A-Level Chemistry

Weak Acids Dissociation Constant (Ka)

Mark Scheme

Time available: 64 minutes
Marks available: 62 marks

Mark schemes

1. (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**

$K_w = [H^+]\,[OH^-]$ therefore $[OH^-] = K_w / [H^+]$ **1**

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

Allow 6.31–6.33 × 10^{-3} (mol dm^{-3}) **1**

(d) At this point, $[NH_3] = [H^+]$

Therefore $K_a = \frac{[H^+]^2}{[NH_4^+]}$ **1**

$[H^+] = 10^{-4.6} = 2.51 \times 10^{-5}$ **1**

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

Allow 3.15 – 3.16 × 10^{-10} (mol dm^{-3}) **1**

(e) When $[NH_3] = [NH_4^+]$, $K_a = [H^+]$ therefore $-\log K_a = -\log [H^+]$

Answer using alternative value **1**

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

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

Allow consequential marking based on answer from part (d) **1**

[12]

2. (a) Proton donor or H^+ donor **1**

(b) (i) $K_a = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]}$ or $\frac{[CH_3COO^-][H_3O^+]}{[CH_3COOH]}$

If K_a wrong, can only score M1 below.

Must be ethanoic acid not HA

Must have square brackets (penalise here only) but mark on in (b)(ii).

1

(ii) M1 $[H^+] = 10^{-2.69}$ ***OR*** 2.042×10^{-3} (mol dm^{-3})

1

M2 $CH_3COOH] = \frac{[H^+]^2}{K_a}$

Ignore ( )
Mark for correctly rearranged expression incl $[H^+]^2$

1

M3

$$= \frac{(2.042 \times 10^{-3})^2}{1.75 \times 10^{-5}}$$

If M2 wrong no further marks.

1

M4 = 0.238 (mol dm^{-3}) Allow 0.229 − 0.24

1

(c) (i) $ClCH_2COOH \rightleftharpoons ClCH_2COO^- + H^+$

OR $ClCH_2COOH + H_2O \rightleftharpoons ClCH_2COO^- + H_3O^+$

Allow $\longrightarrow$

Allow $ClCH_2CO_2H$ and $ClCH_2CO_2^-$

1

(ii) M1 Cl is (more electronegative so) withdraws electrons
OR negative inductive effect of Cl

Ignore electronegativity.

Ignore chloroethanoic acid has a lower K_a value.

Allow Cl reduces +ve inductive effect of methyl group.

1

M2 Weakens O–H bond
OR O–H bond is more polar
OR reduces negative charge on COO^-
OR stabilizes COO^- (more)

M1 & M2 are independent marks.

Ignore H^+ lost more easily.

1

(d) (i) **A**

1

(ii) **C**

1

(iii) **D**

1

(e) M1 Mol NaOH = mol OH^- = $(19.6 \times 10^{-3}) \times 0.720 = 1.41(1) \times 10^{-2}$

Mark for answer.

1

M2 Mol H_2SO_4 = $(26.4 \times 10^{-3}) \times 0.550 = 1.45(2) \times 10^{-2}$

Mark for answer.

1

M3 Mol H^+ added = **2 ×** $(1.452 \times 10^{-2}) = 2.90(4) \times 10^{-2}$

OR

XS mol H_2SO_4 = $7.46(4) \times 10^{-3}$

If factor × 2 missed completely (pH = 2.05)

or used wrongly later,

can score max 4 for M1, M2, M5 & M6

1

M4 XS mol H^+ = 0.0149(3)

1

M5 For dividing by volume

$[H^+] = 0.0149(3) \times (1000 / 46.0) = 0.324 - 0.325$ mol dm^{-3}

If no use or wrong use of volume lose M5 and M6

ie can score 4 for pH = 1.83 (no use of vol)

Treat missing 1000 as AE (−1) & score 5 for pH = 3.49

1

M6 pH = 0.49

2dp *(penalise more or less).*

If × 2 missed & vol not used, pH = 3.39 scores M1 & M2 only.

1

[18]

3. (a) Idea that <u>over time / after storage</u> meter does not give accurate readings

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

Allow 'temperature variations affect reading'.

1

(b)

$$\frac{[[Fe(H_2O)_5OH]^{2+}(aq)]\ [H^+(aq)]}{[[Fe(H_2O)_6]^{3+}(aq)]}$$

Allow without (aq) symbols.

Need at least one set of square brackets around complex ions

1

(c) pH = –log [H^+]

1

[H^+] = 0.0240

Do not penalise precision of [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]

4. (a) –log [H^+]

ecf if [ ] wrong and already penalised

1

4.57×10^{-3}

allow 4.6×10^{-3}

ignore units

1

(b) (i) $K_a = \frac{[H^+][X^-]}{[HX]}$ allow HA etc

not $\frac{[H^+]^2}{[HX]}$ *but mark on*

If expression wrong allow conseq units in (ii)
but no other marks in (ii)

1

(ii) $\frac{[H^+]^2}{[HX]} = \frac{(4 \cdot 57 \times 10^{-3})^2}{[0 \cdot 150]}$

If use 4.6×10^{-3}

1

$K_a = 1.4(1) \times 10^{-4}$ *and pKa = 3.85*

$= 1.39 \times 10^{-4}$

allow $1.39 – 1.41 \times 10^{-4}$ *mol dm*$^{-3}$

1

(iii) $pK_a = 3.86$

Penalise dp of final answer < or > 2 in pH once in paper

1

(c) (i) $\frac{30}{1000} \times 0.480 = 0.0144$ or $1.4(4) \times 10^{-2}$

Mark is for answer (M1)

1

(ii) $\frac{18}{1000} \times 0.350 = 0.0063$ or 6.3×10^{-3}

Mark is for answer (M2)

1

(iii) $0.0144 – 2(0.0063) = 1.80 \times 10^{-3}$

M3 is for (i) – 2(ii)

If x 2 missed, CE i.e. lose M3 and the next mark gained

1

(iv) $1.80 \times 10^{-3} \times \frac{1000}{48} = 0.0375\ (0.038)$

M4 is for answer

If vol is not 48×10^{-3} (unless AE) lose M4 and next mark gained
If multiply by 48 - this is AE - i.e. lose only M4
If multiply by 48×10^{-3} this is AE - i.e. lose only M4

1

(v) 10^{-14} / 0.0375 (10^{-14} / 0.038)

M5 for K_w/[OH^-]

1

(= 2.66×10^{-13}) (= 2.63×10^{-13})

or pOH

or pOH = 1.426 (or pOH = 1.420)

If no attempt to use K_w or pOH lose both M5 and M6

1

pH = 12.57 (12.58) M6

Allow M6 conseq on AE in M5 if method OK

1

[13]

5. (a) $K_a = \frac{[H^+][A^-]}{[HA]}$

(All three sets of square brackets needed, penalise missing brackets or missing charge once in the question)
(Don't penalise extra $[H^+]^2/[HA]$)

1

(b) $K_a = \frac{[H^+]^2}{[HA]}$ or $[H^+] = [A^-]$

$[H^+] = \sqrt{(1.45 \times 10^{-4}) \times 0.25}$

= 6.02×10^{-3}pH = 2.22

(must be to 2dp)
(allow 4th mark consequential on their $[H^+]$)

1

(c) (i) pH (almost) unchanged

(Must be correct to score explanation)

1

H^+ removed by A^- forming HA
or acid reacts with salt
or more HA formed

1

(ii) $[H^+]$ $= 10^{-3.59} = 2.57 \times 10^{-4}$ or 2.6×10^{-4}

1

$[A^-]$ $= \dfrac{K_a[HA]}{[H^+]}$

1

$= \dfrac{(1.45 \times 10^{-4}) \times 0.25}{2.57 \times 10^{-4}}$

1

$= 0.141$ (mol dm^{-3})

(Allow 0.139 to 0.141 and allow 0.14)

(If not used 3.59, to find $[H^+]$ can only score M2 for working)

(If 3.59 used but $[H^+]$ is wrong, can score M2 for correct method and conseq M4)

If wrong method and wrong expression, can only score M1)

1

(ii) *Alternative scheme for first three marks of part (c)(ii)*

$pH = pK_a - \log\dfrac{[HA]}{[A^-]}$

1

$pK_a = 3.84$

1

$3.59 = 3.84 - \log\dfrac{0.250}{[A^-]}$

1

[11]