Q1.

Equal volumes of pairs of solutions are mixed.

Which pair forms a buffer solution?

A ammonia and ammonium chloride ⬭

B ammonia and methylamine ⬭

C ethanoic acid and methanoic acid ⬭

D hydrochloric acid and sodium hydroxide ⬭

(Total 1 mark)

Q2.

A mixture of methanoic acid and sodium methanoate in aqueous solution acts as an acidic buffer solution. The equation shows the dissociation of methanoic acid.

$$HCOOH(aq) \rightleftharpoons HCOO^-(aq) + H^+(aq)$$

Calculate the mass, in g, of sodium methanoate (HCOONa) that must be added to 25.0 cm^3 of 0.100 mol dm^{-3} methanoic acid to produce a buffer solution with pH = 4.05 at 298 K

For methanoic acid, pK_a = 3.75 at 298 K

Assume that the volume of the solution remains constant.

Mass ________________ g

(Total 5 marks)

Q3.

Propanoic acid (C_2H_5COOH) is a weak acid.

The acid dissociation constant (K_a) for propanoic acid is 1.35×10^{-5} mol dm^{-3} at 25 ^{o}C

(a) State the meaning of the term weak acid.

____

____

(1)

(b) Give an expression for the acid dissociation constant for propanoic acid.

K_a

(1)

(c) A student dilutes 25.0 cm^3 of 0.500 mol dm^{-3} propanoic acid by adding water until the total volume is 100.0 cm^3

Calculate the pH of this diluted solution of propanoic acid.

Give your answer to 2 decimal places.

pH _______________

(4)

(d) A buffer solution with a pH of 4.50 is made by dissolving *x* g of sodium propanoate (C_2H_5COONa) in a solution of propanoic acid. The final volume of buffer solution is 500 cm^3 and the final concentration of the propanoic acid is 0.250 mol dm^{-3}

Calculate *x* in g

For propanoic acid, $K_a = 1.35 \times 10^{-5}$ mol dm^{-3}

x ____________________ g

(6)

(Total 12 marks)

Q4.

This question is about different pH values.

(a) For pure water at 40 °C, pH = 6.67
A student thought that the water was acidic. Explain why the student was incorrect.

Determine the value of K_w at this temperature.

Explanation ____

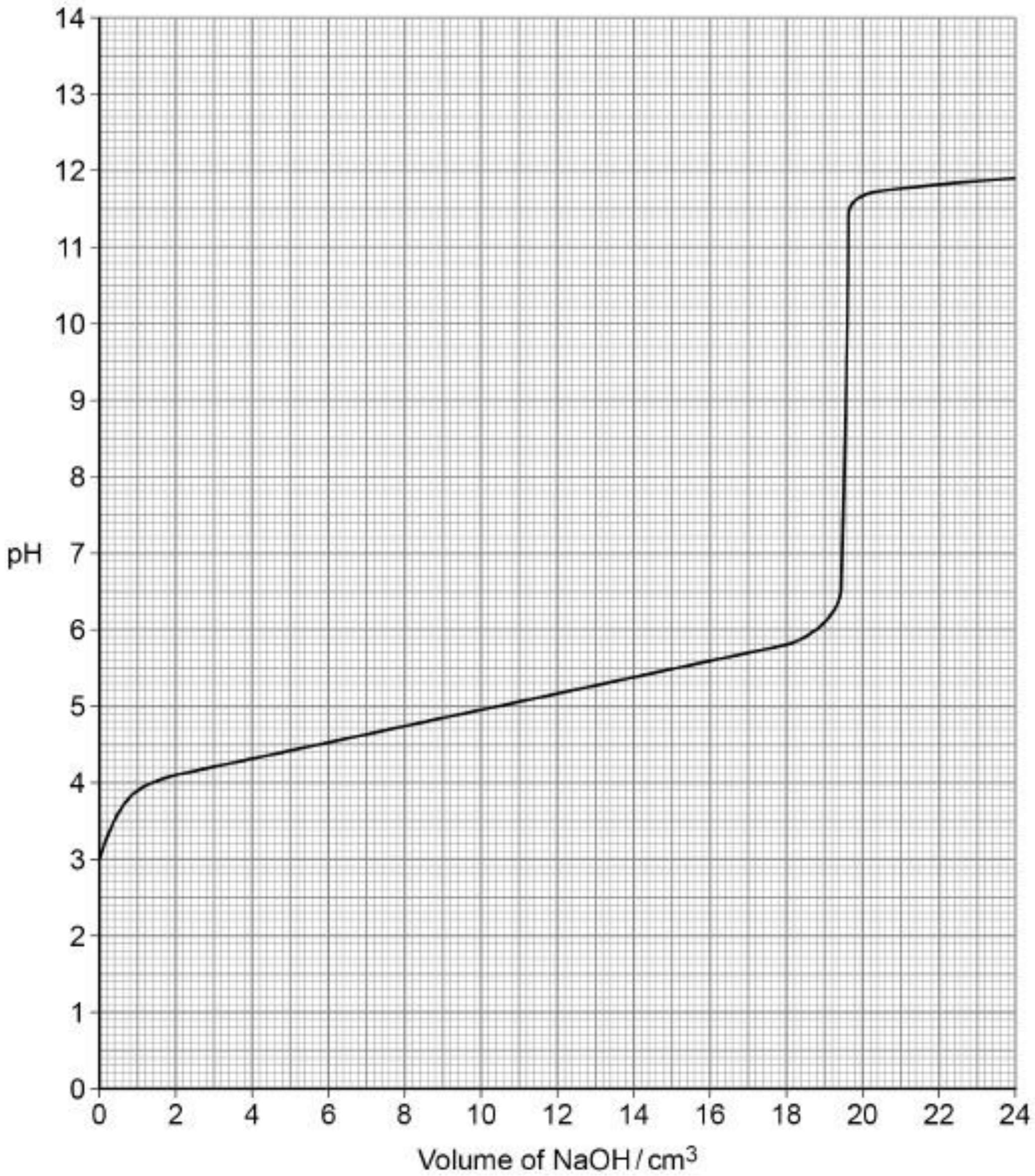
____

K_w ________________________________ $mol^2\ dm^{-6}$

(4)

(b) Sodium hydroxide solution was added gradually from a burette to 25 cm^3 of 0.080 mol dm^{-3} propanoic acid at 25 °C
The pH was measured and recorded at regular intervals.

The results are shown in the diagram.



Use the diagram above to determine the value of K_a for propanoic acid at 25 °C

Show your working.

K_a ______________________________ mol dm^{-3}
(3)

(c) Suggest which indicator is the most appropriate for the reaction in part **(b)**?
Tick (✓) **one** box.

Indicator	**pH range**	**Tick (✓) one box**
methyl orange	3.1 - 4.4	
bromothymol blue	6.0 - 7.6	
cresolphthalein	8.2 - 9.8	
indigo carmine	11.6 - 13.0	

(1)

(d) A student prepared a buffer solution by adding 0.0136 mol of a salt KX to 100 cm^3 of a 0.500 mol dm^{-3} solution of a weak acid HX and mixing thoroughly.

The student then added 3.00×10^{-4} mol of potassium hydroxide to the buffer solution.

Calculate the pH of the buffer solution after adding the potassium hydroxide.

For the weak acid HX at 25 °C the value of the acid dissociation constant, $K_a = 1.41 \times 10^{-5}$ mol dm^{-3}.

Give your answer to two decimal places.

pH ______________________________

(6)

(e) A buffer solution has a constant pH even when diluted.

Use a mathematical expression to explain this.

(1)

(Total 15 marks)

Q5.

Hydrochloric acid is a strong acid and ethanoic acid is a weak acid.

(a) State the meaning of the term strong acid.

____

____

(1)

(b) In an experiment, 10.35 cm^3 of 0.100 mol dm^{-3} hydrochloric acid are added to 25.0 cm^3 of 0.150 mol dm^{-3} barium hydroxide solution.

Calculate the pH of the solution that forms at 30 °C

$K_w = 1.47 \times 10^{-14}$ mol^2 dm^{-6} at 30 °C

Give your answer to 2 decimal places.

pH ____________________

(6)

(c) The pH of water at 30 °C is 6.92

Give the reason why water is neutral at this temperature.

____

____

(1)

(d) Identify the oxide that could react with water to form a solution with pH = 2

Tick (✓) **one** box.

Al_2O_3	☐
Na_2O	☐
SiO_2	☐
SO_2	☐

(1)

(e) Give the expression for the acid dissociation constant (K_a) for ethanoic acid (CH_3COOH).

K_a

(1)

(f) A buffer solution contains 0.025 mol of sodium ethanoate dissolved in 500 cm^3 of 0.0700 mol dm^{-3} ethanoic acid at 25 °C

A sample of 5.00 cm^3 of 2.00 mol dm^{-3} hydrochloric acid is added to this buffer solution.

Calculate the pH of the solution formed.

For ethanoic acid, $K_a = 1.76 \times 10^{-5}$ mol dm^{-3} at 25 °C

pH ______________________

(5)

(Total 15 marks)

Q6.

This question is about acidic solutions.

(a) The acid dissociation constant, K_a, for ethanoic acid is given by the expression

$$K_a = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]}$$

The value of K_a for ethanoic acid is 1.74×10^{-5} mol dm^{-3} at 25 °C

A buffer solution with a pH of 3.87 was prepared using ethanoic acid and sodium ethanoate. In the buffer solution, the concentration of ethanoate ions was 0.136 mol dm^{-3}

Calculate the concentration of the ethanoic acid in the buffer solution.

Give your answer to three significant figures.

Concentration of acid = ____________________ mol dm^{-3}

(3)

(b) In a different buffer solution, the concentration of ethanoic acid was 0.260 mol dm^{-3} and the concentration of ethanoate ions was 0.121 mol dm^{-3}

A 7.00×10^{-3} mol sample of sodium hydroxide was added to 500 cm^3 of this buffer solution. Calculate the pH of the buffer solution after the sodium hydroxide was added.

Give your answer to two decimal places.

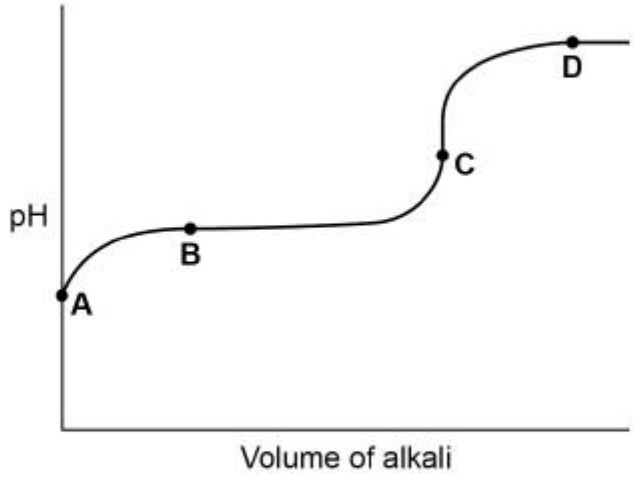
pH of buffer solution ____________________

(6)

(Total 9 marks)

Q7.

The diagram shows a pH curve produced by adding a strong alkali to a weak acid.



Which point on the curve represents a solution that can act as a buffer?

A ⬭

B ⬭

C ⬭

D ⬭

(Total 1 mark)

Q8.

This question is about Brønsted–Lowry acids.

(a) Give the meaning of the term Brønsted–Lowry acid.

____

____

(1)

(b) What is meant by the term strong when describing an acid?

____

____

(1)

(c) At 298 K, 25.0 cm^3 of a solution of a strong monoprotic acid contained 1.45×10^{-3} mol of hydrogen ions.

Calculate a value for the pH of this solution.
Give your answer to 2 decimal places.

pH ____________________

(2)

(d) Calculate the pH of the solution formed after the addition of 35.0 cm^3 of 0.150 mol dm^{-3} NaOH to the original 25.0 cm^3 of monoprotic acid.

The ionic product of water $K_w = 1.00 \times 10^{-14}$ $mol^2\ dm^{-6}$ at 298 K.
Give your answer to two decimal places.

pH ____________________

(5)

(e) A buffer solution is made when 1.50 g of sodium hydroxide are added to 1.00 dm^3 of a 0.150 mol dm^{-3} solution of a weak acid HA.

For HA, the acid dissociation constant, $K_a = 1.79 \times 10^{-5}$ mol dm^{-3}.

Calculate the pH of this buffer solution.

pH ____________________

(6)

(Total 15 marks)

Mark Scheme

Q1.

A

ammonia and ammonium chloride

[1]

Q2.

$K_a = 10^{-3.75} = 1.78 \times 10^{-4}$ mol dm^{-3}

$$pH = pK_a - \log \frac{[HCOOH]}{[HCOO^-]}$$

1

$[H^+] = 10^{-4.05} = 8.91 \times 10^{-5}$ mol dm^{-3}

$$\log \frac{[HCOOH]}{[HCOO^-]} = pK_a - pH = 3.75 - 4.05 = -0.30$$

1

$$[Salt] = \frac{1.78 \times 10^{-4} \times 0.100}{8.91 \times 10^{-5}} = 0.200$$

$$\frac{[HCOOH]}{[HCOO^-]} = 10^{-0.30} = 0.50 \text{ (and [HCOOH] = 0.1)}$$

(so $[HCOO^-] = 0.200$ mol dm^{-3})

1

amount = vol x conc = 0.200 x 25/1000 = 0.00500 mol

OR

amount acid = 0.0025 mol so amount salt = 0.005 mol

amount = vol x conc = 0.200 x 25/1000 = 0.00500 mol

1

mass = amount x M_r = 0.00500 x 68.0 = 0.339 / 0.34 g

mass = amount x M_r = 0.00500 x 68.0 = 0.339 g

1

[5]

Q3.

(a) (Acid) partially or slightly ionises/dissociates (in water to form H^+ ions)

Allow – does not fully ionise/dissociate

1

(b)

$$(K_a) = \frac{[H^+][C_2H_5COO^-]}{[C_2H_5COOH]}$$

Allow $[H_3O^+]$ for $[H^+]$

Do not allow ( )

1

(c) **M1** $[C_2H_5COOH]$ = <u>0.125</u> (mol dm^{-3})

*Allow consequential marking from wrong **M1***
*If $[C_2H_5COOH] = 0.0125$ (mol dm^{-3}) lose **M1**,*
*allow **M2**, **M3** = 4.108×10^{-4} and **M4** = 3.39*

1

M2 $[H^+] = \sqrt{Ka \times [C_2H_5COOH]}$ OR $[H^+] = \sqrt{1.35 \times 10^{-5} \times 0.125}$

1

M3 $[H^+] = 1.30 \times 10^{-3}$ (mol dm^{-3})

1

M4 pH = $-\log_{10} (1.30 \times 10^{-3}) = 2.89$
*Allow **M4** = $-\log_{10}$ **M3***
Answer must be to 2 decimal places

1

(d) **M1** $[H^+] = 10^{-4.5} = \underline{3.16 \times 10^{-5}}$ (mol dm^{-3})

1

M2 $[C_2H_5COO^-] = \frac{[C_2H_5COOH]\ K_a}{[H^+]}$

OR $[C_2H_5COO^-] = \frac{0.250 \times 1.35 \times 10^{-5}}{3.16 \times 10^{-5}}$

***M2**: Rearrangement*
*If rearrangement incorrect, could score **M1 M4 M5** and **M6***

1

M3 $[C_2H_5COO^-] = 0.1068$ (mol dm^{-3})

1

M4 M_r sodium propanoate = 96

1

M5 n (sodium propanoate) = 0.1068 x 0.5 = 0.0534

1

M6 mass (sodium propanoate, x) = 0.0534 x 96 = 5.13 (g)
***M6** Allow 5.09 to 5.14 (g)*

Alternative **M5** and **M6**

M5 0.1068 x 96 = 10.25 (g)
M5** = **M3** x **M4

M6 Mass (sodium propanoate, x) = $\frac{10.25}{2}$ = 5.13 (g)
10.25 g scores 4 marks
If Henderson Hasselbach used
***M1** pKa = $-\log(1.35 \times 10^{-5}) = 4.87$*
***M2** $\log[A^-] = pH - pK_a + \log[HA]$*
***M3** $\log[A^-] = 4.50 - 4.87 + (-0.60206) = -0.9717$*

M4 *$[CH_3CH_2COO^-] = 10^{-0.9717} = 0.1067$*
M5 *$M_r = 96(.0)$*
M6 *$x = 96.0 \times 0.1067/2 = 5.12$ g*

1

[12]

Q4.

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

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

1

M2: $[H^+]$ (= 10^{-pH}) = 2.138×10^{-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: = 1.25×10^{-5}

*Alternative **M1** if calculation incorrect:*
Allow pH = pK_a or $[H^+] = K_a$ at <u>half equivalence</u>

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

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]

Q5.

(a) completely dissociates/ionises (to form H^+ ions)

1

(b) **M1** moles HCl = 1.035 × 10^{-3} and moles $Ba(OH)_2$ = 3.75 × 10^{-3}

If M1 incorrect, lose M1 and M6

1

M2 moles OH^- = $\underline{2 \times}$ (3.75 × 10^{-3} = 7.50 × 10^{-3})

If M2 not x2, lose M2 and M6

1

M3 XS n OH^- = 7.50 × 10^{-3} - 1.035 × 10^{-3} = 6.465 × 10^{-3} mol in 35.35 cm^3

If no subtraction for M3, lose M3 and M6

1

M4 [OH] = 6.465 × 10^{-3} / 35.35 × 10^{-3} = 0.182885 mol dm^{-3}

= M3/35.35 × 10^{-3}

If M4 not /35.35 × 10^{-3}, lose M4 and M6

However, if divided by 35.35 only lose M4 and allow M6 (ecf = 10.09)

1

M5 $[H^+] = K_w/[OH^-]$ = 1.47 × 10^{-14} /0.182885 = 8.0378 × 10–14 mol dm^{-3}

= 1.47 × 10^{-14} / M4

If incorrect rearrangement or wrong equation, lose M5 and M6

If K_w = 1.00 × 10^{-14} used only lose M5 and allow M6 (ecf = 13.26)

1

M6 pH = 13.09 to 13.10

Must be 2dp

1

Alternative MS to get M2:

Starting amounts are 1.035 × 10^{-3} mol HCl and 3.75 × 10^{-3} mol $Ba(OH)_2$ M1

<u>So the HCl will react with 5.175 × 10^{-4} mol of the $Ba(OH)_2$ leaving an excess of 3.2325 × 10^{-3} mol of $Ba(OH)_2$ (as alternative M2)</u>

So n OH^- = 2 × 3.2325 × 10^{-3}= 6.465 × 10^{-3} mol M3

Credit other methods eg limiting reagent method since HCl limiting reagent

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

1

(d) SO_2

1

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

1

(f) **M1** moles HCl added = 0.01 mol and moles CH_3COOH = 0.035 mol

1

M2 moles CH_3COO^- = 0.025 – 0.01 (= 0.015)

M2 mol CH_3COO^- = 0.025 - M1(HCl)

1

M3 moles CH_3COOH = 0.035 + 0.01 (= 0.045)

M3 mol CH_3COOH = M1(CH_3COOH) + M1(HCl)

1

M4 $[H^+] = 1.76 \times 10^{-5} \times \frac{M3\ (/\ V)}{M2\ (/\ V)}$ (= 5.28 × 10^{-5})

M4 is conditional on an attempt at an addition/subtraction in M2 OR M3

1

M5 pH = <u>4.28</u>

M5 must be 2dp
If used 0.07 mol for CH_3COOH can score M2, M3 and M4 (pH = 4.03)

1

[15]

Q6.

(a) $[H^+] = (10^{-3.87} =)\ 1.3489 \times 10^{-4}$

Allow 1.35×10^{-4}. If M1 wrong can only score M2.

1

$$[CH_3COOH] = \frac{[H^+][CH_3COO^-]}{[Ka]} = \left(\frac{[1.3489 \times 10^{-4}][0.136]}{[1.74 \times 10^{-5}]} = 1.05436\right)$$

Mark is for correctly rearranged equation.

1

1.05 – 1.06 (mol dm^{-3})

3 sf or more

1

(b) **If 0.007 moles in 500 cm^3 seen follow Mark Scheme 1**

Mark Scheme 1

moles ethanoic acid = 0.130

1

moles sodium ethanoate = 0.0605

1

mol CH_3COOH after addition = (0.130 - 0.007) = 0.123

1

mol CH_3COO^- after addition = (0.0605+0.007) = 0.0675

1

$$[H^+] = \left(\frac{[Ka][CH_3COOH]}{[CH_3COO^-]}\right) = \frac{[1.74 \times 10^{-5}][0.123]}{[0.0675]} \ (= 3.171 \times 10^{-5})$$

1

pH = <u>4.50</u> (must be 2dp)

1

Method 1
For M3 allow M1 – 0.007
For M4 allow M2 + 0.007

If 0.014 moles in 1 dm^3 follow Mark Scheme 2

Mark Scheme 2

moles CH_3COOH after addition = (0.260 - 0.014) = 0.246 (This scores 2 marks)
moles CH_3COO^- after addition = (0.121 + 0.014) = 0.135 (This scores 2 marks)

$$[H^+] = \left(\frac{[Ka][CH_3COOH]}{[CH_3COO^-]}\right) = \frac{[1.74 \times 10^{-5}][0.246]}{[0.135]}$$

pH = <u>4.50</u> (must be 2dp)

Method 1 and 2
M5 = expression with their numbers
M6 = answer to 2 dp

pH = 4.50 scores 6 marks

If √used in K_a expression, stop at M4
If divide by 2 after M5, lose M6

Allow solutions which use Henderson-Hasselbach Equation

[9]

Q7.

B

[1]

Q8.

(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]