



# **A-Level Chemistry**

## **Calculation of pH**

### **Mark Scheme**

**Time available: 77 minutes**

**Marks available: 73 marks**

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## Mark schemes

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

*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  $\times 2$  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

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

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

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

*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*

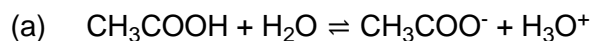
*Do not allow  $Mg(OH)_2$  is insoluble*

1

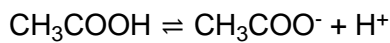
[9]

2. (a) Proton donor 1
- (b) Completely ionises to give  $H^+$  ions in water 1
- (c)  $0.058 \text{ mol dm}^{-3}$  1
- 1.24 1
- (d) Amount of NaOH =  $5.25 \times 10^{-3}$  1
- Since 1:1 reaction amount of  $OH^-$  ions in excess
- =  $5.25 \times 10^{-3} - 1.45 \times 10^{-3} \text{ mol}$
- =  $3.80 \times 10^{-3} \text{ moles } OH^-$  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  $1.5 / 40 = 0.0375 \text{ mol}$  1
- Use of 1:1 ratio to calculate amount of  $A^-$  formed =  $0.0375 \text{ mol}$  1
- Amount of weak acid initially =  $1 \times 0.15 = 0.150 \text{ mol}$  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

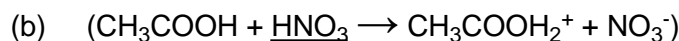
**[15]**

**3.**

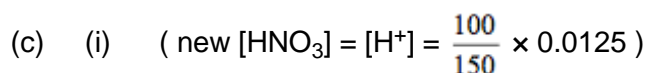
OR

*Must show  $\rightleftharpoons$* *Allow  $\text{CH}_3\text{CO}_2\text{H}$ ,  $\text{CH}_3\text{CO}_2^-$* *Ignore state symbols*

1

*IGNORE  $\rightleftharpoons$* *Allow  $\text{CH}_3\text{CO}_2\text{H}$ ,  $\text{CH}_3\text{CO}_2\text{H}_2^+$ ,  $\text{CH}_3\text{C}^+(\text{OH})_2$* 

1



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

OR

$$\text{new}[\text{HNO}_3] = \frac{\text{mol HNO}_3}{\text{total vol}} = \frac{1.25 \times 10^{-3}}{150 \times 10^{-3}}$$

1

M2  $\text{pH} = -\log \text{M1 OR } 2.08$

*Must be 2dp**Allow correct pH conseq to their  $[\text{H}^+]$  concentration*

1

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

1

M2  $\text{Subtraction of M1 from moles of HNO}_3 (1.25 \times 10^{-3} \text{ or conseq from 1c(i)})$

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

*M2 allow ecf for subtraction of mol****If no subtraction, no further marks***

1

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

*M3 if no use of volume, no further marks (pH=3.15)**If incorrect volume used, can score M4*

1

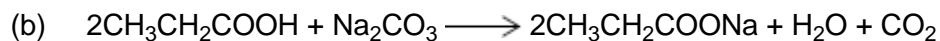
M4  $\text{pH} = -\log \text{M3 OR } 2.32$

*M4 Allow 2.33 Must be 2 dp*

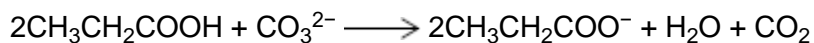
1

- (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  $1.445 \times 10^{-5}$  or  $1.4 \times 10^{-5}$   
 1
- M2  $\frac{[salt]}{[acid]}$  (OR  $\frac{[CH_3COO^-]}{[CH_3COOH]} = \frac{K_a}{[H^+]}$ ) =  $\frac{1.74 \times 10^{-5}}{1.45 \times 10^{-5}}$   
 If M1 incorrect CE=0  
 Inclusion of 0.0125 in calculation can only score M1  
 1
- M3 1.2(0)  
 Ignore units  
 $1.4 \times 10^{-5}$  gives 1.24  
 1

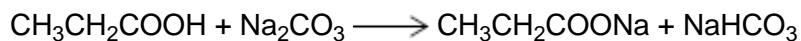
- (e) M1 (Electronegative) chlorine withdraws electrons  
*Allow Cl has negative inductive effect* 1
- M2 Stabilises/reduces charge on COO-  
**OR** weakens O-H bond  
**OR** makes O-H more polar  
*Ignore chloroethanoic acid dissociates more readily*  
*Mark independently* 1
- (f) M1 Strong acids (almost) 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
- 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
- [20]



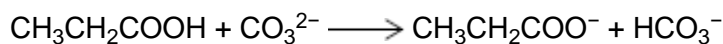
**OR**



**OR**



**OR**



*Must be propanoic acid, allow  $\text{C}_2\text{H}_5\text{COOH}$ .*

*Not molecular formulae.*

*Allow multiples.*

*Ignore reversible sign.*

*Not  $\text{H}_2\text{CO}_3$ .*

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

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)  $K_a = \frac{[\text{H}^+][\text{C}_6\text{H}_5\text{COO}^-]}{[\text{C}_6\text{H}_5\text{COOH}]}$

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

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  $1 \times 10^{-4}$ .

1

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

Ignore ( ) here.

If  $[HX] / [X^-]$  upside down, can score M1 plus

M4 for  $5.26 \times 10^{-7}$ .

1

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

And M5 for  $7.57 \times 10^{-5}$  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**

(b) (i)

1

$$K_a = \frac{[H^+][X^-]}{[HX]^2}$$

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

$$\text{M2 } K_a = \frac{[\text{H}^+]^2}{[\text{HX}]} \quad \text{OR} \quad \frac{[1.62 \times 10^{-3}]^2}{[0.0850]}$$

*Allow HA instead of HX*

1

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

1

**M2** Mol  $\text{H}^+$  ( $= (25.0 \times 10^{-3}) \times 0.620$ )  
 $= 1.55 \times 10^{-2}$  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  $\text{dm}^3$  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  $(10^{-14} / \text{their XS alkali})$*

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]**