

Mark schemes

1

(a) Proton acceptor

1

(b) (i) $\text{CH}_3\text{CH}_2\text{NH}_2 + \text{H}_2\text{O} \rightarrow \text{CH}_3\text{CH}_2\text{NH}_3^+ + \text{OH}^-$

allow eq with or without \rightleftharpoons

allow $\text{C}_2\text{H}_5\text{NH}_2$ and $\text{C}_2\text{H}_5\text{NH}_3^+$ (plus can be on N or H or 3)

allow RHS as $\text{C}_2\text{H}_5\text{NH}_3\text{OH}$

1

(ii) Mark independently of (b)(i)

Allow

Ethylamine is only partly/slightly dissociated

OR

Ethylamine is only partly/slightly ionized

*reaction/equilibrium lies to left or low $[\text{OH}^-]$ **OR** little OH^- formed*

***OR** little ethylamine has reacted*

Ignore "not fully dissociated" or "not fully ionized"

Ignore reference to ionisation or dissociation of water

1

(c) **M1** Ethylamine

If wrong no marks in (c)

1

M2 alkyl group is electron releasing/donating

***OR** alkyl group has (positive) inductive effect*

1

M3 increases electron density on N(H₂)

***OR** increased availability of lp*

***OR** increases ability of lp (to accept H(+))*

Mark M3 is independent of M2

1

(d) $\text{CH}_3\text{CH}_2\text{NH}_3\text{Cl}$

Or any amine hydrochloride

allow name (ethylammonium chloride or ethylamine hydrochloride) or other halide for Cl

*or a strong **organic** acid*

***NOT** NH_4Cl*

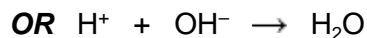
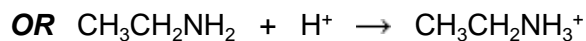
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(e) Mark independently of (d)

Extra H^+ reacts with ethylamine or OH^-

Or makes reference to Equilibrium (in (b)(i)) with amine on LHS

1



Equilibrium shifts to RHS

OR ratio $[CH_3CH_2NH_3^+]/[CH_3CH_2NH_2]$ remains almost constant

1

[9]

2

(a) **M1** $[H^+] = 0.0170$

1

M2 $pH = 1.77$

2 dp

Allow M2 for correct pH calculation from their wrong $[H^+]$ 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** $[H^+] = 10^{-2.79}$ 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^- ($= (38.2 \times 10^{-3}) \times 0.550$)

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

Mark for answer

1

M2 Mol 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

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

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

(M1 – M2) / vol in dm^3 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]

3

(a) C

1

A

1

D

1

(b) (i) Bromocresol green
Allow wrong spellings

1

(ii) Purple to yellow
Must have both colours:
Purple start – yellow finish

1

[5]

4

(a) (i) $-\log[\text{H}^+]$
*penalise missing [] here **and not elsewhere***

1

(ii) $[\text{H}^+][\text{OH}^-]$
Allow () brackets, but must have charges

1

(iii) Mark independently from a(ii)

$[\text{H}^+] = 10^{-13.72} = 1.905 \times 10^{-14}$
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) $K_a = \frac{[\text{H}^+][\text{CH}_3\text{COO}^-]}{[\text{CH}_3\text{COOH}]}$
Must have charges and all brackets, allow ()
Acid/salt shown must be CH_3COOH 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

$$\text{M2 } [H^+] = K_a \frac{[CH_3COOH]}{[CH_3COO^-]}$$

or with numbers

Allow Henderson Hasselbach

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

M3 mol ethanoic acid left = (mol ethanoate ions) = 1.54×10^{-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 (= $(20 \times 10^{-3}) \times 0.154$) = 3.08×10^{-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

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

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

or $\text{pOH} = 1.29$

Mark for K_w divided by their answer to M2

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

1

M4 $\text{pH} = 12.7(1)$

Allow 3sf but not 12.70

1

If no subtraction and no use of volume ($\text{pH} = 11.79$ scores zero)

If no subtraction, max 1 for correct use of volume, (60cm^3)

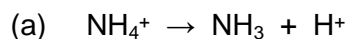
($\text{pH} = 13.01$ scores 1)

If volume not used, $\text{pH} = 11.49$ (gets 2)

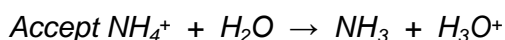
If multiplied by vol, $\text{pH} = 10.27$ (gets 2)

[16]

5



Accept multiples.



Ignore state symbols, even if incorrect.

1

(b) Test indicator / conc HCl

Do not accept 'smell'.

Do not accept precipitation reactions of aqueous ammonia.

1

Observation colour for an alkali / white fumes

If wrong test then lose second mark.

1

[3]

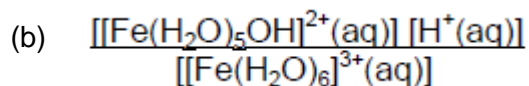
6

(a) Idea that over time / after storage meter does not give accurate readings

Do not accept 'to get an accurate reading' without further qualification.

Allow 'temperature variations affect reading'.

1



Allow without (aq) symbols.

Need at least one set of square brackets around complex ions

1

(c) $\text{pH} = -\log [\text{H}^+]$

1

$[\text{H}^+] = 0.0240$

Do not penalise precision of $[\text{H}^+]$

Correct answer scores M1 and M2.

1

$K_a = (0.0240)^2 / 0.1 = 5.75 \times 10^{-3}$ or 5.76×10^{-3}

Correct answer without working loses M1 and M2.

Allow 7.58×10^{-3}

1

Answer, even if incorrect, given to 3 sig figs

1

(d) Oxygen (in the air) / O_2

Ignore 'air' or 'the atmosphere' or 'chemicals in soil'.

List principle.

1

(e) 4.0 – 6.9

Do not penalise precision.

[7]

7

(a) (i) $-\log[\text{H}^+]$ or $\log 1/[\text{H}^+]$

penalise missing square brackets here only

1

(ii) 0.81

2dp required, no other answer allowed

1

(iii) **M1** mol $\text{H}^+ = 1.54 \times 10^{-3}$

if wrong no further mark

if 1.5×10^{-3} allow M1 but not M2 for 2.82

1

M2 pH = 2.81

allow more than 2dp but not fewer

1

(b) **M1** $[H^+] = 3.31 \times 10^{-3}$ 1

M2 $K_a = \frac{[H^+][X^-]}{[HX]}$ or $\frac{[H^+]^2}{[HX]}$ or using numbers
do not penalise () or one or more missing [] 1

M3 $[HX] = \frac{[H^+]^2}{K_a} = \frac{(3.31 \times 10^{-3})^2}{4.83 \times 10^{-5}}$
*allow conseq on their $[H^+]$ / (4.83×10^{-5}) (AE)
if upside down, no further marks after M2* 1

M4 $[HX] = 0.227$
allow 0.225 – 0.23 1

(c) **M1** extra/added OH^- removed by reaction with H^+ or the acid 1

M2 correct discussion of equn shift i.e. $HX \rightleftharpoons H^+ + X^-$ moves to right 1

OR

ratio $\frac{[HX]}{[X^-]}$ remains almost constant

(d) (i) **M1** $\text{mol HY} = (50 \times 10^{-3}) \times 0.428 = 0.0214$

OR $[Y] = .0236 \times \frac{1000}{50} = 0.472$

mark for answer

1

M2 $[H^+] = 1.35 \times 10^{-5} \times \frac{0.0214}{0.0236}$

OR $1.35 \times 10^{-5} = [H^+] \times \frac{0.0236}{0.0214}$

OR $[H^+] = 1.35 \times 10^{-5} \times \frac{0.428}{0.472}$

OR $1.35 \times 10^{-5} = [H^+] \times \frac{0.472}{0.428}$

must be numbers not just rearrangement of Ka expression

If either HY value or Y⁻ value wrong, (apart from AE -1) lose M2 and M3

1

M3 $[H^+] = 1.22 \times 10^{-5}$

mark for answer

1

M4 pH = 4.91

allow more than 2dp but not fewer

allow M4 for correct pH calculation using their [H⁺] (this applies in (d)(i) only)

1

If Henderson Hasselbalch equation used:

M1 mol HY = $(50 \times 10^{-3}) \times 0.428 = 0.0214$

OR $[Y] = .0236 \times \frac{1000}{50} = 0.472$

mark for answer

1

M2 pKa = 4.87

1

M3 $\log\left(\frac{0.0214}{0.0236}\right) = -0.043$

$$\log\left(\frac{0.428}{0.472}\right) = -0.043$$

If either HY value or Y⁻ value wrong, (apart from AE-1) lose M3 and M4

1

M4 $\text{pH} = 4.87 - (-0.043) = 4.91$

allow more than 2dp but not fewer

1

(ii) Can score full marks for correct consequential use of their HY and Y⁻ values from d(i)

M1 Mol HY after adding NaOH = $0.0214 - 5.0 \times 10^{-4} = 0.0209$

AE in subtraction loses just M1

If wrong initial mol HY (i.e. not conseq to part d(i)) or no subtraction or subtraction of wrong amount, lose M1 and M3

1

M2 Mol Y⁻ after adding NaOH = $0.0236 + 5.0 \times 10^{-4} = 0.0241$

AE in addition loses just M2

If wrong mol Y⁻ (i.e. not conseq to part d(i)) or no addition or addition of wrong amount lose M2 and next mark gained

1

M3 $[\text{H}^+] = 1.35 \times 10^{-5} \times \frac{0.0209}{0.0241} (= 1.17 \times 10^{-5})$

if convert to concentrations

$$[\text{H}^+] = 1.35 \times 10^{-5} \times \frac{0.418}{0.482} (= 1.17 \times 10^{-5})$$

1

if HY/Y⁻ upside down, no further marks

M4 $\text{pH} = 4.93$

allow more than 2dp but not fewer

NOT allow M4 for correct pH calculation using their [H⁺] (this allowance applies in (d)(i) only)

1

If Henderson Hasselbalch equation used:

Can score full marks for correct consequential use of their HY and Y⁻ values from d(i)

M1 Mol HY after adding NaOH = $0.0214 - 5.0 \times 10^{-4} = 0.0209$

AE in subtraction loses just M1

If wrong initial mol HY (i.e. not conseq to part d(i)) or no subtraction or subtraction of wrong amount lose M1 and M3

1

M2 Mol Y⁻ after adding NaOH = $0.0236 + 5.0 \times 10^{-4} = 0.0241$

AE in addition loses just M2

If wrong mol Y⁻ (i.e. not conseq to part d(i)) or no addition or addition of wrong amount lose M2 and next mark gained

1

M3 $\log \left(\frac{0.0209}{0.0241} \right) = -0.062$

if HY/Y⁻ upside down, no further marks

1

M4 pH = $4.87 - (-0.062) = 4.93$

allow more than 2dp but not fewer

1

[18]

8

(a) (i) $-\log[\text{H}^+]$

Penalise missing [] here and not elsewhere

1

(ii) $[\text{H}^+][\text{OH}^-]$

1

(b) (i) $[\text{H}^+] = 2.34 \times 10^{-7}$

1

pH = 6.63

Penalise fewer than 3 sig figs but allow more than 2 dp

1

(ii) $[\text{H}^+] = [\text{OH}^-]$

1

- (iii) **M1** $[H^+] = K_w/[OH^-]$
if upside down or CE, allow M3 only for correct use of their $[H^+]$ 1
- M2** $(= 5.48 \times 10^{-14}/0.140) = 3.91 \times 10^{-13}$ 1
- M3** pH = 12.4(1)
not 12.40 (AE from 12.407) 1
- Penalise fewer than 3 sig figs but allow more than 3 sfs
 For values above 10, allow 3sfs - do not insist on 2 dp.
 For values below 1, allow 2dp – do not insist on 3 sig figs
 Not allow pH = 14 – pOH but can award M3 only for pH = 13.1(46)
 Can award all three marks if $pK_w = 13.26$ is used*
- (c) **M1** mol NaOH = mol OH⁻ = $(30 \times 10^{-3}) \times 0.20 = 6.0 \times 10^{-3}$
mark for answer 1
- M2** mol H₂SO₄ = $(25 \times 10^{-3}) \times 0.15 = 3.75 \times 10^{-3}$
mark for answer 1
- M3** mol H⁺ = $(25 \times 10^{-3}) \times 0.15 \times 2 = 7.5 \times 10^{-3}$
 OR XS mol H₂SO₄ = 0.75×10^{-3}
*if factor of 2 missed or used wrongly, CE - lose M3 and next mark
 gained. In this case they must then use K_w to score any more.
 see examples below* 1
- M4** XS mol H⁺ = 1.5×10^{-3} 1
- M5** $[H^+] = (1.5 \times 10^{-3}) \times (1000/55) = 0.0273$
*if no use or wrong use of volume, lose M5 and M6 except if 1000
 missed
 AE -1 (pH = 4.56)* 1
- M6** pH = 1.56
*Penalise fewer than 3 sig figs but allow more than 3 sfs
 For values above 10, allow 3sfs - do not insist on 2 dp.
 For values below 1, allow 2dp – do not insist on 3 sig figs* 1

[14]

9

- (a) pH on the y-axis, volume of alkali on the x-axis
If axes unlabelled use data to decide that pH is on y-axis.

1

Uses sensible scales

*Lose this mark if plotted paths do not cover **half** of the paper.*

Lose this mark if the graph plot goes off the squared paper.

1

Labels the axes

Allow mark for axes labelled 'pH' and 'volume'.

1

Plots all of the points correctly

1

Line through the points is smooth and has the correct profile

Ignore 0–5 cm³ section of the graph.

Lose this mark if graph is kinked or not a single line.

1

Line ignores the point at 12 cm³

Lose this mark if point clearly not treated as an anomaly.

1

(b) (i) 24.4 cm³ ± 0.2

If no answer in (i) allow answer written on the graph.

*Allow this answer **only**.*

Do not penalise precision.

1

(ii) 12.2 cm³ ± 0.1

If no answer in (ii), allow answer written on the graph.

Allow answer to (i) divided by 2.

Do not penalise precision.

1

(iii) 3.9 ± 0.2

If no answer in (iii), allow answer written on the graph.

Consequential marking from (ii)

Lose this mark if answer not given to 1 dp.

1

(c) $\text{p}K_a = -\log K_a$ or $K_a = 10^x$, where $x = -$ (answer to b(iii))

1

1.26 × 10⁻⁴

3.7 to 4.1 gives $K_a = 7.9 \times 10^{-5}$ to 2.0×10^{-4}

Consequential marking from b(i).

Correct answer without working scores 1 mark only.

Do not penalise precision.

1

(d) Methanoic acid

Consequential marking from (c).

$pK_a = 3.7$ gives methanoic acid.

$pK_a = 4.1$ gives ethanoic acid.

No lucky guesses – candidates must apply answer from (c).

Do not allow answers based on data given in (f).

1

(e) Error in using pipette is 0.2% **and**

Error in using burette is 0.15×100 / (answer to b(i))

Using 24.4 for burette gives 0.6%

Do not penalise precision.

Allow if errors are given without working.

Lose mark if the burette error is not calculated on b(i).

*If the error being calculated is **not** stated, allow **if** the calculations are in the same order as in the question (pipette, burette).*

1

(f) Difference is $1.6 \times 10^{-4} - 1.26 \times 10^{-4} = 0.34 \times 10^{-4}$

Allow consequential answer from (c).

Do not penalise precision.

$0.34 \times 100 / 1.6$ is a 21% error

Correct final answer without working scores 1 mark.

Using 1.9×10^{-4} gives 0.3×10^{-4} and 18.8%.

1

(g) Calibrate meter **or** thermostat the mixture **or** maintain constant temperature

Do not allow 'repeat experiment'.

1

(h) Mixture is a buffer

1

[16]