pH Calculations during neutralisation and dilution

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Working out pH by part neutralising a strong acid with a strong base

We start with a strong acid. Some of it is neutralised.

What are we left with?

A strong acid but fewer moles, so lower concentration

The pH will be higher

50cm^3 of 1M HCl is reacted with 30cm^3 of 0.7M NaOH.
What will be the pH of the resulting mixture?

Working out pH by part neutralising a strong acid with a strong base

First we need to work out how many moles of acid is left.

- work out number of moles in original acid

moles = conc x vol = 1 x 50/1000 = 0.05mol

- work out number of moles in base added

moles = conc x vol = 0.7 x 30/1000 = 0.021mol

- work out moles of acid left by subtracting base moles from acid moles (will need to convert moles if not 1:1 ratio)

Moles HCl left = 0.05-0.021 =0.029 mol

- work out new concentration of remaining acid by dividing the remaining moles by new total volume (vol acid + vol alkali added)

Conc HCl = 0.029/(80/1000) =0.3625M

•work out conc of H^+ and put in pH equation

As strong acid with complete dissociation

Conc H^+ =0.3625M

pH = - log [H^+]

= - log [0.3625]

= 0.44

Working out pH by part neutralising a weak acid with a strong base

We start with a weak acid. Some of it is neutralised.

What are we left with?

A weak acid but fewer moles, so lower concentration, but because weak acids are equilibria we must use the ka expression and also consider what effect the salt formed A^- has on the equilibrium amount of H^+ ions

$$CH_3CO_2H_{(aq)} \rightleftharpoons CH_3CO_2^-{}_{(aq)} + H^+{}_{(aq)}$$

50cm^3 of 1M CH_3COOH is reacted with 30cm^3 of 0.7M NaOH. What will be the pH of the resulting mixture?

Working out pH by part neutralising a weak acid with a strong base

First we need to work out how many moles of acid is left.

This is exactly the same as in the stong acid case

- work out number of moles in original weak acid

moles = conc x vol = 1 x 50/1000 = 0.05mol

- work out number of moles in base added

moles = conc x vol = 0.7 x 30/1000 = 0.021mol

- work out moles of acid left by subtracting base moles from acid moles (will need to convert moles if not 1:1 ratio)

Moles CH_3COOH left = 0.05-0.021 =0.029 mol

- work out new concentration of remaining acid by dividing the remaining moles by new total volume (vol acid + vol alkali added)

Conc CH_3COOH = 0.029/(80/1000) =0.3625M

• work out moles of salt formed from the balanced equation

1 mole of OH^- give 1 mole of salt formed

0.021 moles OH^- gives 0.021 moles of CH_3COO^-

- work out concentration of salt formed by dividing the moles of salt by new total volume (vol acid + vol alkali added)

Conc CH_3COO^- = 0.021/(80/1000) =0.2625M

Put values of Ka, and concs of acid and salt into equilibrium expression to work out conc of H^+

$$Ka = \frac{[H^+_{(aq)}][CH_3CO_2^-{}_{(aq)}]}{[CH_3CO_2H_{(aq)}]}$$

$$[H^+_{(aq)}] = Ka \frac{[HA_{(aq)}]}{[A^-_{(aq)}]}$$

$$[H^+_{(aq)}] = 1.7 \times 10^{-5} \frac{0.3625}{0.2625} = 2.348\times10^{-5}$$

put in pH equation

pH = - log [H+]

$$pH = -\log[H^+]$$
$$= -\log[2.348\times10^{-5}]$$
$$= 4.63$$

Working out pH of a weak acid at half equivalence

When a weak acid has been reacted with exactly half the neutralisation volume of alkali, the calculation can be simplified considerably.

$$[H^+_{(aq)}] = Ka \frac{[HA_{(aq)}]}{[A^-_{(aq)}]}$$

At half neutralisation we can make the assumption that [HA] = [A-]

So $[H^+_{(aq)}]$ = ka

And pH = pka

What is the pH of the resulting solution when $25cm^3$ of 0.1M NaOH is added to $50cm^3$ of 0.1M CH_3COOH (ka 1.7×10^{-5})

pH = -log (1.7×10^{-5}) = 4.77

Working out pH by adding excess alkali when neutralising a strong or weak acid

We start with acid (strong or weak). We add more strong alkali than is needed to neutralise the acid .

What are we left with?

A strong alkali

$30cm^3$ of 0.8M HCl is reacted with $60cm^3$ of 0.7M NaOH. What will be the pH of the resulting mixture?

Working out pH by adding excess alkali when neutralising a strong or weak acid

First we need to work out how many moles of alkali is left.

- work out number of moles in original acid

moles = conc x vol = 0.8 x 30/1000 = 0.024mol

- work out number of moles in base added

moles = conc x vol = 0.7 x 60/1000 = 0.042mol

- work out moles of base left by subtracting acid moles from base moles (will need to convert moles if not 1:1 ratio)

Moles NaOH left = 0.042-0.024 =0.018 mol

- work out new concentration of remaining alkali by dividing the remaining moles by new total volume (vol acid + vol alkali added)

Conc NaOH = 0.018/(90/1000) =0.2M

- use Kw expression to work out $[H^+]$

$Kw = [H^+_{(aq)}][OH^-_{(aq)}] = 1x10^{-14}$

$[H^+(aq)] = kw/ [OH^-_{(aq)}] = 1x10^{-14} / 0.2 = 5x10^{-14}$ M

put in pH equation

pH = - log $[H^+]$

= - log $[5x10^{-14}]$

= 13.3

Diluting an acid or alkali

1. work out number of moles in original acid (conc x vol)
2. work out new concentration by dividing the moles by new total volume (initial volume + what volume water that has been added)
3. calculate pH of new concentration of acid using appropriate method i.e strong acid/weak acid/ strong base

Or more simply

pH of diluted strong acid

$$[H^+] = [H^+]_{old} \times \frac{\text{old volume}}{\text{new volume}}$$

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

pH of diluted base

$$[OH^-] = [OH^-]_{old} \times \frac{\text{old volume}}{\text{new volume}}$$

$$[H^+] = \frac{K_w}{[OH^-]}$$

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