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

or $\log 1/[H^+]$

penalise ( )

1

(ii) $[H^+] = 0.56$

mark for the answer; allow 2dp or more

1

$[H_2SO_4] = ½ \times 0.56 = 0.28$

1

(b) (i) $CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$

OR

$CH_3COOH + OH^- \rightarrow CH_3COO^- + H_2O$

Allow CH_3CO_2H *etc*

1

(ii) mol acid = $(25.0 \times 10^{-3}) \times 0.41 = 1.025 \times 10^{-2}$ or 1.03×10^{-2}

1

$[NaOH] = 1.025 \times 10^{-2}/22.6 \times 10^{-3} = 0.45(4)$

mark for answer

if not 0.454 look back for error

1

OR

$[NaOH] = 1.03 \times 10^{-2}/22.6 \times 10^{-3} = 0.456$ or 0.46

(iii) cresol purple

1

(iv) NaOH reacts with <u>carbon dioxide</u> (in the air)

1

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

allow molecular formulae or minor slip in formulae

penalise ( )
allow H_3O^+
not allow HA etc

1

(ii) $K_a = \frac{[H^+]^2}{[CH_3COOH]}$ or with numbers

1

allow HA etc here
This can be scored in part (c)(i) but doesn't score there.

$[H^+] = (\sqrt{(1.74 \times 10^{-5} \times 0.410)} = \sqrt{(7.13 \times 10^{-6})}) = 2.67 \times 10^{-3}$

1

mark for 2.67×10^{-3} or 2.7×10^{-3} either gives 2.57

pH = 2.57 can give three ticks here for (c)(ii)
penalise decimal places < 2 >

1

pH mark conseq on their $[H^+]$
so 5.15 gets 2 marks where square root not taken

(iii) **M1** mol OH^- = $(10.0 \times 10^{-3}) \times 0.10 = 1.0 \times 10^{-3}$

If no subtraction or other wrong chemistry the max score is 3 for M1, M2 and M4

1

M2 orig mol HA = $(25.0 \times 10^{-3}) \times 0.41 = 0.01025$

1

or 1.025×10^{-2} or 1.03×10^{-2}

M3 mol <u>HA</u> in buffer = orig mol HA – mol OH^-

1

= 0.00925 or 0.0093

If A^- is wrong, max 3 for M1, M2 and M3 or use of $pH = pKa – \log [HA]/[A^-]$

M4 mol A^- in buffer = mol OH^- = 1.0×10^{-3}

Mark is for insertion of correct numbers in correct expression for $[H^+]$

1

M5 $[H^+] = \left(\frac{K_a \times [CH_3COOH]}{[CH_3COO^-]} = \right)$

1

$\frac{(1.74 \times 10^{-5})(0.00925)}{0.0010}$ or $\frac{(1.74 \times 10^{-5})(0.00930)}{0.0010}$

(= 1.61×10^{-4} or 1.62×10^{-4})

M6 pH = 3.79 can give six ticks for 3.79

if $[HA]/[A^-]$ upside down lose M5 & M6

If wrong method e.g. $[H^+]^2/[HA]$ max 3 for M1, M2 and M3

Some may calculate concentrations
[HA] = 0.264 and $[A^-]$ = 0.0286 and rounding this to 0.029 gives pH = 3.80 (which is OK)

NB Unlike (c)(ii), this pH mark is NOT awarded conseq to their $[H^+]$ unless following AE

BEWARE: using 0.01025 wrongly instead of 0.00925 gives pH = 3.75
(this gets 3 for M1, M2 & M4)

1

[18]

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

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) Concentration of acid: $m_1v_1 = m_2v_2$ hence 25 × m_1 = 18.2 × 0.150

OR

moles NaOH = 2.73 ×10^{-3};

1

m_1 = 18.2 × 0.150/25= 0.109;

1

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

1

(ii) pK_a = –logK_a;

1

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

1

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

and –logK_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]

M4. (a) (i) B;

1

C;

1

A;

1

(ii) cresolphthalein

OR

thymolphthalein;

1

(b) (i) $-\log[H^+]$;

1

(ii) $[H^+] = 1.259 \times 10^{-12}$ (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) × 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]