M1.(a) **M1** $[H^+] = 0.0170$

1

M2 pH = 1.77

2 dp

Allow M2 for correct pH calculation from theirwrong $[H^+]$ for this pH calculation only

1

(b) (i) $K_a = \frac{[H^+][X^-]}{[HX]^2}$ Ignore $K_a = \frac{[H^+]^2}{[HX]}$

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

Allow HA instead of HX

1

(ii) **M1** $[H^+] = 10^{-2.79}$ OR $1.6218\ldots \times 10^{-3}$

If $[H^+]$ wrong, can only score M2

1

M2 $K_a = \frac{[H^+]^2}{[HX]}$ OR $\frac{[1.62 \times 10^{-3}]^2}{[0.0850]}$

Allow HA instead of HX

1

M3 $K_a = 3.09 \times 10^{-5}$ 3sfs min (allow 3.10×10^{-5} if 1.6218 rounded to 1.622) Ignore units

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

1

(c) **M1** mol OH^- $(= (38.2 \times 10^{-3}) \times 0.550)$

$= 2.10(1) \times 10^{-2}$ or 0.0210(1)

Mark for answer

1

M2 Mol H^+ (= $(25.0 \times 10^{-3}) \times 0.620$)

= 1.55×10^{-2} or 0.0155

Mark for answer

1

M3 excess mol OH^- = $5.5(1) \times 10^{-3}$

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.

1

M4 $[OH^-] = 5.51 \times 10^{-3} \times \frac{10^3}{63.2}$ [= 0.08718 (0.0872)]

OR $[OH^-] = 5.5 \times 10^{-3} \times \frac{10^3}{63.2} = 0.0870(2)$

(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)

1

M5 $[H^+] = \frac{10^{-14}}{0.08718} = 1.147 \times 10^{-13}$

OR $\frac{10^{-14}}{0.0870} = 1.149 \times 10^{-13}$

OR pOH = 1.06

If no use or wrong use of K_w or pOH no further marks

1

M6 pH = 12.9(4) allow 3sf

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

1

[12]

M2. (a) (i) $-\log[H^+]$

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

1

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

Allow ( ) brackets, but must have charges

1

(iii) Mark independently from a(ii)

$[H^+] = 10^{-13.72} = 1.905 \times 10^{-14}$

If wrong no further mark

1

$K_w = 1.905 \times 10^{-14} \times 0.154 = = (2.93 – 2.94) \times 10^{-15}$

1

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

Must have charges and all brackets, allow ( )
Acid/salt shown must be CH_3COOH not HA
and correct formulae needed

1

(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

$K_a = \dfrac{[H^+]^2}{[CH_3COOH]}$

Allow HA

1

($[H^+]^2 = 1.75 \times 10^{-5} \times 0.154 = 2.695 \times 10^{-6} = 2.70 \times 10^{-6}$)

If √ shown but not done gets pH = 5.57 (scores 2)

$[H^+] = 1.64 \times 10^{-3}$

Allow mark for pH conseq to their [H+] ***here only***

1

pH = 2.78 or 2.79

1

(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^- = $(10 \times 10^{-3}) \times 0.154$ **and**

mol HA = $(20 \times 10^{-3}) \times 0.154$

or mol OH^- = 1.54×10^{-3} **and** mol HA = 3.08×10^{-3}

1

M2 $[H^+] = K_a \dfrac{[CH_3COOH]}{[CH_3COOH^-]}$

or with numbers

Allow Henderson Hasselbach

$pH = pK_a + log \dfrac{[CH_3COO^-]}{[CH_3COOH]}$

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

1

M4 pH (= - log 1.75×10^{-5}) = 4.76 or 4.757

Not 4.75

1

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**

(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 (= $(20 \times 10^{-3}) \times 0.154$) = 3.08×10^{-3}

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*

1

M2 $[OH^-] = 3.08 \times 10^{-3} \times \frac{10^3}{60} = 0.0513(3)$

*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*

1

M3 $[H^+] = \frac{10^{-14}}{0.05133}$ (= 1.948×10^{-13} to 1.95×10^{-13})

or pOH = 1.29

*Mark for K_w divided by their answer to **M2***

If pOH route, give one mark for 14 – pOH

1

M4 pH = 12.7(1)

Allow 3sf but not 12.70

1

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)

[16]

M3.(a) Idea that over time / after storage meter does not give accurate readings

Do not accept 'to get an accurate reading' without further

qualification.
Allow 'temperature variations affect reading'.

1

(b) $$\frac{[[Fe(H_2O)_5OH]^{2+}(aq)]\,[H^+(aq)]}{[[Fe(H_2O)_6]^{3+}(aq)]}$$

Allow without (aq) symbols.
Need at least one set of square brackets around complex ions

1

(c) pH = –log $[H^+]$

1

$[H^+] = 0.0240$

Do not penalise precision of $[H^+]$
Correct answer scores M1 and M2.

1

$K_a = (0.0240)^2 / 0.1 = 5.75 \times 10^{-3}$ or 5.76×10^{-3}

Correct answer without working loses M1 and M2.
Allow 7.58×10^{-3}

1

Answer, even if incorrect, given to 3 sig figs

1

(d) Oxygen (in the air) / O_2

Ignore 'air' or 'the atmosphere' or 'chemicals in soil'.
List principle.

1

(e) 4.0 – 6.9

Do not penalise precision.

[7]

M4. (a) (i) $-\log[H^+]$ or $\log 1/[H^+]$

penalise missing square brackets here only

1

(ii) 0.81

2dp required, no other answer allowed

1

(iii) **M1** 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 pH = 2.81

allow more than 2dp but not fewer

1

(b) **M1** $[H^+] = 3.31 \times 10^{-3}$

1

M2 $K_a = \frac{[H^+][X^-]}{[HX]}$ or $\frac{[H^+]^2}{[HX]}$ or using numbers

do not penalise ( ) or one or more missing [ ]

1

M3 $[HX] = \frac{[H^+]^2}{K_a} = \frac{(3.31 \times 10^{-3})^2}{4.83 \times 10^{-5}}$

allow conseq on their $[H^+]^2/(4.83 \times 10^{-5})$ (AE)
if upside down, no further marks after M2

1

M4 [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 equn shift i.e. $HX \rightleftharpoons H^+ + X^-$ 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 × $\frac{1000}{50} = 0.472$

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 × $\frac{1000}{50}$ = 0.472

mark for answer

1

M2 p*K*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 × 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 × 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 × 10^{-5} × $\frac{0.0209}{0.0241}$ (= 1.17 × 10^{-5})

if convert to concentrations

$[H^+]$ = 1.35 × 10^{-5} × $\frac{0.418}{0.482}$ (= 1.17 × 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]