A-Level Chemistry

Calculation of pH

Mark Scheme

Time available: 77 minutes
Marks available: 73 marks

1.

(a) Ans = C

1

(b) $[H^+] = \sqrt{K_w} = \sqrt{2.93 \times 10^{-15}}$ $(= 5.41 \times 10^{-8})$

1

pH = $(-\log (5.41 \times 10^{-8}) = \underline{7.27}$

Must be 2dp

7.27 scores 2 marks

1

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

allow description in words

equal moles / quantities / numbers / ratio of H^+ and OH^-

1

(d) $[OH^-] = 0.0131 \underline{\times 2} = 0.0262$

pH = 12.95 scores 3 marks

pH = 12.42 scores 2 marks ($K_w = 1 \times 10^{-14}$)

pH = 12.65 scores 1 mark (not multiplied by 2)

pH = 12.35 scores 1 mark (divided by 2)

pH = 12.12 scores 0 marks (no × 2 and wrong K_w)

1

$[H^+] = (K_w / [OH^-]) = 2.93 \times 10^{-15} / 0.0262$ $(= 1.118 \times 10^{-13})$

1

pH = $(-\log (1.118 \times 10^{-13}) = 12.9514 = 12.95$

Or

$[OH^-] = 0.0131 \times 2 = 0.0262$

pOH = $(-\log 0.0262) = 1.5817$

pH = $(-\log K_w - \text{pOH} = -\log 2.93 \times 10^{-15} - 1.58 = 14.53 - 1.58) = 12.95$

allow to 2dp or more

1

(e) smaller / lower pH / less alkaline / more acidic

If not smaller CE = 0/2

Allow pH number between 8 and 12

1

(magnesium hydroxide) is less soluble / sparingly soluble/ solubility of hydroxide increases down group II

M2 dependent on M1 but if blank mark on

Ignore concentration and dissociation

Ignore incorrect formula

Do not allow $Mg(OH)_2$ is insoluble

1

[9]

2. (a) Proton donor

1

(b) Completely ionises to give H^+ ions in water

1

(c) 0.058 mol dm^{-3}

1

1.24

1

(d) Amount of NaOH = 5.25×10^{-3}

1

Since 1:1 reaction amount of OH− ions in excess

= $5.25 \times 10^{-3} - 1.45 \times 10^{-3}$ mol

= 3.80×10^{-3} moles OH^-

1

$[OH^-] = 3.80 \times 10^{-3} \times 1000/60 = 0.0633$

1

$K_w = [H^+][OH^-$ so $H^+ = \frac{10^{-14}}{0.0633} = 1.58 \times 10^{-13}$

1

pH = 12.80

1

(e) Amount of OH^- added 1.5 / 40 = 0.0375 mol

1

Use of 1:1 ratio to calculate amount of A^- formed = 0.0375 mol

1

Amount of weak acid initially = 1 × 0.15 = 0.150 mol so amount of weak acid after addition of NaOH = 0.150 − 0.0375 = 0.1125

If M3 incorrect can only score max of 3 marks

1

$[H^+] = K_a [HA]/[A^-]$ or $[H^+] = 1.79 \times 10^{-5} \times 0.1125/0.0375$

1

$= 5.37 \times 10^{-5}$

1

pH = 4.27

1

[15]

3. (a) $CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$

OR

$CH_3COOH \rightleftharpoons CH_3COO^- + H^+$

Must show $\rightleftharpoons$

Allow CH_3CO_2H, $CH_3CO_2^-$

Ignore state symbols

1

(b) $(CH_3COOH + \underline{HNO_3} \longrightarrow CH_3COOH_2^+ + NO_3^-)$

IGNORE $\rightleftharpoons$

Allow CH_3CO_2H, $CH_3CO_2H_2^+$, $CH_3C^+(OH)_2$

1

(c) (i) (new $[HNO_3] = [H^+] = \frac{100}{150} \times 0.0125$)

M1 $[H^+] = 8.3(3) \times 10^{-3}$ (mol dm^{-3})

OR

new$[HNO_3] = \frac{\text{mol } HNO_3}{\text{total vol}} = \frac{1.25 \times 10^{-3}}{150 \times 10^{-3}}$

1

M2 pH = − log M1 OR 2.08

Must be 2dp

Allow correct pH conseq to their $[H^+]$ *concentration*

1

(ii) M1 mol NaOH (= $50 \times 10^{-3} \times 0.0108$) = 5.40×10^{-4}

1

M2 Subtraction of M1 from moles of HNO_3 (1.25×10^{-3} or conseq from 1c(i))

Excess mol $H^+ = 7.10 \times 10^{-4}$

M2 allow ecf for subtraction of mol

If no subtraction, no further marks

1

M3 $[H^+] = \frac{M2}{150 \times 10^{-3}}$ OR $\frac{7.10 \times 10^{-4}}{150 \times 10^{-3}} = 4.73 \times 10^{-3}$

M3 <u>if no use of volume, no further marks</u> (pH=3.15)

If incorrect volume used, can score M4

1

M4 pH = -log M3 OR 2.32

M4 Allow 2.33 Must be 2 dp

1

(d) (i) M1 $K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]}$

Penalise ( ) once here Not [H+][A-] / [HA]

If K_a expression wrong – Allow correct pH conseq to their $[H^+]$ concentration M4 only

1

M2 $K_a = \frac{[H^+]^2}{[CH_3COOH]}$ or with numbers or with HA

1

M3 $[H^+] = [\sqrt{(1.74 \times 10^{-5} \times 0.0125)}] = 4.66 \times 10^{-4}$

Mark for answer

1

M4 pH = 3.33

Must be 2dp

Allow correct pH conseq to their $[H^+]$ concentration

(pH = 3.83 can score M1, M2 and M4)

1

(ii) Sodium ethanoate

Ignore formula

Allow sodium acetate

1

(iii) M1 $[H^+] = 1.45 \times 10^{-5}$

Accept 1.445×10^{-5} or 1.4×10^{-5}

1

M2 $\frac{[salt]}{[acid]}$ (OR $\frac{[CH_3COO^-]}{[CH_3COOH]} = \frac{Ka}{[H^+]}$)= $\frac{1.74 \times 10^{-5}}{1.45 \times 10^{-5}}$

If M1 incorrect CE=0

Inclusion of 0.0125 in calculation can only score M1

1

M3 1.2(0)

Ignore units

1.4×10^{-5} gives 1.24

1

(e) M1 (Electronegative) chlorine withdraws electrons

Allow Cl has negative inductive effect

1

M2 Stabilises/reduces charge on COO-

OR weakens O-H bond

OR makes O-H more polar

Ignore chloroethanoic acid dissociates more readily

Mark independently

1

(f) M1 Strong acids (almost) completely dissociated/ionised

OR not an equilibrium

OR equilibrium lies far to the right

Cannot have K_a value for a reaction not in equilibrium scores both marks

1

M2 K_a value for strong acids tends to infinity/is very large
OR can't divide by zero in K_a

1

[20]

4. (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

(b) $2CH_3CH_2COOH + Na_2CO_3 \longrightarrow 2CH_3CH_2COONa + H_2O + CO_2$

OR

$2CH_3CH_2COOH + CO_3^{2-} \longrightarrow 2CH_3CH_2COO^- + H_2O + CO_2$

OR

$CH_3CH_2COOH + Na_2CO_3 \longrightarrow CH_3CH_2COONa + NaHCO_3$

OR

$CH_3CH_2COOH + CO_3^{2-} \longrightarrow CH_3CH_2COO^- + HCO_3^-$

Must be propanoic acid, allow C_2H_5COOH.
Not molecular formulae.
Allow multiples.
Ignore reversible sign.
Not H_2CO_3.

1

(c) $[OH^-] = 2 \times 0.0120 = 0.0240$ M1

Correct answer for pH with or without working scores 3.

1

$[H^+] = \frac{1 \times 10^{-14}}{0.0240} = 4.166 \times 10^{-13}$ ***OR*** pOH = 1.62 M2

If × 2 missed or used wrongly can only score M3 for correct calculation of pH from their $[H^+]$.

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

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 $\sqrt{(K_a \times [C_6H_5COOH])}$
$(= \sqrt{(7.572 \times 10^{-7} = 8.70 \times 10^{\times 4})})$

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

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

Ignore ( ) here.

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

1

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

And M5 for 7.57×10^{-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_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 $CO_2 + 2OH^- \longrightarrow CO_3^{2-} + H_2O$

OR $CO_2 + OH^- \longrightarrow HCO_3^-$

Not forms H_2CO_3 H_2SO_3 H_2SO_4 etc OR H^+ ions.

1

[17]

5. (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 $1.6218\ldots \times 10^{-3}$

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^+ (= $(25.0 \times 10^{-3}) \times 0.620$)

= 1.55×10^{-2} or 0.0155

Mark for answer

1

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

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

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

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

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]