



A-Level Chemistry

Buffers

Mark Scheme

Time available: 68 minutes

Marks available: 65 marks

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Mark schemes

1.

(a) $[H^+] = (10^{-3.87} \Rightarrow) 1.3489 \times 10^{-4}$

Allow 1.35×10^{-4} . If M1 wrong can only score M2.

1

$$[CH_3COOH] = \frac{[H^+][CH_3COO^-]}{[K_a]} = \left(\frac{[1.3489 \times 10^{-4}][0.136]}{[1.74 \times 10^{-5}]} \right) = 1.05436$$

Mark is for correctly rearranged equation.

1

1.05 – 1.06 (mol dm⁻³)

3 sf or more

1

(b) **If 0.007 moles in 500 cm³ seen follow Mark Scheme 1**

Mark Scheme 1

moles ethanoic acid = 0.130

1

moles sodium ethanoate = 0.0605

1

mol CH₃COOH after addition = (0.130 - 0.007) = 0.123

1

mol CH₃COO⁻ after addition = (0.0605+0.007) = 0.0675

1

$$[H^+] = \left(\frac{[K_a][CH_3COOH]}{[CH_3COO^-]} \right) = \frac{[1.74 \times 10^{-5}][0.123]}{[0.0675]} (=3.171 \times 10^{-5})$$

1

pH = 4.50 (must be 2dp)

1

Method 1

For M3 allow M1 – 0.007

For M4 allow M2 + 0.007

If 0.014 moles in 1 dm³ follow Mark Scheme 2

Mark Scheme 2

moles CH₃COOH after addition = (0.260 - 0.014) = 0.246 (This scores 2 marks)

moles CH₃COO⁻ after addition = (0.121 + 0.014) = 0.135 (This scores 2 marks)

$$[H^+] = \left(\frac{[K_a][CH_3COOH]}{[CH_3COO^-]} \right) = \frac{[1.74 \times 10^{-5}][0.246]}{[0.135]}$$

pH = 4.50 (must be 2dp)

Method 1 and 2

M5 = expression with their numbers

M6 = answer to 2 dp

pH = 4.50 scores 6 marks

If $\sqrt{\quad}$ used in K_a expression, stop at M4

If divide by 2 after M5, lose M6

Allow solutions which use Henderson-Hasselbach Equation

[9]

2.

(a) $[H^+] = \frac{K_a \times [CH_3COOH]}{CH_3COO^-}$ or $= 1.74 \times 10^{-5} \times \frac{0.186}{0.105}$

Allow ()

M1

1

= 3.08×10^{-5}

If $[HX] / [X^-]$ or $\frac{0.186}{0.105}$ upside down, or any addition or subtraction lose M1 & M2.

M2

1

pH = 4.51 (correct answer scores 3)

Can score M3 for correct pH conseq to their $[H^+]$, so pH = 5.01 scores one

Must be to 2 dp

M3

1

Alternative using Henderson–Hasselbach Equation

$$\text{pH} = \text{pKa} - \log\left[\frac{[\text{HX}]}{[\text{X}^-]}\right] = -\log(1.74 \times 10^{-5}) - \log\left(\frac{0.186}{0.105}\right)$$

Allow ()

M1

$$\text{pKa} = 4.76 - 0.248$$

If $[\text{HX}] / [\text{X}^-]$ or $\frac{0.186}{0.105}$ upside down, can only score 1

M2

$$\text{pH} = 4.51$$

so pH = 5.01

Must be to 2 dp

M3

(b) mol HX after addition (= 0.251 + 0.015) = 0.266

For HX, if no addition or error in addition (other than AE) (or subsequent extra add or sub) MAX 3

M1

1

mol X^- after subtraction (= 0.140 – 0.015) = 0.125

For X^- if no subtraction or error in subtraction (other than AE) (or subsequent extra add or sub) MAX 3

M2

1

$$[H^+] = \left(\frac{K_a \times [CH_3COOH]}{CH_3COO^-} \right) = \frac{1.74 \times 10^{-5} \times 0.266}{0.125}$$

If errors above in both addition AND subtraction can only score M3 for insertion of their numbers in rearranged expression. One exception, if addition and subtraction reversed then pH = 4.58 scores 2

M3

1

$$[H^+] = 3.703 \times 10^{-5} \text{ (mol dm}^{-3}\text{)}$$

If $[HX]/[X^-]$ upside down, lose M3 & M4 (or next two marks) but can score M5 for correct pH consequent to their $[H^+]$, so if M1 & M2 correct, pH = 5.09 scores 3.

M4

1

$$\text{pH} = 4.43$$

Correct use of HX and X^- values from (d) gives
pH = 4.41 and scores 4

If wrong method, e.g. $\sqrt{\quad}$ or no use of rearranged K_a expression, may score M1 & M2 but no more.

Allow more but not fewer than 2dp here.

M5

1

Alternative using Henderson–Hasselbach Equation

$$\text{mol acid after addition} = 0.251 + 0.015 = 0.266$$

For HX, if no addition or error in addition (other than AE) (or subsequent extra add or sub) MAX 3

M1

$$\text{mol salt after addition} = 0.140 - 0.015 = 0.125$$

For X⁻ if no subtraction or error in subtraction (other than AE) (or subsequent extra add or sub) MAX 3

M2

$$\text{pH} = (\text{pKa} - \log[\text{HX}] / [\text{X}^-]) = -\log(1.74 \times 10^{-5}) - \log(0.266 / 0.125)$$

If errors above in both addition AND subtraction can only score M3 for insertion of their numbers – except if addition and subtraction reversed then pH = 4.58 scores 2

M3

$$\text{pH} = 4.76 - 0.328$$

M4

$$\text{pH} = 4.43$$

If [HX] / [X⁻] upside down, lose M3 & M4 (or next two marks) but can score M5 for correct pH consequent to their working, so if M1 & M2 correct, pH = 5.09 scores 3.

Allow more but not fewer than 2dp here.

M5

[8]

3.

(a) (only) slightly or partially dissociated / ionised

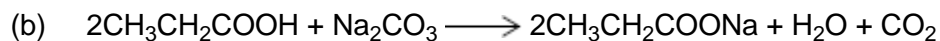
Ignore 'not fully dissociated'.

Allow low tendency to dissociate or to lose / donate a proton.

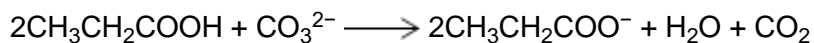
Allow shown equilibrium well to the left.

Otherwise ignore equations.

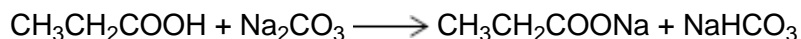
1



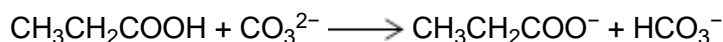
OR



OR



OR



Must be propanoic acid, allow $\text{C}_2\text{H}_5\text{COOH}$.

Not molecular formulae.

Allow multiples.

Ignore reversible sign.

Not H_2CO_3 .

1

(c) $[\text{OH}^-] = 2 \times 0.0120 = 0.0240$ M1

Correct answer for pH with or without working scores 3.

1

$$[\text{H}^+] = \frac{1 \times 10^{-14}}{0.0240} = 4.166 \times 10^{-13} \text{ OR } \text{pOH} = 1.62 \quad \text{M2}$$

If $\times 2$ missed or used wrongly can only score M3 for correct calculation of pH from their $[\text{H}^+]$.

1

pH = 12.38 M3

Lose M3 if not 2 decimal places: 12.4 scores 2.

12.08 scores 1 (missing $\times 2$); 12.1 scores 0.

11.78 scores 1 (dividing by 2) 11.8 scores 0.

1

(d) (i) $K_a = \frac{[\text{H}^+][\text{C}_6\text{H}_5\text{COO}^-]}{[\text{C}_6\text{H}_5\text{COOH}]}$

Ignore () here but brackets must be present.

Must be correct acid and salt.

If wrong, mark part (ii) independently.

1

(ii) M1
$$K^a = \frac{[H^+]^2}{[C_6H_5COOH]}$$
 OR with numbers

Correct answer for pH with or without working scores 3.

Allow HX, HA and ignore () here.

May score M1 in part (i).

1

M2
$$[H^+] = \sqrt{(6.31 \times 10^{-5} \times 0.0120)} \text{ or } \sqrt{(K_a \times [C_6H_5COOH])}$$

$$(\text{= } \sqrt{(7.572 \times 10^{-7} = 8.70 \times 10^{-4})})$$

pH = 6.12 may score 2 if correct working shown and they show the square root but fail to take it.

But if no working shown or wrong
$$K^a = \frac{[H^+]}{[C_6H_5COOH]}$$

used which also leads to 6.12, then zero scored.

1

M3 pH = 3.06

Must be 2 decimal places ie 3.1 loses M3.

1

(iii) M1
$$[H^+] = 10^{-4.00} = 1.00 \times 10^{-4}$$

Correct answer for mass with or without working scores 5.

Allow 1×10^{-4} .

1

M2
$$[X^-] = \frac{K_a \times [HX]}{[H^+]}$$

Ignore () here.

If $[HX] / [X^-]$ upside down, can score M1 plus

M4 for 5.26×10^{-7} .

1

M3
$$= \frac{6.31 \times 10^{-5} \times 0.0120}{1.00 \times 10^{-4}}$$

And M5 for 7.57×10^{-5} g.

1

M4
$$= 7.572 \times 10^{-3}$$

1

M5 Mass (C_6H_5COONa) = $7.572 \times 10^{-3} \times 144 = 1.09$ g
or 1.1 g

Wrong method, eg using $[H^+]$ may only score M1 and M5 for correct multiplication of their M4 by 144 (provided not of obviously wrong substance).

1

(e) M1 CO_2
Allow NO_x and SO_2 .

1

M2 pH (it) falls / decreases
If M1 wrong, no further marks.

1

M3 mark M2 & M3 independently

acidic (gas)

OR reacts with alkali(ne solution) / OH^-

OR $CO_2 + 2OH^- \longrightarrow CO_3^{2-} + H_2O$

OR $CO_2 + OH^- \longrightarrow HCO_3^-$

Not forms H_2CO_3 H_2SO_3 H_2SO_4 etc OR H^+ ions.

1

[17]

4.

(a) (i) $[H^+][OH^-]$ **OR** $[H_3O^+][OH^-]$
Ignore (aq)
Must have [] not ()

1

(ii) $\sqrt{3.46 \times 10^{-14}}$ (= 1.86×10^{-7})
If no square root, CE=0

1

pH = 6.73

Must be 2dp

1

(iii) $[H^+] = 10^{-11.36}$ (= 4.365×10^{-12} OR 4.37×10^{-12})
Mark for working

1

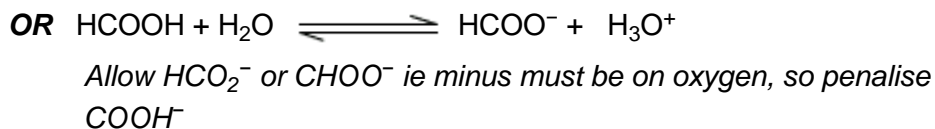
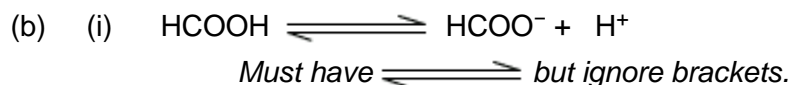
$K_w = [4.365 \times 10^{-12}$ **OR** $4.37 \times 10^{-12} \times 0.047] = 2.05 \times 10^{-13}$

Allow $2.05 \times 10^{-13} - 2.1 \times 10^{-13}$

Mark for answer

Ignore units

1



1

(ii) $K_a = \frac{[\text{H}^+][\text{HCOO}^-]}{\text{HCOOH}}$ **OR** $\frac{[\text{H}_3\text{O}^+][\text{HCOO}^-]}{\text{HCOOH}}$

Must have all brackets but allow ()
 Must be HCOOH etc.
 Allow ecf in formulae from (b)(i)

1

(iii) M1

$$K_a = \frac{[\text{H}^+]^2}{[\text{HCOOH}]} \quad \left([\text{H}^+]^2 = 1.78 \times 10^{-4} \times 0.056 = 9.97 \times 10^{-6} \right)$$

Allow HA or HX etc.
 Allow $[\text{H}^+] = \sqrt{K_a \times [\text{HA}]}$ for M1

1

M2 $[\text{H}^+] = 3.16 \times 10^{-3}$
 Mark for answer

1

M3 pH = 2.50 allow more than 2 dp but not fewer
Allow correct pH from their wrong $[\text{H}^+]$ here only If square root shown but not taken, pH = 5.00 can score max 2 for M1 and M3

1

(iv) M1 Decrease **Mark M1 independently**

1

M2 Eqm shifts / moves to RHS **OR** more H^+ **OR** K_a increases
OR more dissociation

1

M3 To reduce temperature or oppose increase / change in temperature
Only award M3 following correct M2

1

(c) (i) M1 $[H^+] = \frac{K_a \times [HX]}{[X^-]}$ OR $pH = pK_a - \log \frac{[HX]}{[X^-]}$

If [HX]/[X⁻] upside down, no marks

1

M2 $\frac{1.78 \times 10^{-4} \times 2.35 \times 10^{-2}}{1.84 \times 10^{-2}}$ OR $pH = 3.75 - \log \frac{2.35 \times 10^{-2}}{1.84 \times 10^{-2}}$
 (= 2.27×10^{-4})

1

M3 $pH = 3.64$ allow more than 2 dp but not fewer
pH calc NOT allowed from their wrong [H⁺] here

1

(ii) M1 Mol H⁺ added = 5.00×10^{-4}
Mark on from AE in moles of HCl (eg 5×10^{-3} gives $pH = 3.42$ scores 3)

1

M2 Mol HCOOH = 2.40×10^{-2} and Mol HCOO⁻ = 1.79×10^{-2}
If either wrong no further marks except AE (-1) OR if ECF in mol acid and / or mol salt from (c)(i), can score all 4

1

M3 $[H^+] (= \frac{K_a \times [XH]}{[X^-]}) = \frac{1.78 \times 10^{-4} \times 2.40 \times 10^{-2}}{1.79 \times 10^{-2}}$ (= 2.39×10^{-4})

If [HX]/[X⁻] upside down here after correct expression in (c)(i), no further marks

OR $pH = 3.75 - \log \frac{2.40 \times 10^{-2}}{1.79 \times 10^{-2}}$

If [HX]/[X⁻] upside down here and is repeat error from (c)(i), max 3 (pH = 3.88 after 3.86 in (c)(i))

1

M4 $pH = 3.62$ allow more than 2 dp but not fewer
pH calc NOT allowed from their wrong [H⁺] here

1

[20]

5.

- (a) (i) addition of small amounts of acid send eqm to left or extra H^+ removed by reaction with HCO_3^-

1

ratio $[H_2CO_3]/[HCO_3^-]$ remains constant hence $[H^+]$ and pH remain const

1

- (ii) $pH = 7.41 \therefore [H^+] = 3.89 \times 10^{-8} \text{ mol dm}^{-3}$

1

$$K_a = \frac{[H^+][HCO_3^-]}{[H_2CO_3]}$$

1

$$= \frac{(3.89 \times 10^{-8})(2.5 \times 10^{-2})}{1.25 \times 10^{-2}} = 7.78 \times 10^{-8} \text{ mol dm}^{-3}$$

allow error carried forward mark. Do not penalise twice.

1

- (b) (i) moles H^+ added = $10 \times 10^{-3} \times 1.0 = 0.01$

1

- (ii) moles ethanoic acid after addition = $0.15 + 0.01 = 0.16$

1

moles ethanoate ions after addition = $0.10 - 0.01 = 0.09$

1

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

1

$$= 1.74 \times 10^{-5} \times \frac{0.16/V}{0.09/V}$$

1

pH = 4.51

1

[11]