

- M1.** (a) (i) $-\log[\text{H}^+]$
or $\log 1/[\text{H}^+]$
penalise () 1
- (ii) $[\text{H}^+] = 0.56$
mark for the answer; allow 2dp or more 1
- $[\text{H}_2\text{SO}_4] = \frac{1}{2} \times 0.56 = 0.28$ 1
- (b) (i) $\text{CH}_3\text{COOH} + \text{NaOH} \rightarrow \text{CH}_3\text{COONa} + \text{H}_2\text{O}$
OR
 $\text{CH}_3\text{COOH} + \text{OH}^- \rightarrow \text{CH}_3\text{COO}^- + \text{H}_2\text{O}$
Allow CH₃CO₂H etc 1
- (ii) mol acid = $(25.0 \times 10^{-3}) \times 0.41 = 1.025 \times 10^{-2}$ or 1.03×10^{-2} 1
- $[\text{NaOH}] = 1.025 \times 10^{-2} / 22.6 \times 10^{-3} = 0.45(4)$
mark for answer
if not 0.454 look back for error 1
- OR**
- $[\text{NaOH}] = 1.03 \times 10^{-2} / 22.6 \times 10^{-3} = 0.456$ or 0.46
- (iii) cresol purple 1
- (iv) NaOH reacts with carbon dioxide (in the air) 1

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

allow molecular formulae or minor slip in formulae

penalise ()

allow H₃O⁺

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 × 10⁻³) × 0.10 = 1.0 × 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 × 10⁻³) × 0.41 = 0.01025

1

or 1.025 × 10⁻² or 1.03 × 10⁻²

M3 mol HA 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

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

1

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

$$(\text{= } 1.61 \times 10^{-4} \text{ or } 1.62 \times 10^{-4})$$

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

$$4.57 \times 10^{-3}$$

allow 4.6×10^{-3}

ignore units

1

(b) (i) $K_a = \frac{[H^+][X^-]}{[HX]}$ allow HA etc
 $\frac{[H^+]^2}{[HX]}$
 not $[HX]$ 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

$K_a = 1.4(1) \times 10^{-4}$ and $pK_a = 3.85$
 $= 1.39 \times 10^{-4}$
 allow $1.39 - 1.41 \times 10^{-4} \text{ mol dm}^{-3}$

1

(iii) $pK_a = 3.86$
 Penalise dp of final answer < or > 2 in pH once in paper

1

(c) (i) $\frac{30}{1000} \times 0.480 = 0.0144$ or $1.4(4) \times 10^{-2}$
 Mark is for answer (M1)

1

(ii) $\frac{18}{1000} \times 0.350 = 0.0063$ or 6.3×10^{-3}
 Mark is for answer (M2)

1

(iii) $0.0144 - 2(0.0063) = 1.80 \times 10^{-3}$
 M3 is for (i) - 2(ii)
 If x 2 missed, CE i.e. lose M3 and the next mark gained

1

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

$(= 2.66 \times 10^{-13})$ $(= 2.63 \times 10^{-13})$
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 $25 \times m_1 = 18.2 \times 0.150$

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 $0.250 \text{ mol dm}^{-3}$ HCl = 0.60
and pH of $0.150 \text{ mol dm}^{-3}$ 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 = $50 - 30 = 20 \text{ cm}^3$; 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

$\text{pH} = 14 - \text{pOH}$;

1

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

OR

$\text{pOH} = 2.10$;

1

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

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

1

(c) (i) $K_a = [H^+][CH_3CH_2COO^-]/[CH_3CH_2COOH]$

OR

$[H^+][A^-]/[HA]$

OR

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

1

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

1

$= 1.257 \times 10^{-3}$

$\text{pH} = 2.90$;

1

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

OR

$\text{p}K_a = \text{pH}$;

1

$\text{pH} = 4.87$;

(penalise 1dp once)

