A-Level Chemistry

pH Curves and Titrations

Mark Scheme

Time available: 61 minutes
Marks available: 53 marks

1.

(a) $[H_2O]$ is (almost) constant

Allow

$[H_2O]$ is (very) large in comparison (to $[H^+]$ and $[OH^-]$)

or *$[H_2O]$ is incorporated in K_w*
or *$K_w = K_c[H_2O]$*
or *the equilibrium lies <u>very</u> much to the left.*

Ignore *water has negligible dissociation*
Ignore *$[H_2O] = 1$ or $[H_2O]$ is very small 1*

1

(b) M1 Equilibrium is endothermic (in forward direction)

1

M2 <u>Equilibrium</u> shifts to the RHS to minimise/oppose temperature increase

Ignore *more H^+ and OH^- formed*

1

(c) M1 $pH = -\log_{10}[H^+]$

M1 Allow $pH = -log[H^+]$

1

M2 $[H^+] = \sqrt{5.48 \times 10^{-14}}$ $(= 2.34 \times 10^{-7})$

M2 $[H^+]^2 = 5.48 \times 10^{-14}$

1

M3 $pH = -\log_{10} 2.34 \times 10^{-7} = 6.63$

M3 $pH = -log_{10}$ M2

1

M4 $[H^+] = [OH^-]$

or

Dissociation of each water molecule gives one H^+ and one OH^-

M4 Allow equal amounts of H^+ and OH^-

1

(d) 5.55

Allow 5.5 to 5.6

1

(e) Different solutions must not contaminate each other

pH of previous solution doesn't contaminate new solution

or

To wash off any residual solution/substance (which could interfere with the reading)

Ignore to make neutral/neutralise

Ignore so as not to affect concentrations

1

(f) To avoid missing the end point

Or

(Very little pH change per cm^3 added at start) large change in pH (near end point)

1

(g) All have a colour change/pH range within the steep/vertical part of the titration curve

Colour change/pH range between pH 3 and 11

1

(h) M1 Amount of OH^- = 36.25 × 0.200 ÷ 1000 = 7.25×10^{-3} mol **and** Amount of H^+ = 25.0 × 0.150 ÷ 1000 = 3.75×10^{-3} mol

1

M2 Amount of excess OH^- = $7.25 \times 10^{-3} - 3.75 \times 10^{-3} = 3.50 \times 10^{-3}$ mol

1

M3 $[OH^-] = (3.50 \times 10^{-3}) \div (61.25 \times 10^{-3})$ (= 5.71×10^{-2} mol)

M3 $[OH^-] = (M2) \div (61.25 \times 10^{-3})$

1

M4 $[H^+] = \underline{1.00 \times 10^{-14}} \div 5.71 \times 10^{-2} = 1.75 \times 10^{-13}$

M4 $[H^+] = 1.00 \times 10^{-14} \div M3$

1

M5 pH = 12.76

M5 Allow pH = 12.8

M5 $pH = -\log_{10}(M4)$

Alternative Method

M4 p OH = 1.24

M5 pH = 14 – 1.24 = 12.76

1

[16]

2.

(a) **M1**: $[H^+] = [OH^-]$

***M1**: accept equal number/amounts of H^+ and OH^-*

1

M2: $[H^+]$ $(= 10^{-pH}) = 2.138 \times 10^{-7}$

***M2**: allow 2.14×10^{-7}*

1

M3: $K_w = [H^+]^2$ or $(2.138 \times 10^{-7})^2$

***M3**: allow **(M2)**^{2}*

1

M4: $K_w = 4.57 \times 10^{-14}$

***M4**: allow 4.58×10^{-14}*

M4** is dependent on (an answer)^2 in **M3

1

(b) View with Figure X (ie graph) as they may show working there.

Ignore calculations of mols of salt or acid

M1: Determines volume at half equivalence $(= \frac{19.5}{2}$ cm^3 $) = 9.75$ (cm^3)

***M1**: Allow reading on graph to be from 19.4 to 19.7*
*giving **M1** = 9.7 to 9.85*

1

M2: pH = 4.80 to 4.95

***M2**: Reads off pH at half equivalence*

1

M3: K_a $(= 10^{-pH}) = 10^{-4.9} = 1.26 \times 10^{-5}$

***M3**: Allow 1.12×10^{-5} to 1.58×10^{-5}*

***M3**: Allow 2sf or more*

1

Alternative method

M1: pH of pure acid = 3

M2: $K_a = (10^{-3})^2 / 0.080$

M3: $= 1.25 \times 10^{-5}$

*Alternative **M1** if calculation incorrect:*

Allow pH = pK_a or $[H^+] = K_a$ at half equivalence

(c) cresolphthalein

1

(d)

M1: $K_a = \frac{[H^+][X^-]}{[HX]}$ or $[H^+] = \frac{K_a \times [HX]}{[X^-]}$

M1: allow $[H^+] = \frac{K_a \times [acid]}{[salt]}$

1

M2: amount of HX = 0.0500 mol

1

M3: amount of HX after add^n of KOH = $0.05 - \underline{3 \times 10^{-4}} = 0.0497$ mol

M3: = ***M2*** – 3×10^{-4}

1

M4: amount of KX after add^n of KOH = $0.0136 + \underline{3 \times 10^{-4}} = 0.0139$ mol

1

M5: $[H^+] = \left(\frac{1.41 \times 10^{-5} \times 0.0497}{0.0139}\right) = \frac{5.04(15) \times 10^{-5}}{}$

1

M6: pH = $-\log_{10} 5.04(15) \times 10^{-5} = 4.30$

Answer to 2 decimal places

1

*If no attempt at **M3** and **M4** max 2 marks*

*If **M3** or **M4** attempted using 3×10^{-4} max 4 (**M1**, **M2**, **M3** or **M4** and **M6**)*

(e)

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

Allow inverse expression

1

[15]

3.

(a) 7–10.2

any range (i.e. 2 values) within this range

1

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

ALLOW H_3O^+ for H^+ and A for X

IGNORE $[H^+]^2/[HX]$

must be square brackets

IGNORE state symbols

1

(c) Amount NaOH = $(24.0 \times 0.100)/1000 = 2.40 \times 10^{-3}$ mol

(= amount HX)

Conc HX = $2.40 \times 10^{-3}/0.025 = 0.0960$ mol dm^{-3}

ecf for M1/0.025

(d) ($K_a = 2.62 \times 10^{-5} = [H^+]^2/0.0960$)

$[H^+] = \sqrt{(2.62 \times 10^{-5} \times 0.0960)}$ (= 1.59×10^{-3} mol dm^{-3})

ecf from part (c) $[H^+] = \sqrt{(2.62 \times 10^{-5} \times$ ans to part (c))

From alternative data

$[H^+] = \sqrt{(2.62 \times 10^{-5} \times 0.600)}$ (= 3.96×10^{-3} mol dm^{-3})

(pH = –log 1.59×10^{-3} =) 2.80 (must be 2 or more dp)

1

pH = 2.40 (must be 2 or more dp)

M2 dependent on a calculation of $[H^+]$

1

(e) (pH at half-neutralisation = pK_a)

= –log 2.62×10^{-5} = 4.58 (must be 2 or more dp)

ALLOW 1dp if already penalised in part (d)

1

(f) Both points plotted correctly and line touches both points

ecf from (d) and (e) within 1 small square

1

<u>Line steeper at start</u> then levels (to show buffering)

Mark independently

1

[9]

4. (a) Formula of any strong acid (e.g. HCl)

1

Formula of a weak alkali (e.g. NH_3)

1

(b) Place a fixed volume of alkali in a flask or beaker

1

Add acid in small portions from a burette

1

Stir and use a pH meter to record the pH after each addition of acid

1

(c) Repeat the experiment with each indicator

1

Select the indicator that changes colour rapidly when the pH changes from about 7 to 4

1

[7]

5. (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]