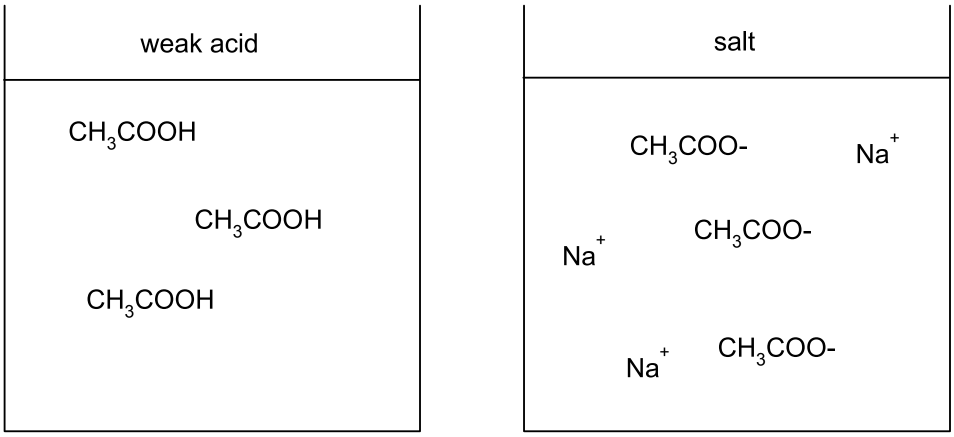
Watch a video tutorial about this at:

www.chemistry.jamesmungall.co.uk

Buffer Solutions Examples

1 a) What is the pH of a buffer solution containing 0.1 moldm^{-3} ethanoic acid and 0.1 moldm^{-3} sodium ethanoate? (pK_a ethanoic acid = 4.75)



$$HA \underset{}{\overset{K_a}{\rightleftharpoons}} H^+ + A^-$$

$$K_a = \frac{[H+]\ [A-]}{[HA]} \xrightarrow{\times [HA]} K_a\,[HA] = [H+]\ [A-]$$

swap sides

$$[H+]\ [A-] = K_a\,[HA]$$

$$[H+] = \frac{K_a\,[HA]}{[A-]} \xleftarrow{/\,[A^-]} [H+]\ [A-] = K_a\,[HA]$$

$$pH = pKa + p\,\frac{[HA]}{[A^-]}$$

$$= 4.75 \ - \log(0.1 / 0.1)$$

$$= \underline{\underline{4.75}}$$

note that pH = pK_a when the concentration of weak acid and salt is the same

b) What is its pH after the addition of 10cm^3 of 1.0 moldm^{-3} HCl(aq) to 1dm^3 of the solution?

How many moles of HCl are added?

$$\text{moles} = \frac{\text{concentration x volume}}{1000}$$

$$= \frac{1.0 \times 10}{1000}$$

= 0.01 moles HCl added

= 0.01 moles H^+ added

$[CH_3COOH]$ = 0.1 moldm^{-3}
$[CH_3COO^-]$ = 0.1 moldm^{-3}
and there is 1dm^3

Equation	CH_3COOH	$\rightleftharpoons$	CH_3COO^-	+	H^+
Ratio	1	:	1	:	1
Initial Moles	$\frac{0.1 \times 1000}{1000}$ = 0.1 moles		$\frac{0.1 \times 1000}{1000}$ = 0.1 moles		
Final Moles	0.1 + 0.01 = 0.11 moles		0.1 - 0.01 = 0.09 moles		

Amount of acid is increased by the amount of H^+ added

Amount of base is reduced by the amount of H^+ added

This is because the base will have reacted with the H^+ from HCl to form more ethanoic acid:

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

i.e. the reverse reaction in the equilibrium is favoured.

$$[CH_3COOH] = \frac{0.11}{1010}$$

$$[CH_3COO^-] = \frac{0.09}{1010}$$

The volume is now 1dm^3 for the original volume plus the 10cm^3 for the HCl added

$$pH = pKa + p\frac{[HA]}{[A^-]}$$

$$= 4.75 - \log\frac{(0.11 / 1010)}{(0.09 / 1010)}$$

but in fact the volumes cancel in this equation

$$\underline{\underline{= 4.66}}$$

The pH has gone down from 4.75 to 4.66.
The buffer has resisted change in pH on addition of a small amount of acid.

c) If $10cm^3$ of $1moldm^{-3}$ HCl had been added to $1dm^3$ of water, what would the change in pH be? (assume pH of pure water at this temperature is 7)

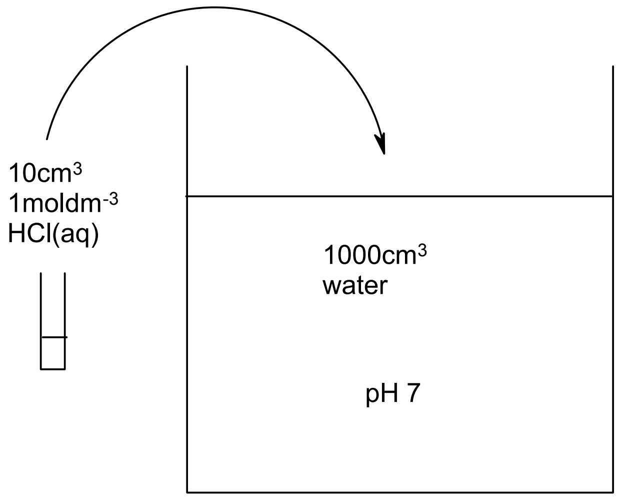
Moles of H^+ added:

$$\text{moles} = \frac{\text{concentration x volume}}{1000}$$

$$= \frac{1.0 \times 10}{1000}$$

= 0.01 moles HCl added

= 0.01 moles H^+ added



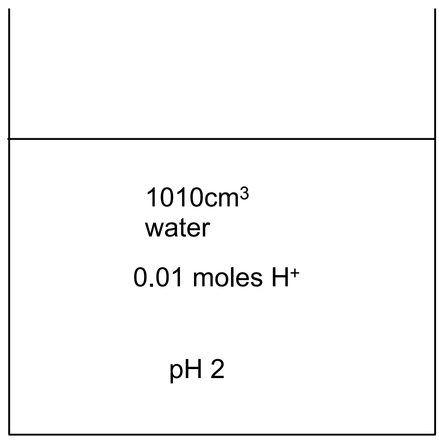
This is in $1010cm^3$ of water ($1dm^3$ plus the $10cm^3$ of acid solution).

Therefore the concentration of H^+ is:

$$\text{concentration} = \frac{\text{moles}}{(\text{ volume / 1000 })}$$

$$[H^+] = \frac{0.01}{(\text{ 1010 / 1000 })}$$

$$= 9.9 \times 10^{-3}\ moldm^{-3}$$



$pH = -\log [H^+]$

$= -\log 9.9 \times 10^{-3}$

$= \underline{2.0}$

Therefore the pH has reduced from 7 to 2. This is a change of 5 on the pH scale. Compare this with the change of pH in the buffer solution. The pH reduced from 4.75 to 4.66. This is a change of only 0.09 on the pH scale.