[AQA A2 Paper 1 2017]

The acid dissociation constant, Ka, for ethanoic acid is given by the expression

$$Ka = \frac{[CH3COO^-][H^+]}{[CH3COOH]}$$

The value of Ka for ethanoic acid is 1.74×10^{-5} moldm^{-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 moldm^{-3}.

a) Calculate the concentration of the ethanoic acid in the buffer solution. Give your answer to three significant figures.

① Rearrange the equation for $[CH_3COOH]$:

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

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

② Calculate $[H^+]$ ions from the solution pH:

$$[H^+] = 10^{-3.87}$$

$$\Rightarrow 1.3489 \times 10^{-4} \text{ moldm}^{-3}$$

$[H^+] = 10^{-pH}$

③ Sub in values to find $[CH_3COOH]$:

$$[CH_3COOH] = \frac{0.136 \times 1.3489 \times 10^{-4}}{1.74 \times 10^{-5}}$$

$$= 1.0543...$$

$$\Rightarrow \underline{1.05 \text{ moldm}^{-3}}$$

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

a buffer question like this can be worth up to 6 marks.

① Write an equation for the dissociation:

$$CH_3COOH \rightleftharpoons CH_3COO^- + H^+$$

② Start a table with the initial moles of each species:

	CH_3COOH	$\rightleftharpoons CH_3COO^-$	$+ H^+$
initial moles	0.130	0.0605	

halve the concentrations to find moles in 500cm^3.

or...

moles = $\frac{\text{conc.} \times \text{vol.}}{1000}$

③ Add the moles added to the solution:

	CH_3COOH	$\rightleftharpoons CH_3COO^-$	$+ H^+$
initial moles	0.130	0.0605	
moles added	$\downarrow 7\times10^{-3}$	$\uparrow 7\times10^{-3}$	$\downarrow 7\times10^{-3}$

this is always the same as the change in hydrogen ions.

these are always opposite as they react in a neutralisation reaction.

④ Calculate the new moles of each species:

	CH_3COOH $\rightleftharpoons$	CH_3COO^- +	H^+
initial moles	0.130	0.0605	
moles added	$\downarrow 7\times10^{-3}$	$\uparrow 7\times10^{-3}$	$\downarrow 7\times10^{-3}$
new moles	0.123	0.0675	

⑤ Rearrange the ka expression for $[H^+]$ ions:

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

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

⑥ Sub in the values to find $[H^+]$ ions:

$$[H^+] = \frac{1.74\times10^{-5}\times 0.123}{0.0675}$$

$$= 3.1706...\times10^{-5}\ moldm^{-3}$$

keep as many sig. figs as possible.

⑦ Calculate pH of the buffer:

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

$$pH = -\log_{10}(3.1706...\times10^{-5})$$

$$= 4.498...$$

$$\Rightarrow \underline{4.50} \ (2dp)$$