M1.(a) Proton donor or H^+ donor

Allow donator

1

(b) (i) B B

Both need to be correct to score the mark

1

(ii) A A

Both need to be correct to score the mark

1

(iii) B A

Both need to be correct to score the mark

1

(c) **M1** $[H^+] = 10^{-1.25}$ OR 0.05623

1

M2 mol HCl = $(25 \times 10^{-3}) \times 0.0850$ $(= 2.125 \times 10^{-3})$

Mark for Working

1

M3 vol $\left(= \frac{2.125 \times 10^{-3}}{0.05623}\right)$ = 0.0378 dm^3 or 37.8 cm^3

allow 0.0375 – 0.038 dm^3 or 37.5 – 38 cm^3

Units and answer tied

Lose M3 if total given as (25 + 37.8) = 62.8 cm^3

Ignore "vol added = 12.8 cm^3 " after correct answer

1

(d) (i) 4.52

Must be 2dp

1

(ii) $K_a = \frac{[H^+][H^-]}{[HX]}$ ignore = $\frac{[H^+]^2}{[HX]}$ but this may score M1 in (d)(iii)

Must have all brackets but allow ( ) Allow HA etc

***NO** mark for 10^{-pKa}*

1

(iii) **M1** $K_a = \frac{[H^+]^2}{[HX]}$ or with numbers

Allow $[H^+] = \sqrt{(Ka \times [HA])}$ for M1

1

M2 $[H^+] = (\sqrt{(3.01 \times 10^{-5} \times 0.174)} = \sqrt{(5.24 \times 10^{-6})})$
$= 2.29 \times 10^{-3}$ - 2.3×10^{-3}

Mark for <u>answer</u>

1

M3 pH = 2.64 (allow more than 2dp but not fewer)

Allow 1 for correct pH from their wrong $[H^+]$

If square root forgotten, pH = 5.28 scores 2 for M1 and M3

1

(e) **M1** mol OH^- = $(10.0 \times 10^{-3}) \times 0.125 = 1.25 \times 10^{-3}$

Mark for answer

1

M2 orig mol HX = $(15.0 \times 10^{-3}) \times 0.174 = 2.61 \times 10^{-3}$

Mark for answer

1

M3 mol HX in buffer = orig mol HX – mol OH^-

Mark for answer

$= 2.61 \times 10^{-3} - 1.25 \times 10^{-3} = 1.36 \times 10^{-3}$

Allow conseq on their (M2 – M1)

([HX] = $1.36 \times 10^{-3}/25 \times 10^{-3} = 0.0544$)

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)

1

M4 mol X^- in buffer = mol OH^- = 1.25×10^{-3}

([X^-] = $1.25 \times 10^{-3}/25 \times 10^{-3} = 0.05$)

May be scored in M5 expression

1

M5 $[H^+]$ $\left(= \frac{Ka \times [HX]}{[X^-]}\right)$

If use K_a = $\frac{[H^+]^2}{[HX]}$ *no further marks*

= $\frac{3.01 \times 10^{-5} \times 1.36 \times 10^{-3}}{1.25 \times 10^{-3}}$ OR $\frac{3.01 \times 10^{-5} \times 0.0544}{0.05}$

(= 3.27×10^{-5})

If either value of HX or X^- used wrongly or expression upside down, no further marks

1

M6 pH = 4.48 or 4.49 (allow more than 2dp but not fewer)

*Do **not** allow M6 for correct calculation of pH using their $[H^+]$ - this only applies in (d)(iii) - apart from earlier AE*

1

[18]

M2.(a) Proton acceptor

1

(b) (i) $CH_3CH_2NH_2 + H_2O \longrightarrow CH_3CH_2NH_3^+ + OH^-$

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 $C_2H_5NH_3OH$

1

(ii) Mark independently of (b)(i)

Allow
Ethylamine is only partly/slightly dissociated
OR
Ethylamine is only partly/slightly ionized

reaction/equilibrium lies to left or low $[OH^-]$ ***OR*** little OH^- formed

OR little ethylamine has reacted
Ignore "not fully dissociated" or "not fully ionized"
Ignore reference to ionisation or dissociation of water

1

(c) **M1** Ethylamine
If wrong no marks in (c)

1

M2 alkyl group is electron releasing/donating

OR alkyl group has (positive) inductive effect

1

M3 increases electron density <u>on N(H_2)</u>

OR increased availability of <u>lp</u>

OR increases ability of <u>lp</u> (to accept H(+))
Mark M3 is independent of M2

1

(d) $CH_3CH_2NH_3Cl$
Or any amine hydrochloride

allow name (ethylammonium chloride or ethylamine hydrochloride) or other halide for Cl
or a strong ***organic*** *acid*
NOT NH_4Cl

1

(e) Mark independently of (d)

Extra H^+ reacts with ethylamine or OH^-

Or makes reference to Equilibrium (in (b)(i)) with amine on LHS

1

OR $CH_3CH_2NH_2 + H^+ \longrightarrow CH_3CH_2NH_3^+$

OR $H^+ + OH^- \longrightarrow H_2O$

Equilibrium shifts to RHS

OR ratio $[CH_3CH_2NH_3^+]/[CH_3CH_2NH_2]$ remains almost constant

1

[9]

M3.(a) $NH_4^+ \rightarrow NH_3 + H^+$

Accept multiples.

Accept $NH_4^+ + H_2O \rightarrow NH_3 + H_3O^+$

Ignore state symbols, even if incorrect.

1

(b) Test indicator / conc HCl

Do not accept 'smell'.

Do not accept precipitation reactions of aqueous ammonia.

1

Observation colour for an alkali / white fumes

If wrong test then lose second mark.

1

[3]

M4.D

[1]

M5.C

[1]

M1.(a) $[H^+] = \frac{K_a \times [CH_3COOH]}{CH_3COO^-}$ or $= 1.74 \times 10^{-5} \times \frac{0.186}{0.105}$

Allow ( )

M1

1

$= 3.08 \times 10^{-5}$

If [HX] / [X^-] or $\frac{0.186}{0.105}$ *upside down, or any addition or subtraction lose M1 & M2.*

M2

1

pH = 4.51 (correct answer scores 3)

Can score M3 for correct pH conseq to their [H^+], so pH = 5.01 scores one

Must be to 2 dp

M3

1

Alternative using Henderson−Hasselbach Equation

$pH = pKa - \log[HX] / X^-] = -\log(1.74 \times 10^{-5}) - \log(\frac{0.186}{0.105})$

Allow ( )

M1

pKa = 4.76 − 0.248

If [HX] / [X^-] or $\frac{0.186}{0.105}$ *upside down, can only score 1*

M2

pH = = 4.51

so pH = 5.01

Must be to 2 dp

M3

(b) mol HX after addition (= 0.251 + 0.015) = 0.266

For HX, if no addition or error in addition (other than AE) (or subsequent extra add or sub) MAX 3

M1

1

mol X^- after subtraction (= 0.140 − 0.015) = 0.125

For X^- if no subtraction or error in subtraction (other than AE) (or subsequent extra add or sub) MAX 3

M2

1

$$[H^+] = \left(\frac{K_a \times [CH_3COOH]}{CH_3COO^-}\right) = \frac{1.74 \times 10^{-5} \times 0.266}{0.125}$$

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

M3

1

$[H^+] = 3.703 \times 10^{-}5$ (mol dm^{-3})

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.

M4

1

pH = 4.43

Correct use of HX and X^- values from (d) gives
pH= 4.41 and scores 4

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.

M5

1

Alternative using Henderson−Hasselbach Equation

mol acid after addition = 0.251 + 0.015 = 0.266

For HX, if no addition or error in addition (other than AE) (or subsequent extra add or sub) MAX 3

M1

mol salt after addition = 0.140 − 0.015 = 0.125

For X^- if no subtraction or error in subtraction (other than AE) (or subsequent extra add or sub) MAX 3

M2

pH = (pKa − log[HX] / [X^-]) = −log(1.74 × 10^{-5}) − log(0.266 / 0.125)

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

M3

pH = 4.76 − 0.328

M4

pH = = 4.43

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.

M5

[8]

M2.(a) $HCO_3^- \rightleftharpoons CO_3^{2-} + H^+$

or

$H_2O + HCO_3^- \rightleftharpoons CO_3^{2-} + H_3O^+$

Must have equilibrium sign but mark on to (b)

Ignore state symbols

1

(b) Acid: Increase in concentration of H^+ ions, equilibrium moves to the left.

Allow H^+ ions react with carbonate ions (to form HCO_3^-)

1

Alkali: OH^- reacts with H^+ ions, equilibrium moves to the right (to replace the H^+ ions)

1

Concentration of H^+ remains (almost) constant

1

[4]

M3.(a) **Z**

Mark independently.

1

The idea that the solution contains both HA and A^-

1

(b) pH

1

[HA] = $[A^-]$

Accept solution half neutralised.

1

pH = pK_a

Accept $[H^+] = K_a$

1

[5]

M4.(a) (only) slightly or partially dissociated / ionised

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.

1

(b) $2CH_3CH_2COOH + Na_2CO_3 \longrightarrow 2CH_3CH_2COONa + H_2O + CO_2$

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

$CH_3CH_2COOH + CO_3^{2-} \longrightarrow CH_3CH_2COO^- + HCO_3^-$

Must be propanoic acid, allow C_2H_5COOH.
Not molecular formulae.
Allow multiples.
Ignore reversible sign.
Not H_2CO_3.

1

(c) $[OH^-] = 2 \times 0.0120 = 0.0240$ M1

Correct answer for pH with or without working scores 3.

1

$[H^+] = \frac{1 \times 10^{-14}}{0.0240} = 4.166 \times 10^{-13}$ ***OR*** pOH = 1.62 M2

If × 2 missed or used wrongly can only score M3 for correct calculation of pH from their $[H^+]$.

1

pH = 12.38 M3

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.

1

(d) (i) $K_a = \frac{[H^+][C_6H_5COO^-]}{[C_6H_5COOH]}$

Ignore ( ) here but brackets must be present.
Must be correct acid and salt.
If wrong, mark part (ii) independently.

1

(ii) M1 $K^a = \frac{[H^+]^2}{[C_6H_5COOH]}$ **OR** with numbers

Correct answer for pH with or without working scores 3.
Allow HX, HA and ignore ( ) here.
May score M1 in part (i).

1

M2 $[H^+] = \sqrt{(6.31 \times 10^{-5} \times 0.0120)}$ or $\sqrt{(K_a \times [C_6H_5COOH])}$
$(= \sqrt{(7.572 \times 10^{-7} = 8.70 \times 10^{-4})}$

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 $K^a = \dfrac{[H^+]}{[C_6H_5COOH]}$

used which also leads to 6.12, then zero scored.

1

M3 pH = 3.06

Must be 2 decimal places ie 3.1 loses M3.

1

(iii) M1 $[H^+] = 10^{-4.00} = 1.00 \times 10^{-4}$

Correct answer for mass with or without working scores 5.
Allow 1×10^{-4}.

1

M2 $[X^-] = \dfrac{Ka \times [HX]}{[H^+]}$

Ignore ( ) here.
If [HX] / [X⁻] upside down, can score M1 plus M4 for 5.26×10^{-7}.

1

M3 $= \dfrac{6.31 \times 10^{-5} \times 0.0120}{1.00 \times 10^{-4}}$

And M5 for 7.57×10^{-5} *g.*

1

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

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).

1

(e) M1 CO_2

Allow NO_x and SO_2.

1

M2 pH (It) falls / decreases

If M1 wrong, no further marks.

1

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 $CO_2 + OH^- \longrightarrow HCO_3^-$

Not forms H_2CO_3 H_2SO_3 H_2SO_4 etc OR H^+ ions.

1

[17]

M5.(a) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

All stages are covered and the explanation of each stage is generally correct and virtually complete.

Answer is communicated coherently and shows a logical progression from stage 1 and stage 2 to stage 3. Steps in stage 3 must be complete, ordered and include a comparison.

Level 3
5 – 6 marks

All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete.

Answer is mainly coherent and shows a progression from stage 1 and stage 2 to stage 3.

Level 2
3 – 4 marks

Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, OR only one stage is covered but the explanation is generally correct and virtually complete.

Answer includes some isolated statements, but these are not presented in a logical order or show confused reasoning.

Level 1
1 – 2 marks

Insufficient correct Chemistry to warrant a mark.

Level 0
0 marks

Indicative Chemistry content

Stage 1: difference in structure of the two acids
- The acids are of the form RCOOH
- but in ethanoic acid R = CH_3
- whilst in ethanedioic acid R = COOH

Stage 2: the inductive effect
- The unionised COOH group contains two very electronegative oxygen atoms
- therefore has a negative inductive (electron withdrawing)effect
- The CH_3 group has a positive inductive (electron pushing) effect

Stage 3: how the polarity of OH affects acid strength
- The O–H bond in the ethanedioic acid is more polarised / H becomes more δ^+
- More dissociation into H^+ ions
- Ethanedioic acid is stronger than ethanoic acid

6

(b) Moles of NaOH = Moles of $HOOCCOO^-$ formed = 6.00×10^{-2}

Extended response

1

Moles of HOOCCOOH remaining = $1.00 \times 10^{-1} - 6.00 \times 10^{-2}$

$= 4.00 \times 10^{-2}$

1

$K_a = [H^+][A^-] / [HA]$

$[H^+] = K_a \times [HA] / [A^-]$

1

$[H^+] = 5.89 \times 10^{-2} \times (4.00 \times 10^{-2} / V) / (6.00 \times 10^{-2} / V) = 3.927 \times 10^{-2}$

1

$pH = -\log_{10}(3.927 \times 10^{-2}) = 1.406 = 1.41$

Answer must be given to this precision

1

(c) $5H_2C_2O_4 + 6H^+ + 2MnO_4^- \longrightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$

OR $5C_2O_4^{2-} + 16H^+ + 2MnO_4^- \longrightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$

1

Moles of $KMnO_4 = 20.2 \times 2.00 \times 10^{-2} / 1000 = 4.04 \times 10^{-4}$

1

Moles of $H_2C_2O_4 = 5 / 2 \times 4.04 \times 10^{-4} = 1.01 \times 10^{-3}$

1

Concentration = moles / volume (in dm^3)

$= 1.01 \times 10^{-3} \times 1000 / 25 = 4.04 \times 10^{-2}$ (mol dm^{-3})

If 1:1 ratio or incorrect ratio used, M2 and M4 can be scored

1

[15]

M1.(a) $[H_2O]$ is very high (compared with $[H^+]$ and $[OH^-]$)

OR

Very few H^+ and OH^- ions

OR

Only / very slightly dissociates

OR

Equilibrium lies far to the left

Not partially dissociates

M1

1

$[H_2O]$ is (effectively) constant
OR is incorporated into the constant K

Allow changes by only a very small amount

M2

1

(b) (Dissociation OR breaking bonds) is endothermic

1

∴ Equilibrium moves to RHS (at higher T) to absorb heat or to lower T or oppose increase in T

Allow to oppose change only if increase T mentioned

1

(c) $[H^+] = \sqrt{K_w}$ (or $= \sqrt{5.48 \times 10^{-14}}$)

Correct pH answer scores 3

1

If wrong method no marks

Using alternative K_w (1.00×10^{-14}) gives pH = 7.00 which scores 1

$= 2.34 \times 10^{-7}$

1

pH = 6.63

Final answer must have 2dp

1

(d) $[H^+]$ = K_w / $[OH^-]$ or (= 5.48×10^{-14} / 0.12)

Correct pH answer scores 3

1

If wrong method no marks

If use alternative K_w (1.00×10^{-14}) again, do not penalise repeat error so pH = 13.08 scores 3

= 4.566×10^{-13}

1

pH = 12.34

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 (c) allow more than 2dp here but not fewer.

1

[10]

M2.(a) Burette

1

Because it can deliver variable volumes

1

(b) The change in pH is gradual / not rapid at the end point

1

An indicator would change colour over a range of volumes of sodium hydroxide

Allow indicator would not change colour rapidly / with a few drops of NaOH

1

(c) $[H^+] = 10^{-pH} = 1.58 \times 10^{-12}$

1

$K_w = [H^+]\,[OH^-]$ therefore $[OH^-] = K_w / [H^+]$

1

Therefore, $[OH^-] = 1 \times 10^{-14} / 1.58 \times 10^{-12} = 6.33 \times 10^{-3}$ (mol dm^{-3})

Allow 6.31–6.33 × 10^{-3} (mol dm^{-3})

1

(d) At this point, $[NH_3] = [H^+]$

$$= \frac{[H^+]^2}{[NH_4^+]}$$

Therefore K_a

1

$[H^+] = 10^{-4.6} = 2.51 \times 10^{-5}$

1

$K_a = (2.51 \times 10^{-5})^2 / 2 = 3.15 \times 10^{-10}$ (mol dm^{-3})

Allow 3.15 – 3.16 × 10^{-10} (mol dm^{-3})

1

(e) When $[NH_3] = [NH_4^+]$, $K_a = [H^+]$ therefore $-\log K_a = -\log [H^+]$

Answer using alternative value

1

Therefore pH = $-\log_{10}(3.15 \times 10^{-10}) = 9.50$

M2 pH = $-\log_{10}(4.75 \times 10^{-9}) = 8.32$

Allow consequential marking based on answer from part (d)

1

[12]

M3.(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^+ $(= (25.0 \times 10^{-3}) \times 0.620)$

$= 1.55 \times 10^{-2}$ or 0.0155

Mark for answer

1

M3 excess mol OH^- = 5.5(1) × 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 × 10^{-13}

OR $\frac{10^{-14}}{0.0870}$ = 1.149 × 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]

M4.B

[1]

M5.(a) (only) slightly or partially dissociated / ionised

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.

1

(b) $2CH_3CH_2COOH + Na_2CO_3 \longrightarrow 2CH_3CH_2COONa + H_2O + CO_2$

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

$CH_3CH_2COOH + CO_3^{2-} \longrightarrow CH_3CH_2COO^- + HCO_3^-$

Must be propanoic acid, allow C_2H_5COOH.
Not molecular formulae.
Allow multiples.
Ignore reversible sign.
Not H_2CO_3.

1

(c) $[OH^-] = 2 \times 0.0120 = 0.0240$ M1

Correct answer for pH with or without working scores 3.

1

$[H^+] = \frac{1 \times 10^{-14}}{0.0240} = 4.166 \times 10^{-13}$ ***OR*** pOH = 1.62 M2

If × 2 missed or used wrongly can only score M3 for correct calculation of pH from their $[H^+]$.

1

pH = 12.38 M3

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.

1

(d) (i) $K_a = \dfrac{[H^+][C_6H_5COO^-]}{[C_6H_5COOH]}$

Ignore ( ) here but brackets must be present.
Must be correct acid and salt.
If wrong, mark part (ii) independently.

1

(ii) M1 $K^a = \dfrac{[H^+]^2}{[C_6H_5COOH]}$ **OR** with numbers

Correct answer for pH with or without working scores 3.
Allow HX, HA and ignore ( ) here.
May score M1 in part (i).

1

M2 $[H^+] = \sqrt{(6.31 \times 10^{-5} \times 0.0120)}$ or $\sqrt{(K_a \times [C_6H_5COOH])}$
$(= \sqrt{(7.572 \times 10^{-7} = 8.70 \times 10^{-4})}$

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 $K^a = \dfrac{[H^+]}{[C_6H_5COOH]}$

used which also leads to 6.12, then zero scored.

1

M3 pH = 3.06

Must be 2 decimal places ie 3.1 loses M3.

1

(iii) M1 $[H^+] = 10^{-4.00} = 1.00 \times 10^{-4}$

Correct answer for mass with or without working scores 5.
Allow 1×10^{-4}.

1

M2 $[X^-] = \frac{Ka \times [HX]}{[H^+]}$

Ignore ( ) here.
If [HX] / $[X^-]$ upside down, can score M1 plus M4 for 5.26×10^{-7}.

1

M3 $= \frac{6.31 \times 10^{-5} \times 0.0120}{1.00 \times 10^{-4}}$

And M5 for 7.57×10^{-5} g.

1

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

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).

1

(e) M1 CO_2

Allow NO_x and SO_2.

1

M2 pH (It) falls / decreases

If M1 wrong, no further marks.

1

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 $CO_2 + OH^- \longrightarrow HCO_3^-$

Not forms H_2CO_3 H_2SO_3 H_2SO_4 etc OR H^+ ions.

1

[17]

M1.B

[1]

M2.C

[1]

M3.C

[1]

M4.C

[1]

M5.C

[1]

M6.D

[1]

M7.A

[1]

M8.A

[1]

M9.C

[1]

M10.C

[1]

M11.C

[1]

M12.D

[1]

M13.D

[1]

M14.B

[1]

M15.B

[1]

M16.D

[1]

M17.B

[1]

M1.(a) (i) G

1

(ii) F

1

(iii) H

1

(b) (i) cresol purple

1

(ii) yellow to red

both colours needed and must be in this order

1

(iii) yellow or pale yellow

Not allow any other colour with yellow

1

[6]

M2.(a) C

1

A

1

D

1

(b) (i) Bromocresol green

Allow wrong spellings

1

(ii) Purple to yellow

Must have both colours:

Purple start – yellow finish

1

[5]

M3.(a) **Z**

Mark independently.

1

The idea that the solution contains both HA and A^-

1

(b) pH

1

[HA] = $[A^-]$

Accept solution half neutralised.

1

pH = pK_a

Accept $[H^+] = K_a$

1

[5]

M4.(a) Over time / after storage meter does not give accurate readings

Do not allow 'to get an accurate reading' or 'reading drifts' on its own.

Allow 'temperature variations affect readings'.

1

(b) Any **five** from:

Ignore references to the use of the pipette, the filling of the burette and the calibration of the pH meter.

- Measure pH (of the acid)
- Add alkali in known small portions

  Allow 1 – 2cm^3.
- Stir mixture
- Measure pH (after each addition)
- Repeat until alkali in excess

  Allow 27 – 50cm^3.
- Add in smaller increments near endpoint

  Allow 0.1 – 0.5cm^3.

To score full marks, the sequence must follow a logical order.

5 max

[6]

M5.(a) Burette

1

Because it can deliver variable volumes

1

(b) The change in pH is gradual / not rapid at the end point

1

An indicator would change colour over a range of volumes of sodium hydroxide

Allow indicator would not change colour rapidly / with a few drops of NaOH

1

(c) $[H^+] = 10^{-pH} = 1.58 \times 10^{-12}$

1

$K_w = [H^+]\,[OH^-]$ therefore $[OH^-] = K_w / [H^+]$

1

Therefore, $[OH^-] = 1 \times 10^{-14} / 1.58 \times 10^{-12} = 6.33 \times 10^{-3}$ (mol dm^{-3})

Allow 6.31–6.33 × 10^{-3} (mol dm^{-3})

1

(d) At this point, $[NH_3] = [H^+]$

Therefore $K_a = \dfrac{[H^+]^2}{[NH_4^+]}$

1

$[H^+] = 10^{-4.6} = 2.51 \times 10^{-5}$

1

$K_a = (2.51 \times 10^{-5})^2 / 2 = 3.15 \times 10^{-10}$ (mol dm^{-3})

Allow 3.15 – 3.16 × 10^{-10} (mol dm^{-3})

1

(e) When $[NH_3] = [NH_4^+]$, $K_a = [H^+]$ therefore $-\log K_a = -\log [H^+]$

Answer using alternative value

1

Therefore pH = $-\log_{10}(3.15 \times 10^{-10}) = 9.50$

M2 pH = $-\log_{10}(4.75 \times 10^{-9}) = 8.32$

Allow consequential marking based on answer from part (d)

1

[12]

M6.(a) Correct orientation of graph (pH on y-axis)

1

Scale – plotted points cover at least half the grid and y-axis should start at pH 4

1

All points plotted correctly

+ / – one small square.

1

Curve of best fit drawn correctly

Allow some leniency here with a complex graph – it is important that the section between pH 8.5 and 9.7 is close to linear.

Lose this mark if the line is pulled towards the anomaly at 3.0

cm^3.

Lose this mark if first point at pH 5.1 is treated as an anomaly.

Do not accept doubled lines but allow some slight discontinuity where the curve changes direction.

1

(b) 11.6-11.9 (cm^3) only

Do not mark consequentially to student's graph.

1

(c) pK_a = value of pH related to part (b) **M1**

Mark consequentially on student's graph – ideally 9.0-9.1

Do not penalise precision of answer.

1

$K_a = 10^{-pKa}$ **M2**

Ideally 1.0×10^{-9} to 7.9×10^{-10}

*Ignore precision of answer but lose **M2** for 1 significant figure here.*

1

(d) pH 8.7

Ineffective stirring / swirling of the mixture

Both points needed for this mark.

Do not allow pH 5.1

Do not allow 'overshooting (at 3 cm^3 addition)'.

1

(e) Take more pH readings around the end-point / add smaller volumes of NaOH near the end-point

Do not allow 'use a more accurate / reliable pH meter / probe'.

Do not allow the use of a thermostatted mixture.

1

[9]

M7.(a) As a droplet from the funnel could enter the burette / affect volume / readings / titre

1

(b) Air bubble in jet or wtte

Do not allow misreading burette or overshooting end point.

1

(c) Ensures **all** reagents are able to react / mix / come into contact

Accept no reagent is left unreacted on sides of flask

Do not allow any reference to 'removal' of the solution unless it is clear that it is added to the flask.

1

(d) The added water does not affect the mols / amount of reagents / reactants / solution Z

Do not allow mols of solution or mols in the flask.

Allow water does not react with the reagents / water is not one of the reactants

Do not allow 'water is not involved'

1

[4]

M1.(a) $[H_2O]$ is very high (compared with $[H^+]$ and $[OH^-]$)

OR

Very few H^+ and OH^- ions

OR

Only / very slightly dissociates

OR

Equilibrium lies far to the left

Not partially dissociates

M1

1

$[H_2O]$ is (effectively) constant
OR is incorporated into the constant K

Allow changes by only a very small amount

M2

1

(b) (Dissociation OR breaking bonds) is endothermic

1

∴ Equilibrium moves to RHS (at higher T) to absorb heat or to lower T or oppose increase in T

Allow to oppose change only if increase T mentioned

1

(c) $[H^+] = \sqrt{K_w}$ (or $= \sqrt{5.48 \times 10^{-14}}$)

Correct pH answer scores 3

1

If wrong method no marks

Using alternative K_w (1.00×10^{-14}) gives pH = 7.00 which scores 1

$= 2.34 \times 10^{-7}$

1

pH = 6.63

Final answer must have 2dp

1

(d) $[H^+]$ = K_w / $[OH^-]$ or (= 5.48×10^{-14} / 0.12)

Correct pH answer scores 3

1

If wrong method no marks

If use alternative K_w (1.00×10^{-14}) again, do not penalise repeat error so pH = 13.08 scores 3

= 4.566×10^{-13}

1

pH = 12.34

*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 (c) allow more than 2dp here but not fewer.

1

[10]

M2.(a) (only) slightly or partially dissociated / ionised

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.

1

(b) $2CH_3CH_2COOH + Na_2CO_3 \longrightarrow 2CH_3CH_2COONa + H_2O + CO_2$

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

$CH_3CH_2COOH + CO_3^{2-} \longrightarrow CH_3CH_2COO^- + HCO_3^-$

Must be propanoic acid, allow C_2H_5COOH.

Not molecular formulae.

Allow multiples.

Ignore reversible sign.

Not H_2CO_3.

1

(c) $[OH^-] = 2 \times 0.0120 = 0.0240$ M1

Correct answer for pH with or without working scores 3.

1

$[H^+] = \frac{1 \times 10^{-14}}{0.0240} = 4.166 \times 10^{-13}$ ***OR*** pOH = 1.62 M2

If × 2 missed or used wrongly can only score M3 for correct calculation of pH from their $[H^+]$.

1

pH = 12.38 M3

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.

1

(d) (i) $K_a = \frac{[H^+][C_6H_5COO^-]}{[C_6H_5COOH]}$

Ignore ( ) here but brackets must be present.
Must be correct acid and salt.
If wrong, mark part (ii) independently.

1

(ii) M1 $K^a = \frac{[H^+]^2}{[C_6H_5COOH]}$ **OR** with numbers

Correct answer for pH with or without working scores 3.
Allow HX, HA and ignore ( ) here.
May score M1 in part (i).

1

M2 $[H^+] = \sqrt{(6.31 \times 10^{-5} \times 0.0120)}$ or $\sqrt{(K_a \times [C_6H_5COOH])}$
$(= \sqrt{(7.572 \times 10^{-7} = 8.70 \times 10^{x4})}$

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 which also leads to 6.12, then zero scored.

1

M3 pH = 3.<u>06</u>

Must be 2 decimal places ie 3.1 loses M3.

1

(iii) M1 $[H^+] = 10^{-4.00} = 1.00 \times 10^{-4}$

Correct answer for mass with or without working scores 5.
Allow 1×10^{-4}.

1

M2 $[X^-] = \frac{Ka \times [HX]}{[H^+]}$

Ignore ( ) here.
If [HX] / [X⁻] upside down, can score M1 plus M4 for 5.26×10^{-7}.

1

M3 $= \frac{6.31 \times 10^{-5} \times 0.0120}{1.00 \times 10^{-4}}$

And M5 for 7.57×10^{-5} *g.*

1

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

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).

1

(e) M1 CO_2

Allow NO_x and SO_2.

1

M2 pH (lt) falls / decreases

If M1 wrong, no further marks.

1

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 $CO_2 + OH^- \longrightarrow HCO_3^-$

Not forms H_2CO_3 H_2SO_3 H_2SO_4 etc OR H^+ ions.

1

[17]

M3.(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^+ $(= (25.0 \times 10^{-3}) \times 0.620)$

$= 1.55 \times 10^{-2}$ 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]

M4. (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) $K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]}$

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

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

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

or with numbers

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*

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]

M1.(a) $HCO_3^- \rightleftharpoons CO_3^{2-} + H^+$

or

$H_2O + HCO_3^- \rightleftharpoons CO_3^{2-} + H_3O^+$

Must have equilibrium sign but mark on to (b)

Ignore state symbols

1

(b) Acid: Increase in concentration of H^+ ions, equilibrium moves to the left.

Allow H^+ ions react with carbonate ions (to form HCO_3^-)

1

Alkali: OH^- reacts with H^+ ions, equilibrium moves to the right (to replace the H^+ ions)

1

Concentration of H^+ remains (almost) constant

1

[4]

M2.(a) Burette

1

Because it can deliver variable volumes

1

(b) The change in pH is gradual / not rapid at the end point

1

An indicator would change colour over a range of volumes of sodium hydroxide

Allow indicator would not change colour rapidly / with a few drops of NaOH

1

(c) $[H^+] = 10^{-pH} = 1.58 \times 10^{-12}$

1

$K_w = [H^+]\,[OH^-]$ therefore $[OH^-] = K_w / [H^+]$

1

Therefore, $[OH^-] = 1 \times 10^{-14} / 1.58 \times 10^{-12} = 6.33 \times 10^{-3}$ (mol dm^{-3})

Allow 6.31–6.33 × 10^{-3} (mol dm^{-3})

1

(d) At this point, $[NH_3] = [H^+]$

Therefore $K_a = \dfrac{[H^+]^2}{[NH_4^+]}$

1

$[H^+] = 10^{-4.6} = 2.51 \times 10^{-5}$

1

$K_a = (2.51 \times 10^{-5})^2 / 2 = 3.15 \times 10^{-10}$ (mol dm^{-3})

Allow 3.15 – 3.16 × 10^{-10} (mol dm^{-3})

1

(e) When $[NH_3] = [NH_4^+]$, $K_a = [H^+]$ therefore $-\log K_a = -\log [H^+]$

Answer using alternative value

1

Therefore $pH = -\log_{10}(3.15 \times 10^{-10}) = 9.50$

M2 $pH = -\log_{10}(4.75 \times 10^{-9}) = 8.32$

Allow consequential marking based on answer from part (d)

1

[12]

M3.(a) Proton donor or H^+ donor

1

(b) (i) $K_a = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]}$ or $\frac{[CH_3COO^-][H_3O^+]}{[CH_3COOH]}$

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).

1

(ii) M1 $[H^+] = 10^{-2.69}$ ***OR*** 2.042×10^{-3} (mol dm^{-3})

1

M2 $CH_3COOH] = \frac{[H^+]^2}{K_a}$

Ignore ( )
Mark for correctly rearranged expression incl $[H^+]^2$

1

M3

$= \frac{(2.042 \times 10^{-3})^2}{1.75 \times 10^{-5}}$

If M2 wrong no further marks.

1

M4 = 0.238 (mol dm^{-3}) Allow 0.229 − 0.24

1

(c) (i) $ClCH_2COOH \rightleftharpoons ClCH_2COO^- + H^+$
OR $ClCH_2COOH + H_2O \rightleftharpoons ClCH_2COO^- + H_3O^+$

Allow $\longrightarrow$
Allow $ClCH_2CO_2H$ and $ClCH_2CO_2^-$

1

(ii) M1 Cl is (more electronegative so) withdraws electrons
OR negative inductive effect of Cl

Ignore electronegativity.
Ignore chloroethanoic acid has a lower K_a value.

Allow Cl reduces +ve inductive effect of methyl group.

1

M2 Weakens O–H bond
OR O–H bond is more polar
OR reduces negative charge on COO^-
OR stabilizes COO^- (more)
M1 & M2 are independent marks.
Ignore H^+ lost more easily.

1

(d) (i) **A**

1

(ii) **C**

1

(iii) **D**

1

(e) M1 Mol NaOH = mol OH^- = $(19.6 \times 10^{-3}) \times 0.720 = 1.41(1) \times 10^{-2}$
Mark for answer.

1

M2 Mol H_2SO_4 = $(26.4 \times 10^{-3}) \times 0.550 = 1.45(2) \times 10^{-2}$
Mark for answer.

1

M3 Mol H^+ added = **2 ×** $(1.452 \times 10^{-2}) = 2.90(4) \times 10^{-2}$
OR
XS mol H_2SO_4 = $7.46(4) \times 10^{-3}$
If factor × 2 missed completely (pH = 2.05)
or used wrongly later,
can score max 4 for M1, M2, M5 & M6

1

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}

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

1

M6 pH = 0.49

***2dp** (penalise more or less).*
If × 2 missed & vol not used, pH = 3.39 scores M1 & M2 only.

1

[18]

M4.(a) (only) slightly or partially dissociated / ionised

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.

1

(b) $2CH_3CH_2COOH + Na_2CO_3 \longrightarrow 2CH_3CH_2COONa + H_2O + CO_2$

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

$CH_3CH_2COOH + CO_3^{2-} \longrightarrow CH_3CH_2COO^- + HCO_3^-$

Must be propanoic acid, allow C_2H_5COOH.
Not molecular formulae.
Allow multiples.
Ignore reversible sign.
Not H_2CO_3.

1

(c) $[OH^-] = 2 \times 0.0120 = 0.0240$ M1

Correct answer for pH with or without working scores 3.

1

$[H^+] = \frac{1 \times 10^{-14}}{0.0240} = 4.166 \times 10^{-13}$ ***OR*** pOH = 1.62 M2

If × 2 missed or used wrongly can only score M3 for correct calculation of pH from their $[H^+]$.

1

pH = 12.38 M3

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.

1

(d) (i) $K_a = \frac{[H^+][C_6H_5COO^-]}{[C_6H_5COOH]}$

Ignore ( ) here but brackets must be present.
Must be correct acid and salt.
If wrong, mark part (ii) independently.

1

(ii) M1 $K^a = \frac{[H^+]^2}{[C_6H_5COOH]}$ **OR** with numbers

Correct answer for pH with or without working scores 3.
Allow HX, HA and ignore ( ) here.
May score M1 in part (i).

1

M2 $[H^+] = \sqrt{(6.31 \times 10^{-5} \times 0.0120)}$ or $\sqrt{(K_a \times [C_6H_5COOH])}$
$(= \sqrt{(7.572 \times 10^{-7} = 8.70 \times 10^{x4})}$

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 which also leads to 6.12, then zero scored.

1

M3 pH = 3.<u>06</u>

Must be 2 decimal places ie 3.1 loses M3.

1

(iii) M1 $[H^+] = 10^{-4.00} = 1.00 \times 10^{-4}$

Correct answer for mass with or without working scores 5.
Allow 1×10^{-4}.

1

M2 $[X^-] = \frac{Ka \times [HX]}{[H^+]}$

Ignore ( ) here.
If [HX] / [X⁻] upside down, can score M1 plus M4 for 5.26×10^{-7}.

1

M3 $= \frac{6.31 \times 10^{-5} \times 0.0120}{1.00 \times 10^{-4}}$

And M5 for 7.57×10^{-5} *g.*

1

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

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).

1

(e) M1 CO_2

Allow NO_x and SO_2.

1

M2 pH (It) falls / decreases

If M1 wrong, no further marks.

1

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 $CO_2 + OH^- \longrightarrow HCO_3^-$

Not forms H_2CO_3 H_2SO_3 H_2SO_4 etc OR H^+ ions.

1

[17]

M5.C

[1]