

M1.(a)  $[H_2O]$  is very high (compared with  $[H^+]$  and  $[OH^-]$ )

OR

Very few  $H^+$  and  $OH^-$  ions

OR

Only / very slightly dissociates

OR

Equilibrium lies far to the left

*Not partially dissociates*

M1

1

$[H_2O]$  is (effectively) constant

OR is incorporated into the constant K

*Allow changes by only a very small amount*

M2

1

(b) (Dissociation OR breaking bonds) is endothermic

1

$\therefore$  Equilibrium moves to RHS (at higher T) to absorb heat or to lower T or oppose increase in T

*Allow to oppose change only if increase T mentioned*

1

(c)  $[H^+] = \sqrt{K_w}$  (or  $= \sqrt{5.48 \times 10^{-14}}$ )

*Correct pH answer scores 3*

1

If wrong method no marks

*Using alternative  $K_w$  ( $1.00 \times 10^{-14}$ ) gives  $pH = 7.00$  which scores 1*

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

1

pH = 6.63

*Final answer must have 2dp*

1

(d)  $[H^+] = K_w / [OH^-]$  or  $(= 5.48 \times 10^{-14} / 0.12)$

*Correct pH answer scores 3*

1

If wrong method no marks

*If use alternative  $K_w$  ( $1.00 \times 10^{-14}$ ) again, do not penalise repeat error so pH = 13.08 scores 3*

$= 4.566 \times 10^{-13}$

1

pH = 12.34

*If use alternative  $K_w$  ( $1.00 \times 10^{-14}$ ) **not** as a repeat error, pH = 13.08 scores 1*

*If AE in  $K_w$  value made in part (c) is repeated here, do not penalise again.*

*Final answer must have 2dp, but if dp penalised in (c) allow more than 2dp here but not fewer.*

1

[10]

**M2.(a)** (only) slightly or partially dissociated / ionised

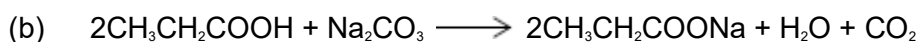
*Ignore 'not fully dissociated'.*

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

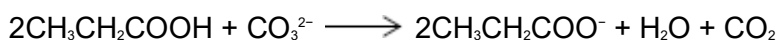
*Allow shown equilibrium well to the left.*

*Otherwise ignore equations.*

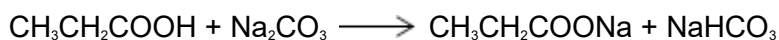
1



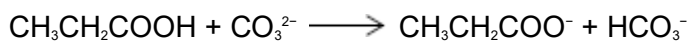
**OR**



**OR**



**OR**



*Must be propanoic acid, allow  $C_2H_5COOH$ .*

*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 × 2 missed or used wrongly can only score M3 for correct calculation of pH from their [H<sup>+</sup>].*

1

pH = 12.38 M3  
 Lose M3 if not 2 decimal places: 12.4 scores 2.  
 12.08 scores 1 (missing × 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  $K_a = \frac{[\text{H}^+]^2}{[\text{C}_6\text{H}_5\text{COOH}]}$  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  $[\text{H}^+] = \sqrt{(6.31 \times 10^{-5} \times 0.0120)}$  or  $\sqrt{(K_a \times [\text{C}_6\text{H}_5\text{COOH}])}$   
 $(= \sqrt{(7.572 \times 10^{-7}} = 8.70 \times 10^{-4})$   
 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  $1 \times 10^{-4}$ .

1

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

Ignore ( ) here.

If  $[HX] / [X^-]$  upside down, can score M1 plus M4 for  $5.26 \times 10^{-7}$ .

1

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

And M5 for  $7.57 \times 10^{-5}$  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  $[H^+]^2$  may only score M1 and M5 for correct multiplication of their M4 by 144

(provided not of obviously wrong substance).

1

(e) M1 CO<sub>2</sub>  
Allow NO<sub>x</sub> and SO<sub>2</sub>.

1

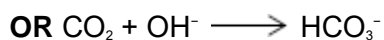
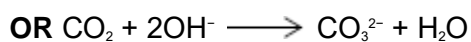
M2 pH (It) falls / decreases  
If M1 wrong, no further marks.

1

M3 mark M2 & M3 independently

acidic (gas)

**OR** reacts with alkali(ne solution) / OH<sup>-</sup>



Not forms H<sub>2</sub>CO<sub>3</sub> H<sub>2</sub>SO<sub>3</sub> H<sub>2</sub>SO<sub>4</sub> etc OR H<sup>+</sup> ions.

1

[17]

M3.(a) M1 [H<sup>+</sup>] = 0.0170

1

M2 pH = 1.77  
2 dp

**Allow M2 for correct pH calculation from their wrong [H<sup>+</sup>]  
for this pH calculation only**

1

(b) (i)  $K_a = \frac{[H^+][X^-]}{[HX]^2}$  Ignore  $K_a = \frac{[H^+]^2}{[HX]}$   
**Penalize missing [ ] here and not elsewhere**  
**Allow HA instead of HX**

1

(ii) M1 [H<sup>+</sup>] = 10<sup>-2.79</sup> OR 1.6218... × 10<sup>-3</sup>

If  $[H^+]$  wrong, can only score M2

1

$$\text{M2} \quad K_a = \frac{[H^+]^2}{[HX]} \quad \text{OR} \quad \frac{[1.62 \times 10^{-3}]^2}{[0.0850]}$$

Allow HA instead of HX

1

**M3**  $K_a = 3.09 \times 10^{-5}$  3sfs min (allow  $3.10 \times 10^{-5}$  if 1.6218 rounded to 1.622) Ignore units

If  $[HX]$  used as  $(0.0850 - 1.62 \times 10^{-3})$

this gives  $K_a = 3.15 \times 10^{-5}$

$(0.0016)^2/0.085 = 3.01 \times 10^{-5}$  scores 2 for AE

1

(c) **M1** mol  $\text{OH}^-$  ( $= (38.2 \times 10^{-3}) \times 0.550$ )

$$= 2.10(1) \times 10^{-2} \text{ or } 0.0210(1)$$

Mark for answer

1

**M2** Mol  $\text{H}^+$  ( $= (25.0 \times 10^{-3}) \times 0.620$ )

$$= 1.55 \times 10^{-2} \text{ or } 0.0155$$

Mark for answer

1

**M3** excess mol  $\text{OH}^- = 5.5(1) \times 10^{-3}$

Allow conseq for M1 – M2

**If wrong method** e.g. no subtraction or use of  $\sqrt{\quad}$   
**can only score max of M1, M2, M3 and M4.**

1

$$\text{M4} \quad [\text{OH}^-] = 5.51 \times 10^{-3} \times \frac{10^3}{63.2} \quad [= 0.08718 \quad (0.0872)]$$

$$\text{OR} \quad [\text{OH}^-] = 5.5 \times 10^{-3} \times \frac{10^3}{63.2} = 0.0870(2)$$

(M1 – M2) / vol in dm<sup>3</sup> mark for dividing by volume  
 (take use of 63.2 without 10<sup>-3</sup> as AE so 9.94 scores 5)  
 If no use or wrong use of vol lose M4 & M6  
 Can score M5 for showing (10<sup>-14</sup>/ their XS alkali)

1

**M5**  $[H^+] = \frac{10^{-14}}{0.08718} = 1.147 \times 10^{-13}$

**OR**  $\frac{10^{-14}}{0.0870} = 1.149 \times 10^{-13}$

**OR** pOH = 1.06

If no use or wrong use of K<sub>w</sub> or pOH no further marks

1

**M6** pH = 12.9(4) allow 3sf

If vol missed score max 4 for 11.7(4)

If acid– alkali reversed max 4 for pH = 1.06

Any excess acid – max 4

1

[12]

**M4.** (a) (i) - log[H<sup>+</sup>]  
 penalise missing [ ] here **and not elsewhere**

1

(ii) [H<sup>+</sup>][OH<sup>-</sup>]  
 Allow ( ) brackets, but must have charges

1

(iii) Mark independently from a(ii)

$[H^+] = 10^{-13.72} = 1.905 \times 10^{-14}$

If wrong no further mark

1

$K_w = 1.905 \times 10^{-14} \times 0.154 = = (2.93 - 2.94) \times 10^{-15}$

1

- (b) (i) 
$$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]}$$
  
*Must have charges and all brackets, allow ( )*  
*Acid/salt shown must be CH<sub>3</sub>COOH not HA*  
*and correct formulae needed*

1

- (ii) **In pH values penalise fewer than 3 sig figs each time but allow more than 2 dp**  
**For values above 10, allow 3sfs - do not insist on 2 dp**

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

*Allow HA*

1

$$([H^+]^2 = 1.75 \times 10^{-5} \times 0.154 = 2.695 \times 10^{-6} = 2.70 \times 10^{-6})$$

*If  $\sqrt{\quad}$  shown but not done gets pH = 5.57 (scores 2)*

$$[H^+] = 1.64 \times 10^{-3}$$

*Allow mark for pH conseq to their [H+] here only*

1

$$pH = 2.78 \text{ or } 2.79$$

1

- (c) (i) **In pH values penalise fewer than 3 sig figs each time but allow more than 2 dp**

**For values above 10, allow 3sfs - do not insist on 2 dp**

**M1** Initially

$$\text{mol OH}^- = (10 \times 10^{-3}) \times 0.154 \text{ and}$$

$$\text{mol HA} = (20 \times 10^{-3}) \times 0.154$$

$$\text{or mol OH}^- = 1.54 \times 10^{-3} \text{ and mol HA} = 3.08 \times 10^{-3}$$

1

$$\text{M2 } [H^+] = K_a \frac{[CH_3COOH]}{[CH_3COOH^-]}$$



or with numbers

*Allow Henderson Hasselbach*

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

**M3** mol ethanoic acid left = (mol ethanoate ions) =  $1.54 \times 10^{-3}$

$K_a = [H^+]$  or  $pH = pK_a$  scores **M1**, **M2** and **M3**

*1 If either mol acid in mixture or mol salt wrong*

*- max 2 for M1 and M2*

*Any mention of  $[H^+]^2$  - max 2 for M1 and M3*

1

**M4**  $pH = -\log 1.75 \times 10^{-5} = 4.76$  or  $4.757$

*Not 4.75*

1

If no subtraction (so mol ethanoic acid in buffer = original mol)

$pH = 4.46$  scores 2 for **M1** and **M2**

If  $[H^+]^2$  used,  $pH = 3.02$  scores 2 for **M1** and **M3**

(ii) **In pH values penalise fewer than 3 sig figs each time but allow more than 2 dp**

**For values above 10, allow 3sfs - do not insist on 2 dp**

**M1** XS mol KOH (=  $(20 \times 10^{-3}) \times 0.154$ ) =  $3.08 \times 10^{-3}$

*If no subtraction: max 1 for correct use of volume*

*No subtraction and no use of volume scores zero*

*If wrong subtraction or wrong moles*

*Can only score **M2** and **M3** for process*

1

$$\mathbf{M2} [OH] = 3.08 \times 10^{-3} \times \frac{10^3}{60} = 0.0513(3)$$

*Mark for dividing their answer to **M1** by correct volume (method mark)*

*If no volume or wrong volume or multiplied by volume, max 2 for **M1** and **M3** process*

1

$$\mathbf{M3} \text{ [H}^+\text{]} = \frac{10^{-14}}{0.05133} (= 1.948 \times 10^{-13} \text{ to } 1.95 \times 10^{-13})$$

or pOH = 1.29

*Mark for  $K_w$  divided by their answer to M2*

*If pOH route, give one mark for  $14 - \text{pOH}$*

1

**M4** pH = 12.7(1)

*Allow 3sf but not 12.70*

1

If no subtraction and no use of volume (pH = 11.79 scores zero)

If no subtraction, max 1 for correct use of volume, (60cm<sup>3</sup>)

(pH = 13.01 scores 1)

If volume not used, pH = 11.49 (gets 2)

If multiplied by vol, pH = 10.27 (gets 2)

[16]