M1. (a) $pH = -\log[H^+]$

$K_a = \frac{[H^+]^2}{[CH_3COOH]}$ or $[H^+]=[A^-]$ **1**

$[H^+] = \sqrt{1.74 \times 10^{-5} \times 0.15}$ (or 1.62×10^{-3}) **1**

pH = 2.79 (penalise 1 dp or more than 2dp once in the qu) **1**

(b) (i) Solution which resists change in pH /maintains pH **1**

despite the addition of (small amounts of) acid/base (or dilution) **1**

(ii) $CH_3COO + H^+ \rightarrow CH_3COOH$

must show an equation full or ionic in which ethanoate ions are converted to ethanoic acid **1**

(c) (i) $[H^+] = \frac{K_a[CH_3COOH]}{[CH_3COO^-]}$ if rearrangement incorrect, no further marks **1**

$= 1.74 \times 10^{-5} \times \frac{0.15}{0.10}$ **1**

(= 2.61×10^{-5})

pH = 4.58 **1**

(ii) Ml moles H^+ added = $10 \times 10^{-3} \times 1.0 = 0.01$ **1**

M2 moles ethanoic acid after addition = 0.15 + 0.01 = 0.16 **1**

M3 moles ethanoate ions after addition = 0.10 -0.01 = 0.09 **1**

M4 $[H^+] = \frac{K_a[CH_3COOH]}{[CH_3COO^-]} = 1.74 \times 10^{-5} \times \frac{0.16/V}{0.09/V}$ **1**

(= 3.09×10^{-5})

M5 pH = 4.51

The essential part of this calculation is addition/subtraction of 0.01 moles to gain marks M2 and M3. If both of these are missing, only mark M1 is available. Thereafter treat each mark independently, except if the expression in M4 is wrong, in which case both M4 and M5 are lost.

1

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alternative scheme for part (c)(i)

$$\text{pH } pK_a - \log \frac{[CH_3COOH]}{[CH_3COO^-]}$$

1

$pK_a = 4.76$

1

$$\text{pH} = (4.76 - \log \frac{0.15}{0.10}) = 4.58$$

1

alternative for penultimate mark of part (c)(ii)

$$pH = 4.76 - \log \frac{0.16}{0.09}$$

1

M2. Penalise pH given to 1 dp <u>first</u> time it would have scored only

(a) (i) $K_w = [H^+]\,[OH^-]$ **(1)**

(ii) $pH = -\log [H^+]$ **(1)**

or in words or below unless contradiction

(iii) *Calculation*: $[H^+] = \sqrt{5.48 \times 10^{-14}}$ **(1)**

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

$\therefore$ pH = 6.63 or 6.64 **(1)**

Explanation: pure water $\therefore$ $[H^+] = [OH^-]$ **(1)**

5

(b) (i) $[OH^-] = 0.150$ $\therefore$ $[H^+] = 10^{-14}/0.15 = 6.66 \times 10^{-14}$

or pOH = 0.82

$\therefore$ pH = 13.18 **(1)**

or pH= 13.17

(ii) moles $OH^- = (35 \times 10^{-3}) \times 0.150 = 5.25 \times 10^{-3}$ **(1)**[a]

moles $H^+ = (40 \times 10^{-3}) \times 0.120 = 4.8(0) \times 10^{-3}$ **(1)**[b]

$\therefore$ excess moles of $OH^- = 4.5 \times 10^{-4}$ **(1)**[c]

$\therefore$ $[OH^-] = (4.5(0) \times 10^{-4}) \times 1000/\underline{75}$[d] **(1)**[e]
$= 6.0(0) \times 10^{-3}$

$[H^+] = \frac{10^{-14}}{6.00 \times 10^{-3}} = 1.66 \times 10^{-12}$ or pOH = 2.22

$\therefore$ pH = 11.78 **(1)**[f]
or 11.77

8

(c) (i) $K_a = \frac{[H^+][X^-]}{[HX]}$ **(1)**

(ii) $[H^+] = 1.80 \times 10^{-2} \times 0.150 = 2.70 \times 10^{-3}$ (1)

$K_a = \frac{[H^+]^2}{[HX]}(1) = \frac{(2.70 \times 10^{-3})^2}{0.150} = 4.86 \times 10^{-5}$ **(1)** mol dm^{-3} **(1)**

or $\frac{(2.70 \times 10^{-3})^2}{0.1473} = 4.95 \times 10^{-5}$

5

Notes

(a) If K_w includes H_2O allow 6.63 if seen otherwise no marks likely

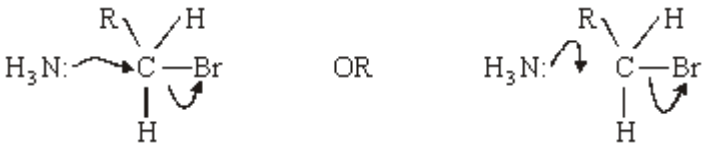
(b) (ii) If no vol, max 4 for a, b, c, f answer = 10.65
If wrong volume max 5 for a, b, c, e, f
If no substraction max 3 for a, b, d
If missing 1000 max 5 for a, b, c, d, f answer = 8.78
If uses excess as acid, max 4 for a, b, d, f answer = 2.22
If uses excess as acid and no volume, max 2 for a,
b answer = 3.35

(c) If wrong K_a in (i) max 2 in part (ii) for $[H^+]$ **(1)** and conseq units **(1)**

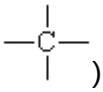
but mark on fully from minor errors
eg no [ ] or charges missing

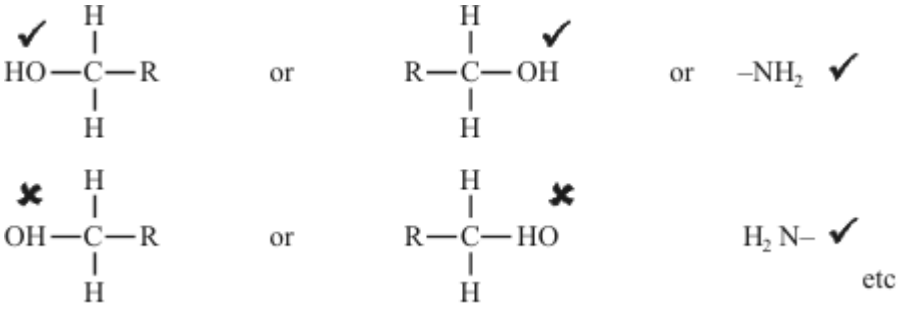
Organic points

(1) Curly arrows: must show movement of a pair of electrons,
i.e. from bond to atom or from lp to atom / space
e.g.



(2) Structures

penalise sticks (i.e. ) once per paper



Penalise once per paper

allow CH_3– or $–CH_3$ or  or CH_3
or H_3C–

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M3. (a) moles HA = $\frac{25}{10^3} \times 0.150 = 3.75 \times 10^{-3}$ **(1)**

$\therefore$ vol NaOH = $\frac{3.75 \times 10^{-3}}{0.20}$ = 1.875×10^{-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 $[A^-] = [HA]$

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

∴ pH = 4.5$\underline{6}$ (1)

3

[13]