M1. (a) (i) **B** 1

C

1

A

1

(ii) cresolphthalein or thymolphthalein

1

(b) $pH = -\log[H^+]$

1

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

[8]

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

ecf if [ ] wrong and already penalised

1

4.57×10^{-3}

allow 4.6×10^{-3}

ignore units

1

(b) (i) $K_a = \frac{[H^+][X^-]}{[HX]}$ allow HA etc

$\frac{[H^+]^2}{[HX]}$ *not* $\frac{[H^+]^2}{[HX]}$ *but mark on*

If expression wrong allow conseq units in (ii)
but no other marks in (ii)

1

(ii) $\frac{[H^+]^2}{[HX]} = \frac{(4.57 \times 10^{-3})^2}{[0.150]}$

If use 4.6 × 10^{-3}

1

K_a = 1.4(1) × 10^{-4} and pKa = 3.85

= 1.39 × 10^{-4}

allow 1.39 – 1.41 × 10^{-4} mol dm^{-3}

1

(iii) *pK_a* = 3.86

Penalise dp of final answer < or > 2 in pH once in paper

1

(c) (i) $\frac{30}{1000}$ × 0.480 = 0.0144 or 1.4(4) ×10^{-2}

Mark is for answer (M1)

1

(ii) $\frac{18}{1000}$ × 0.350 = 0.0063 or 6.3 × 10^{-3}

Mark is for answer (M2)

1

(iii) 0.0144 – 2(0.0063) = 1.80 × 10^{-3}

M3 is for (i) – 2(ii)

If x 2 missed, CE i.e. lose M3 and the next mark gained

1

(iv) 1.80 × 10^{-3} × $\frac{1000}{48}$ = 0.0375 (0.038)

M4 is for answer

If vol is not 48 × 10^{-3} (unless AE) lose M4 and next mark gained
If multiply by 48 - this is AE - i.e. lose only M4
If multiply by 48 × 10^{-3} this is AE - i.e. lose only M4

1

(v) 10^{-14} / 0.0375 (10^{-14} / 0.038)

M5 for K_w/[OH^-]

1

(= 2.66×10^{-13}) (= 2.63×10^{-13})

or pOH

or pOH = 1.426 (or pOH = 1.420)

If no attempt to use K_w or pOH lose both M5 and M6

1

pH = 12.57 (12.58) M6

Allow M6 conseq on AE in M5 if method OK

1

[13]

M3. (a) $K_a = \frac{[H^+][A^-]}{[HA]}$

(All three sets of square brackets needed, penalise missing brackets or missing charge once in the question)
(Don't penalise extra $[H^+]^2/[HA]$)

1

(b) $K_a = \frac{[H^+]^2}{[HA]}$ or $[H^+] = [A^-]$

$[H^+] = \sqrt{(1.45 \times 10^{-4}) \times 0.25}$

$= 6.02 \times 10^{-3}$ pH = 2.22

(must be to 2dp)
(allow 4th mark consequential on their $[H^+]$)

1

(c) (i) pH (almost) unchanged

(Must be correct to score explanation)

1

H^+ removed by A^- forming HA
or acid reacts with salt
or more HA formed

1

(ii) $[H^+] = 10^{-3.59} = 2.57 \times 10^{-4}$ or 2.6×10^{-4}

1

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

1

$$= \frac{(1.45 \times 10^{-4}] \times 0.25}{2.57 \times 10^{-4}}$$

1

$= 0.141$ (mol dm^{-3})

(Allow 0.139 to 0.141 and allow 0.14)

(If not used 3.59, to find $[H^+]$ can only score M2 for working)

(If 3.59 used but $[H^+]$ is wrong, can score M2 for correct method and conseq M4)

If wrong method and wrong expression, can only score M1)

1

(ii) *Alternative scheme for first three marks of part (c)(ii)*

$$pH = pK_a - \log \frac{[HA]}{[A^-]}$$

1

$pK_a = 3.84$

1

$$3.59 = 3.84 - \log \frac{0.250}{[A^-]}$$

1

[11]

M4. (a) (i) B;

1

C;

1

A;

1

(ii) cresolphthalein

OR

thymolphthalein;

1

(b) (i) –log[H^+];

1

(ii) [H^+] = 1.259×10^{-12} (or 1.26 or 1.3)

OR

OH = 14 – pH;

1

$$[OH^-] = \frac{10^{-14}}{1.258 \times 10^{-12}}$$

OR

= 2.10;

1

= $7.9(4) \times 10^{-3}$;

(if [H^+] is wrong allow 1 for [OH] = $K_w/[H^+]$ or as numbers)

1

(c) (i) $K_a = [H^+]^2/[CH_3CH_2COOH]$

OR

$[H+]^2/[HA]$

OR

[H^+] = [A^-] etc;

1

[H^+] = $\sqrt{1.35 \times 10^{-5}} \times 0.117$ or expression without numbers;

1

= 1.257×10^{-3}

pH = 2.90;

1

(iii) $K_a = [H^+]$

OR

$pK_a = pH$;

1

pH = 4.87;
(penalise 1dp once)

1

[13]

M5. (a) Concentration of acid: $m_1v_1 = m_2v_2$ hence $25 \times m_1 = 18.2 \times 0.150$

OR

moles NaOH = 2.73×10^{-3};

1

$m_1 = 18.2 \times 0.150/25 = 0.109$;

1

(b) (i) $K_a=[H^+][A^-]/[HA]$ *not* $K_a = [H^+]^2 / [HA]$;

1

(ii) $pK_a = -\log K_a$;

1

(iii) $[A^-] = [HA]$;

1

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

and $-\log K_a = -\log[H^+]$;

1

(c) ratio $[A^-]$: [HA] remains constant;

1

hence as $[H^+] = K_a [HA] / [A^-]$; $[H^+]$ remains constant;

1

(d) (i) pH of 0.250 mol dm^{-3} HCl = 0.60
and pH of 0.150 mol dm^{-3} HCl = 0.82;

1

pH change = 0.22;

1

(ii) moles HCl = $30 \times 0.250 \times 10^{-3} = v \times 0.150 \times 10^{-3} = 7.50 \times 10^{-3}$

OR

$v = 30 \times 0.250 \times 10^{-3} / 0.150 \times 10^{-3} = 50$;

1

water added = 50 – 30 = 20 cm^3;

1

[12]