

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

ratio $\frac{[HX]}{[X^-]}$ remains almost constant

(d) (i) **M1** mol HY = $(50 \times 10^{-3}) \times 0.428 = 0.0214$

OR $[Y] = .0236 \times \frac{1000}{50} = 0.472$
mark for answer

1

M2 $[H^+] = 1.35 \times 10^{-5} \times \frac{0.0214}{0.0236}$

OR $1.35 \times 10^{-5} = [H^+] \times \frac{0.0236}{0.0214}$

OR $[H^+] = 1.35 \times 10^{-5} \times \frac{0.428}{0.472}$

OR $1.35 \times 10^{-5} = [H^+] \times \frac{0.472}{0.428}$

*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*

1

M3 $[H^+] = 1.22 \times 10^{-5}$
mark for answer

1

M4 pH = 4.91
*allow more than 2dp but not fewer
allow M4 for correct pH calculation using their [H⁺] (this
applies in (d)(i) only)*

1

If Henderson Hasselbalch equation used:

M1 mol HY = $(50 \times 10^{-3}) \times 0.428 = 0.0214$

OR $[Y] = .0236 \times \frac{1000}{50} = 0.472$
mark for answer

1

M2 $pK_a = 4.87$

1

M3 $\log\left(\frac{0.0214}{0.0236}\right) = -0.043$

$\log\left(\frac{0.428}{0.472}\right) = -0.043$

If either HY value or Y⁻ value wrong, (apart from AE-1) lose M3 and M4

1

M4 $pH = 4.87 - (-0.043) = 4.91$
allow more than 2dp but not fewer

1

(ii) Can score full marks for correct consequential use of their HY and Y⁻ values from d(i)

M1 Mol HY after adding NaOH = $0.0214 - 5.0 \times 10^{-4} = 0.0209$
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

1

M2 Mol Y⁻ after adding NaOH = $0.0236 + 5.0 \times 10^{-4} = 0.0241$
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

1

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
 allow more than 2dp but not fewer
 NOT allow M4 for correct pH calculation using their $[H^+]$ (this allowance applies in (d)(i) only)

1

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 = $0.0214 - 5.0 \times 10^{-4} = 0.0209$
 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

1

M2 Mol Y⁻ after adding NaOH = $0.0236 + 5.0 \times 10^{-4} = 0.0241$
 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

1

M3 $\log \left(\frac{0.0209}{0.0241} \right) = -0.062$
 if HY/Y⁻ upside down, no further marks

1

M4 pH = $4.87 - (-0.062) = 4.93$
 allow more than 2dp but not fewer

1

[18]

M2. (a) (i) $-\log[H^+]$
 or $\log 1/[H^+]$
 penalise ()

1

(ii) $[H^+] = 0.56$

mark for the answer; allow 2dp or more

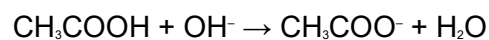
1

$$[\text{H}_2\text{SO}_4] = \frac{1}{2} \times 0.56 = 0.28$$

1



OR



Allow $\text{CH}_3\text{CO}_2\text{H}$ etc

1

(ii) mol acid = $(25.0 \times 10^{-3}) \times 0.41 = 1.025 \times 10^{-2}$ or 1.03×10^{-2}

1

$$[\text{NaOH}] = 1.025 \times 10^{-2} / 22.6 \times 10^{-3} = 0.45(4)$$

mark for answer

if not 0.454 look back for error

1

OR

$$[\text{NaOH}] = 1.03 \times 10^{-2} / 22.6 \times 10^{-3} = 0.456 \text{ or } 0.46$$

(iii) cresol purple

1

(iv) NaOH reacts with carbon dioxide (in the air)

1

(c) (i)
$$K_a = \frac{[\text{H}^+][\text{CH}_3\text{COO}^-]}{[\text{CH}_3\text{COOH}]}$$

allow molecular formulae or minor slip in formulae

penalise ()

allow H_3O^+

not allow HA etc

1

(ii) $K_a = \frac{[H^+]^2}{[CH_3COOH]}$ or with numbers 1

allow HA etc here

This can be scored in part (c)(i) but doesn't score there.

$[H^+] = (\sqrt{(1.74 \times 10^{-5} \times 0.410)}) = \sqrt{(7.13 \times 10^{-6})} = 2.67 \times 10^{-3}$ 1

mark for 2.67×10^{-3} or 2.7×10^{-3} either gives 2.57

pH = 2.57 can give three ticks here for (c)(ii)
penalise decimal places < 2 > 1

pH mark conseq on their $[H^+]$

so 5.15 gets 2 marks where square root not taken

(iii) **M1** mol OH⁻ = $(10.0 \times 10^{-3}) \times 0.10 = 1.0 \times 10^{-3}$
If no subtraction or other wrong chemistry the max score is 3 for M1, M2 and M4 1

M2 orig mol HA = $(25.0 \times 10^{-3}) \times 0.41 = 0.01025$ 1

or 1.025×10^{-2} or 1.03×10^{-2}

M3 mol HA in buffer = orig mol HA – mol OH⁻ 1

= 0.00925 or 0.0093

*If A⁻ is wrong, max 3 for M1, M2 and M3 or use of
 pH = pKa – log [HA]/[A⁻]*

M4 mol A⁻ in buffer = mol OH⁻ = 1.0×10^{-3}
Mark is for insertion of correct numbers in correct expression for $[H^+]$ 1

M5 $[H^+] = \left(\frac{K_a \times [CH_3COOH]}{[CH_3COO^-]} \right)$ 1

$\frac{(1.74 \times 10^{-5})(0.00925)}{0.0010}$ or $\frac{(1.74 \times 10^{-5})(0.00930)}{0.0010}$

(= 1.61×10^{-4} or 1.62×10^{-4})

M6 pH = 3.79 can give six ticks for 3.79
 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)

NB Unlike (c)(ii), this pH mark is NOT awarded conseq to their
 $[H^+]$ unless following AE
*BEWARE: using 0.01025 wrongly instead of 0.00925 gives
 pH = 3.75
 (this gets 3 for M1, M2 & M4)*

1

[18]

M3.(a) (i) $[H^+][OH^-]$

1

$-\log [H^+]$

1

(ii) $[H^+] = [OH^-]$

1

(iii) $(2.0 \times 10^{-3}) \times 0.5 = 1.0 \times 10^{-3}$

1

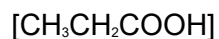
(iv) $[H^+] = \frac{4.02 \times 10^{-14}}{1.0 \times 10^{-3}} \quad (= 4.02 \times 10^{-11})$

1

pH = 10.40

1

(b) (i) $K_a = \frac{[H^+][CH_3CH_2COO^-]}{[CH_3CH_2COOH]}$



1

$$= \frac{[\text{H}^+]}{[\text{CH}_3\text{CH}_2\text{COOH}]}$$

1

$$[\text{H}^+] = \sqrt{(1.35 \times 10^{-5}) \times 0.125} \quad (= 1.30 \times 10^{-3})$$

1

$$\text{pH} = 2.89$$

1

(c) (i) $(50.0 \times 10^{-3}) \times 0.125 = 6.25 \times 10^{-3}$

1

(ii) $(6.25 \times 10^{-3}) - (1.0 \times 10^{-3}) = 5.25 \times 10^{-3}$

1

(iii) mol salt formed = 1.0×10^{-3}

1

$$[\text{H}^+] = K_a \times \frac{[\text{CH}_3\text{CH}_2\text{COOH}]}{[\text{CH}_3\text{CH}_2\text{COO}^-]}$$

1

$$= (1.35 \times 10^{-5}) \times \frac{(5.25 \times 10^{-3})/V}{(1.0 \times 10^{-3})/V} \quad (= 7.088 \times 10^{-5})$$

1

$$\text{pH} = 4.15$$

1

[16]