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 $K_a = \frac{[H^+]^2}{[NH_4^+]}$ **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.<u>38</u> 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 $\sqrt{(K_a \times [C_6H_5COOH])}$
$(= \sqrt{(7.572 \times 10^{-7}} = 8.70 \times 10^{\times 4})$

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 $K_a = \frac{[H^+]}{[C_6H_5COOH]}$

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 <u>pH</u> <u>(It)</u> <u>falls / decreases</u>

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]