pH and Indicators Marking Scheme

2017

Q9

QUESTION 9

(*a*) DEFINE: (*i*) **proton (H^+) acceptor //**

(*ii*) two species that **differ by a proton (H^+)** (2 × 3)

[Examples insufficient on their own.]

WHAT: **H_3O^+ / hydronium ion** (3)

(*b*) DEFINE: pH = **–log$_{10}$ [H^+]** / **–log$_{10}$ [H_3O^+]** / **minus log** base 10 **hydrogen ion concentration** expressed in moles per litre (3)

ACCOUNT: [Allow '*hydrochloric*' for HCl, '*sulfuric*' *for* H_2SO_4 and '*methanoic*' for HCOOH. Allow *H^+, proton, H_3O^+* or *hydronium ion* for '*hydrogen ion*'.]

(*i*) & (*ii*) First (9) marks available from **one** of the boxes below.

> RELEVANT HCl information
>
> 0.10 M **HCl produces 0.10** M **H^+** ion **/ pH HCl = –log (0.10)** (6)
>
> *or*
>
> **HCl monoprotic (monobasic) /** one molecule **HCl produces one H^+** ion **//**
>
> **HCl** is **strong (fully dissociated** into H^+ ions, **a good proton donor)** (2 × 3)
>
> *and*
>
> RELEVANT H_2SO_4 information
>
> 0.10 M **H_2SO_4 produces 0.20** M **H^+** ion **/**
>
> **pH H_2SO_4 = –log (0.20) /**
>
> **H_2SO_4 diprotic (dibasic) /**
>
> one molecule **H_2SO_4 produces two H^+** ions **/**
>
> **H_2SO_4 produces (has) more (twice as many) H^+ ions as HCl** (3)

or

> RELEVANT H_2SO_4 information
>
> 0.10 M **H_2SO_4 produces 0.20** M **H^+** ion **/ pH H_2SO_4 = –log (0.20)** (6)
>
> *or*
>
> **H_2SO_4 diprotic (dibasic) /**
>
> one molecule **H_2SO_4 produces two H^+** ions **/**
>
> **H_2SO_4 produces (has) more (twice as many) H^+ ions as HCl** (3)
>
> *and*
>
> RELEVANT HCl information
>
> 0.10 M **HCl produces 0.10** M **H^+** ion **/ pH HCl = –log (0.10)** (3)

and

RELEVANT HCOOH information

0.10 M **methanoic acid (HCOOH)** solution **produces 4.27 × 10^{-3}** M **(less than 0.10** M**) H^+** ion **/**

pH HCOOH = inverse log (–2.37) {antilog (–2.37)} /

HCOOH is **weak {slightly (not fully) dissociated** into H^+ ions, **a poor proton donor} /**

HCOOH weaker than HCl (3)

USE: (*iii*) K_a = **1.82 × 10⁻⁴** (6)

[H⁺] = **inverse log (–2.37)** */ **antilog (–2.37)*** / **4.27 × 10⁻³** / **10⁻²·³⁷** (3) ***Omission of minus loses this (3)** $\Rightarrow K_a = \frac{[H^+][A^-]}{[HA]} \left(\frac{[H^+]^2}{[HA]}, \frac{[H^+]^2}{[0.1]}\right)$ / $[H^+] = \sqrt{K_a[HA]}$ / $4.27 \times 10^{-3} = \sqrt{K_a[0.1]}$ / $[H^+]^2 = K_a[HA]$ / $(4.27 \times 10^{-3})^2 = K_a(0.1)$] K_a = **1.82 × 10⁻⁴** (3) [acid] = [HA] = [HX] = *M* = M_a

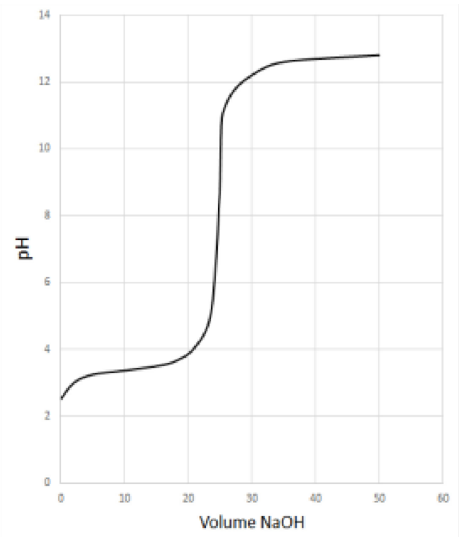
(*iv*) pH = **2.52** (3)

pH = –log $\sqrt{K_a[HA]}$*= –log $\sqrt{1.82 \times 10^{-4}[0.05]}$* = **2.52** (3) ***Omission of minus loses this (3)** [acid] = [HA] = [HX] = *M* = M_a

(*c*) DRAW: **axes labelled (pH and volume) //**
curve of correct shape with steep rise at 25 cm³ **//**
vertical part mostly above pH = 7 //
steep rise coincides with 25 cm³ NaOH

ANY THREE: (3 × 3)

[Allow correct work with volume scale increasing from right to left or pH decreasing on *y*-axis towards 0.]
[Allow volume on *y*-axis.]



NAME: **phenolphthalein** (6)

EXPLAIN: **colour change** (indicator **range) coincides with sharp rise on graph /**
colour change occurs > 7 /colour change occurs between 7 and 10 /
indicator **range** is **8.3 – 10** **(2)**
[NAME and EXPLAIN linked]

QUESTION 10

(*a*) (*i*) DISTNG: *stong acid:* **good proton donor / readily donates protons /** almost **fully dissociated** //
weak acid: **poor proton donor / slightly (poorly, weakly) dissociated** (2 × 3)
[Allow *'Partly (partially, not fully) dissociated' and 'does not readily donate protons' for weak acid description.*]

(*ii*) CALCULATE: **0.005** M (6)

pH= –log $[H^+]$ ⇒$[H^+]$ = inverse log (–2) = **0.01**	(3)
0.01 ÷ 2 (dibasic) = **0.005** M	(3)

CALCULATE: **5/9 (0.556)** M [**0.55 – 0.56** M] (6)

pH= –log $[H^+]$ ⇒$[H^+]$ = inverse log (–2) = **0.01**	
⇒ $\boldsymbol{K_a}$ **(1.8 × 10⁻⁴)** = $\frac{[H^+][A^-]}{[HA]}$ ($\frac{[H^+]^2}{[HA]}$, $\frac{(0.01)^2}{[HA]}$) / **[HA] =** $\frac{(0.01)^2}{1.8\times10^{-4}}$ / **[HA] =** $\frac{(0.01)^2}{Ka}$ / $[H^+] = \sqrt{Ka[HA]}$ / $0.01 = \sqrt{1.8\times10^{-4}[HA]}$ / $[H^+]^2 = Ka[HA]$ / $(0.01)^2 = 1.8\times10^{-4}[HA]$	(3)
[HA] = = **5/9 (0.55555)** M **[0.5556 – 0.56** M**]**	(3)
[acid] = [HA] = [HX] = *M* = M_a	

(*iii*) DEFINE: K_w = $\mathbf{[H^+][OH^-]}$ / K_w = $\mathbf{[H_3O^+][OH^-]}$ / **product of molar concentrations of hydrogen (hydronium) ions (H^+, H_3O^+) and hydroxide (hydroxyl) ions (OH^-) in water** (3)

WHAT: **3.0** × **10⁻⁷** M (4)

K_w (9.0 × 10⁻¹⁴) = $[H^+]^2$ / $[H^+] = \sqrt{K_w}$ ($\sqrt{9.0\times10^{-14}}$) / $[H^+]$ = $[OH^-]$	
⇒ $[H^+]$ = **3.0** × **10⁻⁷** M	**(4)**

2015 Q9

QUESTION 9

(*a*) DEFINE: (*i*) *Arrhenius acid*: **produces H^+ (hydrogen ion)** by dissociation **in water (aqueous solution)** //
(*ii*) *Brønsted-Lowry acid*: **proton (hydrogen ion, H^+) donor** (2 × 3)

(*b*) DEFINE: **$-\log_{10}[H^+]$ / $-\log_{10}[H_3O^+]$ / negative log** to base ten **of hydrogen (hydronium) ion concentration in moles per litre** (6)

STATE: **reliable (accurate, suitable)** only **for dilute solutions** / only **valid (useful)** in **0 - 14** range / **applies to aqueous solutions** only / **unreliable (inaccurate, unsuitable) in** very **concentrated solutions** / **unreliable for negative pH values** (3)
['*Temperature dependent* / *(25 °C)*' acceptable.]['*Valid range 1 – 14*' unacceptable but does not cancel.]

(*c*) GRAPH: *See graph on next page.*
both axes correctly labelled (*pH, V, volume, cm³, NaOH*) (3)
appropriate, correct numeric scales on both axes (3)
smooth curve of correct shape corresponding to 0 -15 cm³ NaOH added and from 25- 40 cm³ NaOH added (3)
careful plotting of vertical part (6)
[*Volume versus pH* acceptable.][(3) marks deducted if graph not on graph paper.]

(*d*) (*i*) CALCULATE: **0.014** M **[0.0139 – 0.014 M]** (9)

$[H^+] = \sqrt{K_a[CH_3COOH]}$ / inverse log (–3.3) / 5.01 × 10^{-4} /
$-\log\sqrt{K_a[CH_3COOH]} = 3.3$ / $\log\sqrt{K_a[CH_3COOH]} = -3.3$ (6)

$K_a = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]} / \frac{[H^+]^2}{[CH_3COOH]} / 1.8 \times 10^{-5} = \frac{[5.01 \times 10^{-4}]^2}{[CH_3COOH]}$

$[CH_3COOH]$ = **0.014** M **[0.0139 – 0.014 M]** (3)
Take [acid] or [HA] or *M* to be $[CH_3COOH]$ and $[A^-]$ to be $[CH_3COO^-]$

or

$[H^+] = \sqrt{K_a[CH_3COOH]}$ / inverse log (–3.3) / 5.01 × 10^{-4} /
$-\log\sqrt{K_a[CH_3COOH]} = 3.3$ / $\log\sqrt{K_a[CH_3COOH]} = -3.3$ (6)

$K_a[CH_3COOH] / 1.8 \times 10^{-5} \times [CH_3COOH] = (5.01 \times 10^{-4})^2$

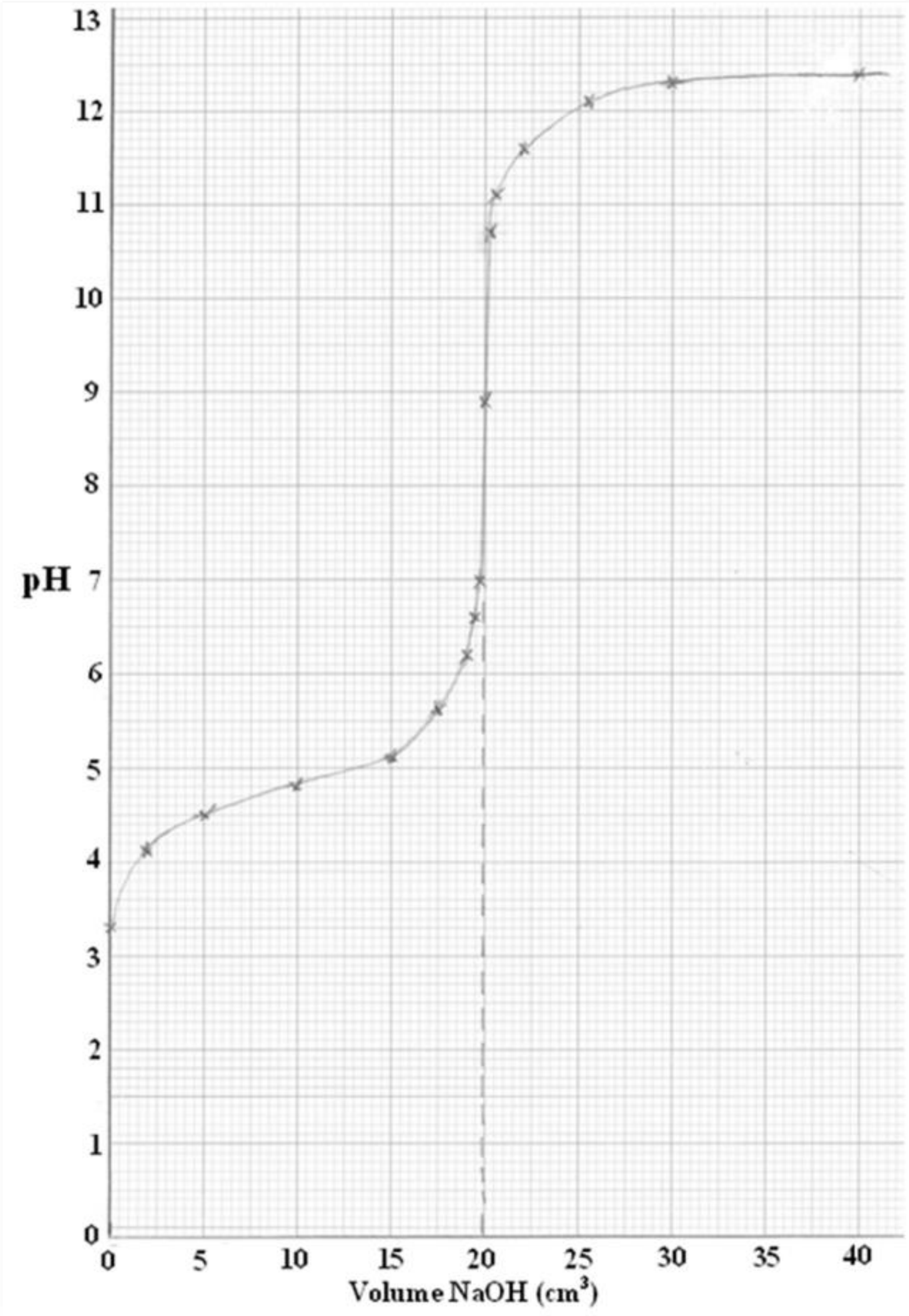
$[CH_3COOH] = \frac{(5.01 \times 10^{-4})^2}{1.8 \times 10^{-5}} = \frac{2.51 \times 10^{-7}}{1.8 \times 10^{-5}}$ = **0.014** **[0.0139 – 0.014 M]** (3)
Take [acid] or [HA] or *M* to be $[CH_3COOH]$ and $[A^-]$ to be $[CH_3COO^-]$

[*1 mark deducted for incorrect rounding off.*]

(*ii*) MAKE USE: **20 cm³** (3)

(*e*) WHAT: **phenolphthalein / thymol blue / cresol purple / thymolphthalein** **(6)**

REFER: **range** of phenolphthalein **coincides with vertical part of graph** / **range (8 -10) within pH jump** / phenolphthalein **changes colour corresponding to steep (vertical) part of graph** / phenolphthalein **changes colour within (coinciding with) pH jump** at end point / phenolphthalein **has one colour at pH = 8 (7, 6, before neutralisation, before vertical part of graph) and another at (after) pH = 10 (11, after neutralisation, after vertical part of graph)** **(2)**
[K_a (K_{In}, pK_a, pK_{In}) value of phenolphthalein acceptable for (4).]
[REFER marks available only if WHAT marks awarded.]


pH
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0
5
10
15
20
25
30
35
40
Volume NaOH (cm³)