Acids, Bases & Buffers Test: Answers

1. (a) Any **two** from:

Weigh by difference or rinse weighing bottle and add to beaker

Rinse beaker and add washings to graduated flask

Invert flask several times to ensure uniform solution

Use a funnel to transfer to the flask and rinse the funnel

Use a stirrer to prepare the solution and rinse the stirrer

If more than two answers apply the list rule.

Max 2

(b) $K_a = [H^+]^2 / [HA]$

Allow any correct expression relating K_a, $[H^+]$ and [HA]

1

$[HA] = (10^{-2.50})^2 / 1.07 \times 10^{-3}$

M2 also scores M1

1

$= 9.35 \times 10^{-3}$ (mol dm^{-3})

Do not allow 9.4 (answer is 9.346).

Correct answer only scores 1 mark.

Do not penalise precision but must be to at least two significant figures.

1

(c) (b) × 138.0 / 4

1

= 0.322

Using 8.50×10^{-3} gives 0.293

Correct answer scores M1 and M2.

Do not penalise precision but must be to at least two significant figures.

1

(d) (c) × 100 / 0.500 = 64.5%

Using 0.293 from (c) gives 58.7%

Using 0.347 gives 69.4%

Do not penalise precision.

1

[8]

2. (a) (i) $-\log[H^+]$

*Penalise missing [ ] here **and not elsewhere***

1

(ii) $[H^+][OH^-]$

1

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

1

pH = 6.63

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

1

(ii) $[H^+] = [OH^-]$

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 H_2SO_4 = $(25 \times 10^{-3}) \times 0.15 = 3.75 \times 10^{-3}$

mark for answer

1

M3 mol H^+ = $(25 \times 10^{-3}) \times 0.15 \times 2 = 7.5 \times 10^{-3}$
OR XS mol H_2SO_4 = 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 $H^+ = 1.5 \times 10^{-3}$

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]

3. (a) Proton donor or H^+ donor

Allow donator

1

(b) (i) B B

Both need to be correct to score the mark

1

(ii) A A

Both need to be correct to score the mark

1

(iii) B A

Both need to be correct to score the mark

1

(c) **M1** $[H^+] = 10^{-1.25}$ OR 0.05623

1

M2 mol HCl = $(25 \times 10^{-3}) \times 0.0850$ $(= 2.125 \times 10^{-3})$

Mark for Working

1

M3 vol $\left(= \frac{2.125 \times 10^{-3}}{0.05623}\right)$ = 0.0378 dm^3 or 37.8 cm^3

allow 0.0375 – 0.038 dm^3 or 37.5 – 38 cm^3

Units and answer tied

Lose M3 if total given as (25 + 37.8) = 62.8 cm^3

Ignore "vol added = 12.8 cm^3 " after correct answer

1

(d) (i) 4.52

Must be 2dp

1

(ii) $K_a = \frac{[H^+][H^-]}{[HX]}$ ignore = $\frac{[H^+]^2}{[HX]}$ but this may score M1 in (d)(iii)

Must have all brackets but allow ( ) Allow HA etc

***NO** mark for 10^{-pKa}*

1

(iii) **M1** $K_a = \frac{[H^+]^2}{[HX]}$ or with numbers

Allow $[H^+] = \sqrt{(Ka \times [HA])}$ for M1

1

M2 $[H^+] = (\sqrt{(3.01 \times 10^{-5} \times 0.174)} = \sqrt{(5.24 \times 10^{-6})})$

$= 2.29 \times 10^{-3} - 2.3 \times 10^{-3}$

Mark for <u>answer</u>

1

M3 pH = 2.64 (allow more than 2dp but not fewer)

Allow 1 for correct pH from their wrong $[H^+]$

If square root forgotten, pH = 5.28 scores 2 for M1 and M3

1

(e) **M1** mol OH^- = $(10.0 \times 10^{-3}) \times 0.125 = 1.25 \times 10^{-3}$

Mark for answer

1

M2 orig mol HX = $(15.0 \times 10^{-3}) \times 0.174 = 2.61 \times 10^{-3}$

Mark for answer

1

M3 mol HX in buffer = orig mol HX – mol OH^-

Mark for answer

= $2.61 \times 10^{-3} - 1.25 \times 10^{-3} = 1.36 \times 10^{-3}$

Allow conseq on their (M2 – M1)

([HX] = $1.36 \times 10^{-3}/25 \times 10^{-3} = 0.0544$)

If no subtraction, max 3 for M1, M2 & M4 (pH = 4.20)

If $[H^+] = [X^-]$ & √used, max 3 for M1, M2 & M3 (pH = 2.89)

1

M4 mol X^- in buffer = mol OH^- = 1.25×10^{-3}

([X^-] = $1.25 \times 10^{-3}/25 \times 10^{-3} = 0.05$)

May be scored in M5 expression

1

M5 $[H^+]$ $\left(= \frac{Ka \times [HX]}{[X^-]}\right)$

If use $K_a = \frac{[H^+]^2}{[HX]}$ no further marks

$= \frac{3.01 \times 10^{-5} \times 1.36 \times 10^{-3}}{1.25 \times 10^{-3}}$ OR $\frac{3.01 \times 10^{-5} \times 0.0544}{0.05}$

($= 3.27 \times 10^{-5}$)

If either value of HX or X^- used wrongly or expression upside down, no further marks

1

M6 pH = 4.48 or 4.49 (allow more than 2dp but not fewer)

*Do **not** allow M6 for correct calculation of pH using their $[H^+]$ - this only applies in (d)(iii) - apart from earlier AE*

1

[18]

4. (a) before any KOH added: $K_a = \frac{[H^+][A^-]}{[HA]}$ **or** $\frac{[H^+][CH_3COO^-]}{[CH_3COOH]}$ **(1)**

$\therefore K_a = \frac{[H^+]^2}{[CH_3COOH]}$ **(1)**

$\therefore [H^+] = \sqrt{1.74 \times 10^{-5} \times 0.160} = 1.67 \times 10^{-3}$ **(1)**

$\therefore$ pH = 2.78 **(1)**

4

(b) at 8 cm^3 KOH:

Moles KOH added = $(8 \times 10^{-3}) \times 0.210 = 1.68 \times 10^{-3}$ **(1)**

$\therefore$ moles of CH_3COO^- formed = 1.68×10^{-3} **(1)**

Original moles of $CH_3COOH = (25 \times 10^{-3}) \times 0.160 = 4.0 \times 10^{-3}$ **(1)**

$\therefore$ moles of CH_3COOH left = $(4.0 \times 10^{-3}) - (1.68 \times 10^{-3})$

$= 2.32 \times 10^{-3}$ **(1)**

$[H^+] = K_a \times \frac{[CH_3COOH]}{[CH_3COO^-]}$ **(1)**

$= 1.74 \times 10^{-5} \times \frac{2.32 \times 10^{-3} / V}{1.68 \times 10^{-3} / V} = 2.40 \times 10^{-5}$ **(1)**

$\therefore$ <u>pH = 4.62</u> **(1)**

It forget subtraction : max 5
If K_a expression not used max 5
if moles of CH_3COOH wrong but substitution used max 5

7

(c) at 40 cm^3 of KOH:

Total moles of KOH = $(40 \times 10^{-3}) \times 0.21 = 8.4 \times 10^{-3}$ **(1)**

$\therefore$ excess moles of KOH = $(8.4 \times 10^{-3}) - (4.0 \times 10^{-3})$

$= 4.4 \times 10^{-3}$ **(1)**

in total volume = 40 + 25 = 65 cm^3 **(1)**

$\therefore [OH^-] = 4.4 \times 10^{-3} \times \frac{1000}{65} = 0.0677$ **(1)**

$\therefore [H^+] = \frac{10^{-14}}{0.0677}$

OR pOH =1.17

$= 1.477 \times 10^{-13}$ **(1)**

$\therefore$ pH = 12.8<u>3</u> **(1)**

If volume missed : max 4
If moles of acid wrong but method includes subtraction : max 5
If no subtraction : max 4

6

[16]

5. (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

$= 3.08 \times 10^{-5}$

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

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

Allow ( )

M1

pKa = 4.76 − 0.248

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

M2

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

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

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

M4

1

pH = 4.43

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

If wrong method, e.g. √ 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

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

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

pH = (pKa − log[HX] / [X^-]) = −log(1.74 × 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

pH = 4.76 − 0.328

M4

pH = = 4.43

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

Allow more but not fewer than 2dp here.

M5

[8]

6. (a) (i) G

1

(ii) F

1

(iii) H

1

(b) (i) cresol purple

1

(ii) yellow to red

both colours needed and must be in this order

1

(iii) yellow or pale yellow

Not allow any other colour with yellow

1

[6]

7. (a) $NH_4^+ \rightarrow NH_3 + H^+$

Accept multiples.

Accept $NH_4^+ + H_2O \rightarrow NH_3 + H_3O^+$

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]

8. (Calibrate) meter with solution(s) of known pH/buffer(s)

Do not accept 'repeat reading'

1

Adjust meter/plot calibration curve

1

[2]

9. C

[1]

10. D

[1]

11. B

[1]

12. D

[1]

13. A

[1]