M1. (a) Hydrogen bonding **(1)**
between H_2O and NH_3 **(1)** **2**

(b) (i) $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$ **(1)**

(ii) Ammonia is weak base **(1)**
NOT partially ionised

Equilibrium to left or incomplete reaction **(1)** **3**

(c) A proton donor **(1)** **1**

(d) *Buffer solution*: A solution which resists change in pH **(1)**
when small amounts of acid or base added or on dilution **(1)**

Reagent: NH_4Cl **(1)**
Allow a correct strong acid **3**

(e) (i) $K_a = [H^+] [A^-] / [HA]$ **(1)**
$= [H^+] [0.125 \times 4]$ **(1)** $/ 1.00$
$[H^+] = 1.70 \times 10^{-5} / 0.125 \times 4 = 3.40 \times 10^{-5}$ **(1)**

pH = $-\log_{10} [H^+] = 4.47$ **(1)**
Allow pH conseq to [H+] if 2 place decimals given

(ii) $H^+ + CH_3COO^- \rightarrow CH_3COOH$ **(1)** **5**

[14]

M2. (a) moles HA = $\frac{25}{10^3} \times 0.150 = 3.75 \times 10^{-3}$ **(1)**

$\therefore$ vol NaOH = $\frac{3.75 \times 10^{-3}}{0.20} = 1.875 \times 10^{-2}$ dm^3 **(1)**

or 18.75 cm^3

2

(b) (i) pH = $-\log_{10} [H^+]$ **(1)**

(ii) Value above 7 but below 11 **(1)**

(iii) phenol red / thymol blue / phenolphthalein / thymolphthalein

i.e. indicator with $7 < pK_{in} < 11$

3

(c) (i) Only slightly dissociated/ionised **(1)**

NOT "not fully dissociated / ionised"

(ii) $K_a = \frac{[H^+][A^-]}{[HA]}$ **(1)**

NOT $\frac{[H^+]^2}{[HA]}$

(iii) For weak acid alone:

$Ka = \frac{[H^+]^2}{[HA]}$ **(1)**

$\therefore [H^+] = \sqrt{(2.75 \times 10^{-5}) \times 0.15}$

$= 2.03 \times 10^{-3}$ (1)

$\therefore$ pH = 2.69 (1)

pH should be given to 2 decimal places
penalise answer to 1 d.p. once in question

5

(d) moles OH^- added = 1.875×10^{-3} = moles A^- = moles HA left **(1)**

or $[A^-] = [HA]$

∴ $Ka = [H^+]$ **or** $pH = pK_a$ **(1)**

∴ pH = 4.5<u>6</u> (1)

3

[13]

M3. (a) before any KOH added: $K_a = \frac{[H^+][A^-]}{[HA]}$ **or** $\frac{[H^+][CH_3COO^-]}{[CH_3COOH]}$ **(1)**

∴ $K_a = \frac{[H^+]^2}{[CH_3COOH]}$ **(1)**

∴ $[H^+] = \sqrt{1.74 \times 10^{-5} \times 0.160} = 1.67 \times 10^{-3}$ **(1)**

∴ pH = 2.78 **(1)**

4

(b) at 8 cm^3 KOH:
Moles KOH added = $(8 \times 10^{-3}) \times 0.210 = 1.68 \times 10^{-3}$ **(1)**
∴ moles of CH_3COO^- formed = 1.68×10^{-3} **(1)**

Original moles of $CH_3COOH = (25 \times 10^{-3}) \times 0.160 = 4.0 \times 10^{-3}$ **(1)**

∴ moles of CH_3COOH left = $(4.0 \times 10^{-3}) - (1.68 \times 10^{-3})$
$= 2.32 \times 10^{-3}$ **(1)**

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

$= 1.74 \times 10^{-5} \times \frac{2.32 \times 10^{-3} / V}{1.68 \times 10^{-3} / V} = 2.40 \times 10^{-5}$ **(1)**

∴ <u>pH = 4.62</u> **(1)**

It forget subtraction : max 5
If K_a expression not used max 5
if moles of CH_3COOH wrong but substitution used max 5

7

(c) at 40 cm^3 of KOH:

Total moles of KOH = $(40 \times 10^{-3}) \times 0.21 = 8.4 \times 10^{-3}$ **(1)**

$\therefore$ excess moles of KOH = $(8.4 \times 10^{-3}) - (4.0 \times 10^{-3})$

$= 4.4 \times 10^{-3}$ **(1)**

in total volume = 40 + 25 = 65 cm^3 **(1)**

$\therefore [OH^-] = 4.4 \times 10^{-3} \times \frac{1000}{65} = 0.0677$ **(1)**

$\therefore [H^+] = \frac{10^{-14}}{0.0677}$

OR pOH =1.17

$= 1.477 \times 10^{-13}$ **(1)**

$\therefore$ pH = 12.8<u>3</u> **(1)**

If volume missed : max 4

If moles of acid wrong but method includes subtraction : max 5

If no subtraction : max 4

6

[Max 16]

M4. (a) (i) $K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]}$ **(1)** ($[H^+]$ or H_3O^+)

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

(2) $[H^+] = \sqrt{1.74 \times 10^{-5} \times 0.220} = 1.96 \times 10^{-3}$ **(1)**

(3) pH = $-\log_{10}[H^+]$ **(1)**

can score independently

(4) pH = 2.<u>71</u> **(1)**

2 d.p. essential

If forget √ can score (1) and (3) for pH = 5.42

5

(b) (i) moles acid = $\frac{25}{1000} \times 0220$ **(1)** = 5.50 ×10^{-3}

$= \frac{x}{10^3} \times 0.150$

$\therefore x = 25 \times \frac{0.220}{0.150}$ **or** 5.50 × 10^{-3} × $\frac{1000}{0.150}$

= 36.7 (or 37) cm^3 (or 36.6) **(1)**

NOT 36 NOR 37.0 units must match

(ii) *Indicator*: thymol blue **(1)**

Explanation: weak acid – strong base **(1)**

equivalent at pH > 7 **(1)**

or high pH

5

(c) (1) mol NaOH added = $\frac{2.0}{40.0}$ = 0.050 **(1)**

If wrong M_r: CE $\therefore$ lose marks (1) and (2) then mark on consequentially → max 4

(2) mol CH_3COOH left = 0.220 – 0.050 = 0.170 **(1)**

(3) mol CH_3COO^- formed = 0.050 **(1)**

(4) $[H^+] = Ka \frac{[acid]}{[salt]}$ OR $pH = pKa + \log\frac{[A^-]}{[HA]}$ etc **(1)**

If expression wrong no marks for 4 / 5 / 6

can score (1) to (4) in (5)

(5) $[H^+] = 1.74 \times 10^{-5} \times \frac{(0.170)}{(0.05)}$ OR $pH = 4.76 + \log\left(\frac{0.05}{0.17}\right)$ **(1)**

(6) pH = 4.23 **(1)**

Correct answer gets ***(1)(1)(1)(1)(1)(1)***
Mark (5) is for use of correct values of (acid moles) and (salt moles)
if one wrong allow pH conseq
if both wrong, no further marks
e.g. if candidate forgets substitution in (2)
he loses (2) and (5) but can score (1) (3) (4) (6) = max 4

for pH = 4.12 if $\frac{[acid]}{[salt]}$ *upside down; answer 5.29 scores 3 for (1) (2) (3)*

6

[16]