0.08718 (0.0872)] ***OR*** $[OH^-] = 5.5 \times 10^{-3} \times \frac{10^3}{63.2}$ = 0.0870(2)	M4	1	(M1 – M2) / vol in dm^3 mark for dividing by volume (take use of 63.2 without 10^{-3} as AE so 9.94 scores 5) If no use or wrong use of vol lose M4 & M6 Can score M5 for showing (10^{-14}/their XS alkali)
	$[H^+] = \frac{10^{-14}}{0.08718} = 1.147 \times 10^{-13}$ ***OR*** $\frac{10^{-14}}{0.0870} = 1.149 \times 10^{-13}$ ***OR*** pOH = 1.06	M5	1	If no use or wrong use of K_w or pOH no further marks
	pH = 12.9(4) allow 3sf	M6	1	If vol missed score max 4 for 11.7(4)
				If acid- alkali reversed max 4 for pH = 1.06 Any excess acid - max 4

Question		Marking Guidance	Mark	Comments
3(a)		Proton donor or H^+ donor	1	
3(b)(i)		$K_a = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]}$ or $\frac{[CH_3COO^-][H_3O^+]}{[CH_3COOH]}$	1	If K_a wrong, can only score M1 below. Must be ethanoic acid not HA Must have square brackets (penalise here only) but mark on in (b)(ii).
3(b)(ii)	M1	$[H^+] = 10^{-2.69}$ ***OR*** 2.042×10^{-3} (mol dm^{-3})	1	
	M2	$[CH_3COOH] = \frac{[H^+]^2}{K_a}$	1	Ignore ( ) Mark for correctly rearranged expression incl $[H^+]^2$
	M3	$= \frac{(2.042 \times 10^{-3})^2}{1.75 \times 10^{-5}}$	1	If M2 wrong no further marks.
	M4	= 0.238 (mol dm^{-3}) Allow 0.229 – 0.24	1	
3(c)(i)		$ClCH_2COOH \rightleftharpoons ClCH_2COO^- + H^+$ ***OR*** $ClCH_2COOH + H_2O \rightleftharpoons ClCH_2COO^- + H_3O^+$	1	Allow $\rightarrow$ Allow $ClCH_2CO_2H$ and $ClCH_2CO_2^-$
3(c)(ii)	M1	Cl is (more electronegative so) withdraws electrons **OR** negative inductive effect of Cl	1	Ignore electronegativity. Ignore chloroethanoic acid has a lower K_a value. Allow Cl reduces +ve inductive effect of methyl group.
	M2	Weakens O—H bond ***OR*** O—H bond is more polar ***OR*** reduces negative charge on COO^- ***OR*** stabilizes COO^- (more)	1	M1 & M2 are independent marks. Ignore H^+ lost more easily.

3(d)(i)	**A**	1	

3(d)(ii)	**C**	1	

3(d)(iii)	**D**	1	

3(e)	M1	Mol NaOH = mol OH^- = $(19.6 \times 10^{-3}) \times 0.720 = 1.41(1) \times 10^{-2}$	1	Mark for answer.
	M2	Mol H_2SO_4 = $(26.4 \times 10^{-3}) \times 0.550 = 1.45(2) \times 10^{-2}$	1	Mark for answer.
	M3	Mol H^+ added = **2 ×** $(1.452 \times 10^{-2}) = 2.90(4) \times 10^{-2}$ ***OR*** XS mol H_2SO_4 = $7.46(4) \times 10^{-3}$	1	If factor × 2 missed completely (pH = 2.05) or used wrongly later, can score max 4 for M1, M2, M5 & M6
	M4	XS mol H^+ = 0.0149(3)	1	
	M5	For dividing by volume $[H^+] = 0.0149(3) \times (1000 / 46.0) = 0.324 – 0.325$ mol dm^{-3}	1	If no use or wrong use of volume lose M5 and M6 ie can score 4 for pH = 1.83 (no use of vol) Treat missing 1000 as AE (-1) & score 5 for pH = 3.49
	M6	pH = 0.49	1	**2dp** (penalise more or less).
				If × 2 missed & vol not used, pH=3.39 scores M1 & M2 only.

Question		Marking Guidance	Mark	Comments
2(a)(i)		$[H^+][OH^-]$ ***OR*** $[H_3O^+][OH^-]$ Ignore (aq)	1	Must have [ ] not ( )
2(a)(ii)		$\sqrt{3.46 \times 10^{-14}}$ (= 1.86×10^{-7}) pH = 6.73	1 1	If no square root, CE=0 **Must be 2dp**
2(a)(iii)		$[H^+] = 10^{-11.36}$ (= 4.365×10^{-12} OR 4.37×10^{-12}) $K_w = [4.365 \times 10^{-12}$ ***OR*** $4.37 \times 10^{-12} \times 0.047] = 2.05 \times 10^{-13}$ Allow 2.05×10^{-13} - 2.1×10^{-13}	1 1	Mark for working Mark for answer Ignore units
2(b)(i)		$HCOOH \rightleftharpoons HCOO^- + H^+$ ***OR*** $HCOOH + H_2O \rightleftharpoons HCOO^- + H_3O^+$	1	Must have $\rightleftharpoons$ but ignore brackets. Allow HCO_2^- or $CHOO^-$ ie minus must be on oxygen, so penalise $COOH^-$
2(b)(ii)		$K_a = \frac{[H^+][HCOO^-]}{[HCOOH]}$ ***OR*** $\frac{[H_3O^+][HCOO^-]}{[HCOOH]}$	1	Must have all brackets but allow ( ) Must be HCOOH etc. Allow ecf in formulae from 2(b)(i)
2(b)(iii)	M1	$K_a = \frac{[H^+]^2}{[HCOOH]}$ ($[H^+]^2 = 1.78 \times 10^{-4} \times 0.056 = 9.97 \times 10^{-6}$)	1	Allow HA or HX etc. Allow $[H^+] = \sqrt{(Ka \times [HA])}$ for M1
	M2	$[H^+] = 3.16 \times 10^{-3}$	1	Mark for answer
	M3	pH = 2.50 allow more than 2 dp but not fewer	1	**Allow correct pH from their wrong $[H^+]$ here only** If square root shown but not taken, pH = 5.00 can score max 2 for M1 and M3

2(b)(iv)	M1	Decrease **Mark M1 independently**	1	
	M2	Equm shifts/moves to RHS ***OR*** more H^+ ***OR*** K_a increases ***OR*** more dissociation	1	
	M3	To reduce temperature or oppose increase/change in temperature	1	**Only award M3 following correct M2**

2(c)(i)	M1	$[H^+] = \frac{Ka \times [HX]}{[X^-]}$ ***OR*** $pH = pK_a - \log \frac{[HX]}{[X^-]}$	1	If [HX]/[X⁻] upside down, no marks
	M2	$\frac{1.78\times10^{-4} \times 2.35\times10^{-2}}{1.84\times10^{-2}}$ ***OR*** $pH = 3.75 - \log\frac{2.35\times10^{-2}}{1.84\times10^{-2}}$ (= 2.27×10^{-4})	1	
	M3	pH = 3.64 allow more than 2 dp but not fewer	1	**pH calc NOT allowed from their wrong $[H^+]$ here**

2(c)(ii)	M1	Mol H^+ added = 5.00×10^{-4}	1	Mark on from AE in moles of HCl (eg 5×10^{-3} gives pH = 3.42 scores 3)
	M2	Mol $HCOOH = 2.40 \times 10^{-2}$ **and** Mol $HCOO^- = 1.79 \times 10^{-2}$	1	If either wrong no further marks except AE (-1) OR if ECF in mol acid and/or mol salt from (c)(i), can score all 4
	M3	$[H^+] (= \frac{Ka \times [HX]}{[X^-]}) = \frac{1.78\times10^{-4} \times 2.40\times10^{-2}}{1.79\times10^{-2}}$ ($= 2.39 \times 10^{-4}$) ***OR*** $pH = 3.75 - \log\frac{2.40\times10^{-2}}{1.79\times10^{-2}}$	1	If [HX]/[X⁻] upside down here after correct expression in (c)(i), no further marks If [HX]/[X⁻] upside down here and is repeat error from (c)(i), max 3 (pH = 3.88 after 3.86 in 2(c)(i))
	M4	pH = 3.62 allow more than 2 dp but not fewer	1	**pH calc NOT allowed from their wrong $[H^+]$ here**

Question	Marking Guidance		Mark	Comments
2(a)	(only) slightly or partially dissociated / ionised		1	Ignore 'not fully dissociated'. Allow low tendency to dissociate or to lose / donate a proton. Allow shown equilibrium well to the left. otherwise ignore equations
2(b)	$2CH_3CH_2COOH + Na_2CO_3 \rightarrow 2CH_3CH_2COONa + H_2O + CO_2$ **OR** $2CH_3CH_2COOH + CO_3^{2-} \longrightarrow 2CH_3CH_2COO^- + H_2O + CO_2$ **OR** $CH_3CH_2COOH + Na_2CO_3 \longrightarrow CH_3CH_2COONa + NaHCO_3$ **OR** $CH_3CH_2COOH + CO_3^{2-} \longrightarrow CH_3CH_2COO^- + HCO_3^-$		1	Must be propanoic acid, allow C_2H_5COOH not molecular formulae Allow multiples. Ignore reversible sign. Not H_2CO_3
2(c)	$[OH^-] = 2 \times 0.0120 = 0.0240$ $[H^+] = \frac{1 \times 10^{-14}}{0.0240} = 4.166 \times 10^{-13}$ ***OR*** pOH = 1.62 pH = 12.38	M1 M2 M3	1 1 1	Correct answer for pH with or without working scores 3 If × 2 missed or used wrongly can only score M3 for correct calculation of pH from their $[H^+]$ Lose M3 if not 2 decimal places: 12.4 scores 2 12.08 scores 1 (missing × 2) ; 12.1 scores 0 11.78 scores 1 (dividing by 2) 11.8 scores 0

2(d)(i)		$K_a = \frac{[H^+][C_6H_5COO^-]}{[C_6H_5COOH]}$	1	Ignore ( ) here but brackets must be present. Must be correct acid and salt. If wrong, mark (d)(ii) independently.
2(d)(ii)	M1	$K_a = \frac{[H^+]^2}{[C_6H_5COOH]}$ **OR** with numbers	1	Correct answer for pH with or without working scores 3 Allow HX, HA and ignore ( ) here. May score M1 in (d)(i).
	M2	$[H^+] = \sqrt{(6.31 \times 10^{-5} \times 0.0120)}$ or $\sqrt{(K_a \times [C_6H_5COOH])}$ $(= \sqrt{(7.572 \times 10^{-7} = 8.70 \times 10^{-4})}$	1	pH = 6.12 may score 2 if correct working shown and they show the square root but fail to take it. but if no working shown or wrong $K_a = \frac{[H^+]}{[C_6H_5COOH]}$ used
	M3	pH = 3.<u>06</u>	1	which also leads to 6.12, then zero scored. Must be 2 decimal places ie 3.1 loses M3

2(d)(iii)	M1	$[H^+] = 10^{-4.00} = 1.00 \times 10^{-4}$	1	Correct answer for mass with or without working scores 5 Allow 1×10^{-4}
	M2	$[X^-] = \frac{Ka \times [HX]}{[H^+]}$	1	Ignore ( ) here. If $[HX]/[X^-]$ upside down, can score M1 plus M4 for 5.26×10^{-7}
	M3	$= \frac{6.31 \times 10^{-5} \times 0.0120}{1.00 \times 10^{-4}}$	1	And M5 for 7.57×10^{-5} g
	M4	$= 7.572 \times 10^{-3}$	1	
	M5	Mass (C_6H_5COONa) $= 7.572 \times 10^{-3} \times 144 = 1.09$ g or 1.1 g	1	Wrong method, eg using $[H^+]^2$ may only score M1 and M5 for correct multiplication of their M4 by 144 (provided not of obviously wrong substance)

2(e)	M1	CO_2	1	Allow NO_x and SO_2
	M2	pH (It) falls/decreases	1	If M1 wrong, no further marks.
	M3	mark M2 & M3 independently acidic (gas) **OR** reacts with alkali(ne solution)/ OH^- **OR** $CO_2 + 2OH^- \longrightarrow CO_3^{2-} + H_2O$ **OR** $CO_2 + OH^- \longrightarrow HCO_3^-$	1	Not forms H_2CO_3 H_2SO_3 H_2SO_4 etc OR H^+ ions.

Question	Marking Guidance	Mark	Comments
3(a)(i) **A**	G	1	
3(a)(ii) **A**	F	1	
3(a)(iii) **A**	H	1	
3(b)(i) **A**	cresol purple	1	
3(b)(ii) **G**	yellow to red	1	both colours needed and must be in this order
3(b)(iii) **G**	Yellow or pale yellow	1	Not allow any other colour with yellow

Question		Marking Guidance	Mark	Comments
4(a)	M1	$[H_2O]$ is <u>very</u> high (compared with $[H^+]$ and $[OH^-]$) **OR** <u>Very few</u> H^+ and OH^- ions **OR** <u>Only / very</u> slightly dissociates **OR** Equilibrium lies <u>far</u> to the left	1	Not partially dissociates
	M2	$[H_2O]$ is (effectively) constant OR is incorporated into the constant K	1	Allow changes by only a very small amount
4(b)		(Dissociation OR breaking bonds) is endothermic	1	
		∴ Equilibrium moves to RHS (at higher T) <u>to absorb heat or to lower T or oppose increase in T</u>	1	Allow to oppose change only if increase T mentioned

4(c) Marked with 4(d)	$[H^+]$ = $\sqrt{K_w}$ (or = $\sqrt{5.48 \times 10^{-14}}$) If wrong method no marks = 2.34×10^{-7} pH = 6.63	1 1 1	Correct pH answer scores 3 Using alternative K_w (1.00×10^{-14}) gives pH = 7.<u>00</u> which scores 1 Final answer must have 2dp

4(d) Marked with 4(c)	$[H^+]$ = $K_w / [OH^-]$ or (= $5.48 \times 10^{-14}/0.12$) If wrong method no marks = 4.566×10^{-13} pH = 12.34	1 1 1	Correct pH answer scores 3 If use alternative K_w (1.00×10^{-14}) again, do not penalise repeat error so pH = 13.08 scores 3 If use alternative K_w (1.00×10^{-14}) **not** as a repeat error, pH = 13.08 scores 1 If AE in K_w value made in part (c) is repeated here, do not penalise again. Final answer must have 2dp, but if dp penalised in 4(c) allow more than 2dp here but not fewer.

Question		Answers	Mark	Comments
9(a)	M1	$[H^+] = \frac{K_a \times [CH_3COOH]}{[CH_3COO^-]}$ or = $1.74 \times 10^{-5} \times \frac{0.186}{0.105}$	1	Allow ( )
	M2	$= 3.08 \times 10^{-5}$	1	If $[HX]/[X^-]$ or $\frac{0.186}{0.105}$ upside down, or any addition or subtraction lose M1 & M2.
	M3	pH = 4.51 (correct answer scores 3)	1	Can score M3 for correct pH conseq to their $[H^+]$, so pH = 5.01 scores one Must be to 2 dp
9(b)	M1	mol HX after addition (= 0.251 + 0.015) = 0.266	1	For HX, if no addition or error in addition (other than AE) (or subsequent extra add or sub) MAX 3
	M2	mol X^- after subtraction (= 0.140 – 0.015) = 0.125	1	For X^- if no subtraction or error in subtraction (other than AE) (or subsequent extra add or sub) MAX 3
	M3	$[H^+] = \left(\frac{K_a \times [CH_3COOH]}{[CH_3COO^-]} \right) = \frac{1.74 \times 10^{-5} \times 0.266}{0.125}$	1	If errors above in both addition AND subtraction can only score M3 for insertion of their numbers in rearranged expression. One exception, if addition and subtraction reversed then pH =4.58 scores 2
	M4	$[H^+] = 3.703 \times 10^{-5}$ (mol dm^{-3})	1	If $[HX]/[X^-]$ upside down, lose M3 & M4 (or next two marks) but can score M5 for correct pH conseq to their $[H^+]$, so if M1 & M2 correct, pH = 5.09 scores 3.
	M5	pH = 4.43 Correct use of HX and X^- values from 9(a) gives pH= 4.41 and scores 4	1	If wrong method, e.g √ or no use of rearranged K_a expression, may score M1 & M2 but no more. Allow more but not fewer than 2dp here.

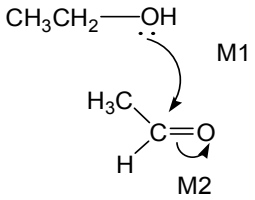
Questio	Answers		Mar	Comments
	Alternative using Henderson-Hasselbach Equation			
9(a)	M1	pH = pKa – log[HX]/X^-] = -log(1.74 × 10^{-5}) – log($\frac{0.186}{0.105}$)	1	Allow ( )
	M2	pKa = 4.76 – 0.248	1	If [HX]/[X^-] or $\frac{0.186}{0.105}$ upside down, can only score 1
	M3	pH = = 4.51	1	so pH = 5.01 Must be to 2 dp
9(b)	M1	mol acid after addition = 0.251 + 0.015 = 0.266	1	For HX, if no addition or error in addition (other than AE) (or subsequent extra add or sub) MAX 3
	M2	mol salt after addition = 0.140 – 0.015 = 0.125	1	For X^- if no subtraction or error in subtraction (other than AE) (or subsequent extra add or sub) MAX 3
	M3	pH = (pKa – log[HX]/[X^-]) = -log(1.74 × 10^{-5}) – log(0.266/0.125)	1	If errors above in both addition AND subtraction can only score M3 for insertion of their numbers - except if addition and subtraction reversed then pH =4.58 scores 2
	M4	pH = 4.76 – 0.328	1	
	M5	pH = = 4.43	1	If [HX]/[X^-] upside down, lose M3 & M4 (or next two marks) but can score M5 for correct pH conseq to their working, so if M1 & M2 correct, pH = 5.09 scores 3. Allow more but not fewer than 2dp here.

Question	Answers	Mark	Additional Comments/Guidance	ID detail
1a	$CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$ OR $CH_3COOH \rightleftharpoons CH_3COO^- + H^+$	1	Must show ⇌ allow CH_3CO_2H, $CH_3CO_2^-$ Ignore state symbols	
1b	$CH_3COOH + \underline{HNO_3} \rightarrow CH_3COOH_2^+ + NO_3^-$	1	Ignore ⇌ Allow CH_3CO_2H, $CH_3CO_2H_2^+$, $CH_3C^+(OH)_2$	

1c(i) marked with 1c(ii)	(new $[HNO_3] = [H^+] = \frac{100}{150} \times 0.0125$) M1 $[H^+] = 8.3(3) \times 10^{-3}$ (mol dm^{-3}) M2 pH = –log M1 OR 2.08	 1 1	OR new $[HNO_3] = \frac{\text{mol } HNO_3}{\text{total vol}} = \frac{1.25 \times 10^{-3}}{150 \times 10^{-3}}$ Must be 2 dp Allow correct pH conseq to their $[H^+]$ concentration	
1c(ii) marked with 1c(i)	M1 mol NaOH (= $50 \times 10^{-3} \times 0.0108$) = 5.40×10^{-4} M2 Subtraction of M1 from moles of HNO_3 (1.25×10^{-3} or conseq from 1c(i)) Excess mol $H^+ = 7.10 \times 10^{-4}$ M3 $[H^+] = \frac{M2}{150 \times 10^{-3}}$ OR $\frac{7.10 \times 10^{-4}}{150 \times 10^{-3}} = 4.73 \times 10^{-3}$ M4 pH = –log M3 OR 2.32	1 1 1 1	 M2 allow ecf for subtraction of mol **If no subtraction, no further marks** M3 **if no use of volume, no further marks (**pH=3.15) If incorrect volume used, can score M4 M4 Allow 2.33 Must be 2 dp	

1d(i)	M1 $K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]}$ M2 $K_a = \frac{[H^+]^2}{[CH_3COOH]}$ or with numbers or with HA M3 $[H^+] = [\sqrt{(1.74 \times 10^{-5} \times 0.0125)}] = 4.66 \times 10^{-4}$ M4 pH = 3.33	1 1 1 1	penalise ( ) once here Not [H+][A-] / [HA] if K_a expression wrong – Allow correct pH conseq to their $[H^+]$ concentration M4 only mark for answer Must be 2 dp Allow correct pH conseq to their $[H^+]$ concentration (pH = 3.83 can score M1, M2 and M4)	
G 1d(ii)	<u>sodium ethanoate</u>	1	Ignore formula allow sodium acetate	
1d(iii)	M1 $[H^+] = 1.45 \times 10^{-5}$ M2 $\frac{[salt]}{[acid]}$ (OR $\frac{[CH_3COO^-]}{[CH_3COOH]} = \frac{Ka}{[H^+]} = \frac{1.74 \times 10^{-5}}{1.45 \times 10^{-5}}$) M3 1.2(0)	1 1 1	Accept 1.445×10^{-5} or 1.4×10^{-5} If M1 incorrect CE=0 Inclusion of 0.0125 in calculation can only score M1 ignore units 1.4×10^{-5} gives 1.24	
1e	M1 (Electronegative) chlorine withdraws electrons M2 Stabilises/reduces charge on COO- **OR** weakens <u>O-H</u> bond **OR** makes <u>O-H</u> more polar	1 1	Allow Cl has negative inductive effect Ignore chloroethanoic acid dissociates more readily Mark independently	

1f	M1	Strong acids (almost) completely dissociated/ionised **OR** not an equilibrium **OR** equilibrium lies <u>far</u> to the right	1 1	Cannot have $\underline{K_a}$ value for a reaction not in equilibrium scores both marks	
	M2	$\underline{K_a}$ value for strong acids tends to infinity/is very large **OR** can't divide by zero in $\underline{K_a}$			
Total			**20**		

Question	Answers	Mark	Additional Comments/Guidance	ID details
G 2a(i)	<u>Nucleophilic addition</u>	1	any extra loses the mark allow minor spelling errors e.g. nucleophyllic	
2a(ii)		1 1	M1 for arrow from lone pair on oxygen in ethanol to C of C=O (or to space half way between O and C) M2 for arrow from C=O bond to oxygen in ethanal Do not allow M2 as first step without nucleophilic attack, but can allow M1 for attack on C+ produced + rather than δ+ on C=O loses M2 Ignore any further steps Mark independently	
2b(i)	<u>Equal</u> mixture of enantiomers/optical isomers OWTTE	1		
2b(ii)	(non-superimposable) mirror images	1	Ignore rotates light in opposite directions Ignore stereoisomers	