ACIDS AND BASES AHL (HL only)

Please ensure that you have also completed the Core (SL & HL) questions

1. (a) Methanoic acid, HCOOH (aq), is a weak organic acid.

(i) Write the K_a expression for methanoic acid.

[1]

$K_a = \dfrac{[H^+][HCOO^-]}{[HCOOH]}$ ✓

(ii) Using section 21 of the data booklet, calculate the pH of a 0.0010 mol dm^{-3} solution of methanoic acid.

[3]

$K_a = \dfrac{[H^+]^2}{[HCOOH]_{initial}}$ $pK_a = 3.75$ $K_a = 10^{-3.75} = 1.778... \times 10^{-4}$ ✓

$[H^+] = \sqrt{1.778... \times 10^{-4} \times 0.0010}$

$= 4.2169... \times 10^{-4}$ ✓

(allow ecf)

correct answer scores 3

$pH = -\log_{10}[H^+]$ $pH = 3.375 = 3.4$ ✓

(iii) State one assumption that you made for your calculation in 1(a)(ii) above.

[1]

$[H^+] = [HCOO^-]$ (there is no H^+ contribution from water)

or $[HCOOH]_{eqm} = [HCOOH]_{initial}$ (negligible dissociation)

either ✓

(iv) Explain, with the aid of chemical equations, how an equimolar mixture of methanoic acid and sodium methanoate can act as a buffer solution, upon addition of small amounts of acid or base.

[4]

✓ $HCOONa \rightarrow Na^+ + HCOO^-$ (fully dissociates)

✓ $HCOOH \rightleftharpoons H^+ + HCOO^-$

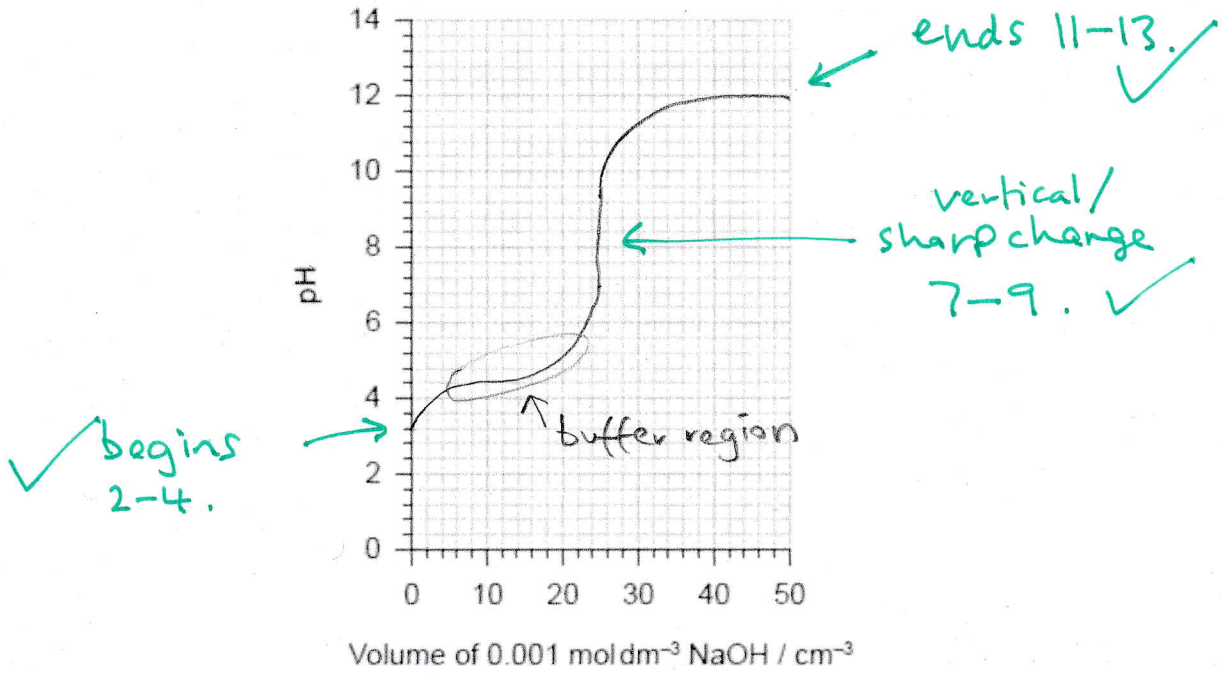
Upon addition of acid / when $[H^+]$ increases the equilibrium shifts Left / methanoate ions react with H^+ (to minimise the pH change) ✓

Upon addition of base $OH^- + H^+ \rightarrow H_2O$ / $[H^+]$ decreases the equilibrium shifts right / unreacted acid dissociates / unreacted acid reacts with the base ✓

(b) A titration is carried out: 50cm^3 of NaOH (0.0010 mol dm^{-3}) is gradually added to 25cm^3 of 0.0010 mol dm^{-3} methanoic acid.

(i) Sketch the shape of the titration curve on the graph.

[3]



(ii) Identify and label the buffer region on the graph.

shown and labelled ✓ (single arrow is fine) [1]

(iii) Explain how you could **use the graph** to determine the pK_a of methanoic acid.

[2]

Find the pH on the graph when 12.5cm^3 of NaOH has been added / at half-equivalence point. ✓

At this point pKa = pH ✓

(iv) Identify an indicator that could be used for the titration in 1(b)(i) using section 22 of the data booklet.

[1]

phenolphthalein or phenol red ✓

PTO

(vi) Calculate the K_b of the conjugate base of methanoic acid using sections 2 and 21 of the data booklet.

[2]

$pK_a + pK_b = 14$ (for acid-base pair) $\quad pK_a = 3.75 \quad pK_b = 10.25$ ✓

$K_b = 10^{-10.25} = 5.62 \times 10^{-11}$ ✓

Correct answer scores 2.

(c) Identify whether the following solutions are acidic, basic or neutral. Explain your reasoning.

* one mark for both basic & acidic ✓

[3]

Sodium methanoate: *basic, because methanoate ion reacts with water, $HCOO^- + H_2O \rightleftharpoons HCOOH + OH^-$ producing OH^- ions. words or equation ✓ (allow → rather than ⇌)

Ammonium chloride: *acidic, because ammonium ion reacts with water, $NH_4^+ + H_2O \rightleftharpoons NH_4OH + H^+$ producing H^+ ions. words or equation ✓ ditto

2. (a) Explain the Brønsted-Lowry acid-base **and** Lewis acid-base nature of water, H_2O.

[2]

H_2O can act as a B-L acid and donate a proton / H^+ to form OH^-, and can accept a proton / H^+ ion to form H_3O^+ therefore acting as a BL base ✓

H_2O can donate a lone-pair (Lewis base) but cannot accept a lone-pair, so cannot act as a Lewis acid. ✓

(b) Bromocresol green is a weak acid used as an indicator, and listed in section 22 of the data booklet. Using HIn (aq) to represent the protonated species, explain how bromocresol green functions as an indicator.

[3]

$HIn_{(aq)} \rightleftharpoons H^+_{(aq)} + In^-_{(aq)}$ ✓

yellow ✓ blue

when acid added eqm shifts left (Indicator goes yellow)

when alkali added eqm shifts right (Indicator goes blue) ✓

Total 26 marks (39 minutes)