Question number	Answer	Marks	Guidance
1 (a)	$K_a = [H^+]^2 / [CH_3CH_2COOH]$	1	if wrong, score max 1 for M3 from their $[H^+]$ penalise round brackets once in the question
	$[H^+] = \sqrt{(1.35 \times 10^{-5} \times 0.169)} = 1.51 \times 10^{-3}$	1	If $\sqrt{}$ visible can score 2 for 5.64
	pH = 2.82	1	allow 1 for correct pH from their $[H^+]$
1 (b) (i)	$CH_3CH_2COOH + NaOH \rightarrow CH_3CH_2COONa + H_2O$ OR $CH_3CH_2COOH + OH^- \rightarrow CH_3CH_2COO^- + H_2O$	1	Penalise covalent Na
1 (b) (ii)	mol propanoic acid = 0.250 – 0.015 = 0.235	1	penalise rounding to 2sfs once
	mol propanoate ions = 0.190 + 0.015 = 0.205	1	
1 (b) (iii)	$[H^+] = K_a \times [CH_3CH_2COOH] / [CH_3CH_2COO^-]$	1	Correct rearrangement, as here or with their numbers even if *x* allow $K_a \times [HA] / [A^-]$
	$= (1.35 \times 10^{-5}) \times 0.235 / 0.205$ $= 1.548 \times 10^{-5}$	1	Insertion of correct numbers here or in K_a expression
	pH = 4.81	1	Allow 1 for correct pH from their $[H^+]$
2 (a) (i)	$[H^+][OH^-]$ OR $[H_3O^+][OH^-]$	1	Must have [ ] not ( ) Ignore (aq)
2 (a) (ii)	$\sqrt{(3.46 \times 10^{-14})} = 1.86 \times 10^{-7}$	1	If no square root, CE=0 **Must be 2 d.p.**
	pH = 6.73	1	
2 (a) (iii)	$[H^+] = 10^{-11.36}$ (= 4.365×10^{-12} OR 4.37×10^{-12})	1	Mark for working
	$K_w = [4.365 \times 10^{-12}$ OR $4.37 \times 10^{-12} \times 0.047]$ $= 2.05 \times 10^{-13}$	1	Mark for answer Ignore units Allow 2.05×10^{-13} – 2.1×10^{-13}
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 $CHOO^-$, i.e., minus must be on oxygen, so penalise $COOH^-$

2 (b) (ii)	$K_a = [H^+][HCOO^-] / [HCOOH]$ OR $[H_3O^+][HCOO^-] / [HCOOH]$	1	Must have all brackets but allow ( ) Must be HCOOH etc. Allow ecf in formulae from 2(b)(i)
2 (b) (iii)	$K_a = [H^+]^2 / [HCOOH]$ $([H^+]^2 = 1.78 \times 10^{-4} \times 0.056 = 9.97 \times 10^{-6})$ $[H^+] = 3.16 \times 10^{-3}$ pH = 2.50	1 1 1	Allow HA or HX etc. Allow $[H^+] = \sqrt{}(K_a \times [HA])$ for M1 Mark for answer allow more than 2 d.p. but not fewer **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)	Decrease Equilibrium shifts/moves to RHS **OR** more H^+ **OR** K_a increases **OR** more dissociation To reduce temperature or oppose increase/change in temperature	1 1 1	Mark M1 independently Only award M3 following correct M2
2 (c) (i)	$[H^+] = K_a \times [HX] / [X^-]$ **OR** $pH = pK_a - \log ([HX] / [X^-])$ $1.78 \times 10^{-4} \times 2.35 \times 10^{-2} / 1.84 \times 10^{-2}$ **OR** $pH = 3.75 - \log (2.35 \times 10^{-2} / (1.84 \times 10^{-2}))$ $= 2.27 \times 10^{-4}$ pH = 3.64	1 1 1	If $[HX] / [X^-]$ upside down, no marks allow more than 2 d.p. but not fewer pH calc NOT allowed from their wrong $[H^+]$ here

2 (c) (ii)	Mol H^+ added = 5.00×10^{-4}	1	Mark on from AE in moles of HCl (e.g., 5 x 10^{-3} gives pH = 3.42 scores 3)
	Mol HCOOH = 2.40×10^{-2} **AND** Mol $HCOO^-$ = 1.79×10^{-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
	$[H^+] = K_a \times [HX] / [X^-]$ $= 1.78 \times 10^{-4} \times 2.40 \times 10^{-2} / (1.79 \times 10^{-2})$ $= 2.39 \times 10^{-4}$ **OR** pH = 3.75 – log ($2.40 \times 10^{-2} / (1.79 \times 10^{-2})$)	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))
	pH = 3.62	1	allow more than 2 d.p. but not fewer **pH calc NOT allowed from their wrong $[H^+]$ here**
3 (a) (i)	$K_w = [H^+][OH^-]$	1	if wrong only score in (ii) and (iii) except if $[H_2O]$ = 1 *
3 (a) (ii)	2.34×10^{-7}	1	penalise 2.3×10^{-7}, i.e., 2 s.f. once in the question
3 (a) (iii)	2.34×10^{-7}	1	conseq = (ii)
3 (a) (iv)	5.48 to 5.50 $\times 10^{-14}$	1	conseq = (ii) × (iii) 1 *if $[H_2O]$ = 1 can score for correct answer here
3 (b)	$[H^+] = 10^{-14} / 0.136 = 7.35 \times 10^{-14}$ OR pOH = 0.87 pH = 13.13	1 1	
4 (a) (i)	C	1	
4 (a) (ii)	A	1	
4 (a) (iii)	D	1	
4 (b) (i)	Bromocresol green	1	Allow wrong spellings
4 (b) (ii)	Purple to yellow	1	Must have both colours: Purple start – yellow finish