**M1.**B

**[1]**

**M2.**A

**[1]**

**M3.**(a) (i) $-\log[H^+]$

*Penalise missing [ ] here **and not elsewhere***

**1**

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

**1**

(b) (i) $[H^+] = 2.34 \times 10^{-7}$

**1**

pH = 6.63

*Penalise fewer than 3 sig figs but allow more than 2 dp*

**1**

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

**1**

(iii) **M1** $[H^+] = K_w/[OH^-]$

*if upside down or CE, allow M3 only for correct use of their $[H^+]$*

**1**

**M2** $(= 5.48 \times 10^{-14}/0.140) = 3.91 \times 10^{-13}$

**1**

**M3** pH = 12.4(1)

*not 12.40 (AE from 12.407)*

**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*
*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*

(c) **M1** mol NaOH = mol $OH^-$ = $(30 \times 10^{-3}) \times 0.20 = 6.0 \times 10^{-3}$

*mark for answer*

**1**

**M2** mol $H_2SO_4$ = $(25 \times 10^{-3}) \times 0.15 = 3.75 \times 10^{-3}$

*mark for answer*

**1**

**M3** mol $H^+$ = $(25 \times 10^{-3}) \times 0.15 \times 2 = 7.5 \times 10^{-3}$
OR XS mol $H_2SO_4$ = $0.75 \times 10^{-3}$

*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*

**1**

**M4** XS mol $H^+$ = $1.5 \times 10^{-3}$

**1**

**M5** $[H^+]$ = $(1.5 \times 10^{-3}) \times (1000/55) = 0.0273$

*if no use or wrong use of volume, lose M5 and M6 except if 1000 missed*
*AE –1 (pH = 4.56)*

**1**

**M6** 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*

**1**

**[14]**

**M4.**C

**[1]**

**M5.**(a) pH on the *y*-axis, volume of alkali on the *x*-axis

*If axes unlabelled use data to decide that pH is on y-axis.*

**1**

Uses sensible scales

*Lose this mark if plotted paths do not cover **half** of the paper.*
*Lose this mark if the graph plot goes off the squared paper.*

**1**

Labels the axes

*Allow mark for axes labelled 'pH' and 'volume'.*

**1**

Plots all of the points correctly

**1**

Line through the points is smooth and has the correct profile

*Ignore 0–5 $cm^3$ section of the graph.*
*Lose this mark if graph is kinked or not a single line.*

**1**

Line ignores the point at 12 $cm^3$

*Lose this mark if point clearly not treated as an anomaly.*

**1**

(b) (i) 24.4 $cm^3$ ± 0.2

*If no answer in (i) allow answer written on the graph.*
*Allow this answer **only**.*
*Do not penalise precision.*

**1**

(ii) 12.2 $cm^3$ ± 0.1

*If no answer in (ii), allow answer written on the graph.*
*Allow answer to (i) divided by 2.*
*Do not penalise precision.*

**1**

(iii) 3.9 ± 0.2

*If no answer in (iii), allow answer written on the graph.*
*Consequential marking from (ii)*

*Lose this mark if answer not given to 1 dp.*

**1**

(c) $pK_a = -\log K_a$ or $K_a = 10^{x}$, where $x = -$ (answer to b(iii))

**1**

$1.26 \times 10^{-4}$

*3.7 to 4.1 gives $K_a = 7.9 \times 10^{-5}$ to $2.0 \times 10^{-4}$*

*Consequential marking from b(i).*

*Correct answer without working scores 1 mark only.*

*Do not penalise precision.*

**1**

(d) Methanoic acid

*Consequential marking from (c).*

*$pK_a = 3.7$ gives methanoic acid.*

*$pK_a = 4.1$ gives ethanoic acid.*

*No lucky guesses – candidates must apply answer from (c).*

*Do not allow answers based on data given in (f).*

**1**

(e) Error in using pipette is 0.2% **and**
Error in using burette is 0.15 × 100 / (answer to b(i))

*Using 24.4 for burette gives 0.6%*

*Do not penalise precision.*

*Allow if errors are given without working.*

*Lose mark if the burette error is not calculated on b(i).*

*If the error being calculated is **not** stated, allow **if** the calculations are in the same order as in the question (pipette, burette).*

**1**

(f) Difference is $1.6 \times 10^{-4} - 1.26 \times 10^{-4} = 0.34 \times 10^{-4}$

*Allow consequential answer from (c).*

*Do not penalise precision.*

$0.34 \times 100 / 1.6$ is a 21% error

*Correct final answer without working scores 1 mark.*

*Using $1.9 \times 10^{-4}$ gives $0.3 \times 10^{-4}$ and 18.8%.*

**1**

(g) Calibrate meter **or** thermostat the mixture **or** maintain constant temperature

*Do not allow 'repeat experiment'.*

**1**

(h) Mixture is a <u>buffer</u>

**1**

**[16]**

**M6.** C

**[1]**

**M7.** (a) (i) $-\log[H^+]$

*or* $\log 1/[H^+]$

*penalise ( )*

**1**

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

*mark for the answer; allow 2dp or more*

**1**

$[H_2SO_4] = ½ \times 0.56 = 0.28$

**1**

(b) (i) $CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$

***OR***

$CH_3COOH + OH^- \rightarrow CH_3COO^- + H_2O$

*Allow $CH_3CO_2H$ etc*

**1**

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

**1**

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

*mark for answer*
*if not 0.454 look back for error*

**1**

***OR***

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

(iii) cresol purple

**1**

(iv) NaOH reacts with <u>carbon dioxide</u> (in the air)

**1**

(c) (i) $K_a = \dfrac{[H^+][CH_3COO^-]}{[CH_3COOH]}$

allow molecular formulae or minor slip in formulae

*penalise ( )*
*allow $H_3O^+$*
*not allow HA etc*

**1**

(ii) $K_a = \dfrac{[H^+]^2}{[CH_3COOH]}$ 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 $2.67 \times 10^{-3}$ or $2.7 \times 10^{-3}$ 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 $1.025 \times 10^{-2}$ or $1.03 \times 10^{-2}$

**M3** mol <u>HA</u> 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 $OH^-$ = $1.0 \times 10^{-3}$

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

(= $1.61 \times 10^{-4}$ or $1.62 \times 10^{-4}$)

**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]**