

M1.(a) $[\text{H}_2\text{O}]$ is very high (compared with $[\text{H}^+]$ and $[\text{OH}^-]$)

OR

Very few H^+ and OH^- ions

OR

Only / very slightly dissociates

OR

Equilibrium lies far to the left

Not partially dissociates

M1

1

$[\text{H}_2\text{O}]$ 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) $[\text{H}^+] = \sqrt{K_w}$ (or $= \sqrt{5.48 \times 10^{-14}}$)

Correct pH answer scores 3

1

If wrong method no marks

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

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

1

$\text{pH} = 6.63$

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 (1.00×10^{-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 (1.00×10^{-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) Burette

1

Because it can deliver variable volumes

1

(b) The change in pH is gradual / not rapid at the end point

1

An indicator would change colour over a range of volumes of sodium hydroxide

Allow indicator would not change colour rapidly / with a few drops of NaOH

1

(c) $[H^+] = 10^{-pH} = 1.58 \times 10^{-12}$

1

$$K_w = [\text{H}^+] [\text{OH}^-] \text{ therefore } [\text{OH}^-] = K_w / [\text{H}^+]$$

1

$$\text{Therefore, } [\text{OH}^-] = 1 \times 10^{-14} / 1.58 \times 10^{-12} = 6.33 \times 10^{-3} \text{ (mol dm}^{-3}\text{)}$$

$$\text{Allow } 6.31 - 6.33 \times 10^{-3} \text{ (mol dm}^{-3}\text{)}$$

1

(d) At this point, $[\text{NH}_3] = [\text{H}^+]$

$$= \frac{[\text{H}^+]^2}{[\text{NH}_4^+]}$$

Therefore K_a

1

$$[\text{H}^+] = 10^{-4.6} = 2.51 \times 10^{-5}$$

1

$$K_a = (2.51 \times 10^{-5})^2 / 2 = 3.15 \times 10^{-10} \text{ (mol dm}^{-3}\text{)}$$

$$\text{Allow } 3.15 - 3.16 \times 10^{-10} \text{ (mol dm}^{-3}\text{)}$$

1

(e) When $[\text{NH}_3] = [\text{NH}_4^+]$, $K_a = [\text{H}^+]$ therefore $-\log K_a = -\log [\text{H}^+]$
Answer using alternative value

1

$$\text{Therefore pH} = -\log_{10}(3.15 \times 10^{-10}) = 9.50$$

$$\text{M2 pH} = -\log_{10}(4.75 \times 10^{-9}) = 8.32$$

Allow consequential marking based on answer from part (d)

1

[12]

M3.(a) M1 $[\text{H}^+] = 0.0170$

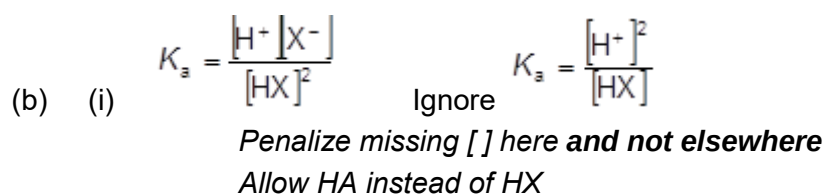
1

M2 $\text{pH} = 1.77$

2 dp

Allow M2 for correct pH calculation from their wrong $[\text{H}^+]$ for this pH calculation only

1



1

(ii) **M1** $[H^+] = 10^{-2.79}$ OR $1.6218... \times 10^{-3}$
 If $[H^+]$ wrong, can only score M2

1

M2 $K_a = \frac{[H^+]^2}{[HX]}$ OR $\frac{[1.62 \times 10^{-3}]^2}{[0.0850]}$
 Allow HA instead of HX

1

M3 $K_a = 3.09 \times 10^{-5}$ 3sfs min (allow 3.10×10^{-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 $OH^- (= (38.2 \times 10^{-3}) \times 0.550)$
 $= 2.10(1) \times 10^{-2}$ or 0.0210(1)
 Mark for answer

1

M2 Mol $H^+ (= (25.0 \times 10^{-3}) \times 0.620)$
 $= 1.55 \times 10^{-2}$ or 0.0155
 Mark for answer

1

- M3** excess mol OH⁻ = 5.5(1) × 10⁻³
 Allow conseq for M1 – M2
*If wrong method e.g. no subtraction or use of √
 can only score max of M1, M2, M3 and M4.*

1

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

OR $[\text{OH}^-] = 5.5 \times 10^{-3} \times \frac{10^3}{63.2} = 0.0870(2)$
 (M1 – M2) / vol in dm³ mark for dividing by volume
 (take use of 63.2 without 10⁻³ as AE so 9.94 scores 5)
 If no use or wrong use of vol lose M4 & M6
 Can score M5 for showing (10⁻¹⁴/ their XS alkali)

1

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

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

OR pOH = 1.06
If no use or wrong use of K_w 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.B

[1]

M5.(a) (only) slightly or partially dissociated / ionised

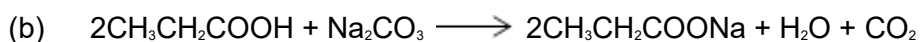
Ignore 'not fully dissociated'.

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

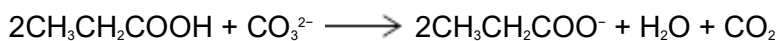
Allow shown equilibrium well to the left.

Otherwise ignore equations.

1



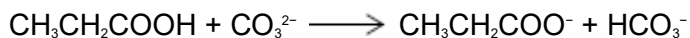
OR



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

$\text{pH} = 12.38$ 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) $K_a = \frac{[H^+][C_6H_5COO^-]}{[C_6H_5COOH]}$

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 $[H^+] = \sqrt{(6.31 \times 10^{-5} \times 0.0120)}$ or $\sqrt{(K_a \times [C_6H_5COOH])}$
 $(= \sqrt{(7.572 \times 10^{-7} = 8.70 \times 10^{-4})})$
 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

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

Ignore () here.

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

1

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

And M5 for 7.57×10^{-6} g.

1

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

1

$$\text{M5} \quad \text{Mass (C}_6\text{H}_5\text{COONa)} = 7.572 \times 10^{-3} \times 144 = 1.09 \text{ g}$$

or 1.1 g

Wrong method, eg using $[\text{H}^+]^2$ may only score M1 and M5 for correct multiplication of their M4 by 144 (provided not of obviously wrong substance).

1

(e) M1 CO_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 $\text{CO}_2 + 2\text{OH}^- \longrightarrow \text{CO}_3^{2-} + \text{H}_2\text{O}$

OR $\text{CO}_2 + \text{OH}^- \longrightarrow \text{HCO}_3^-$
Not forms H_2CO_3 H_2SO_3 H_2SO_4 etc OR H^+ ions.

1
[17]