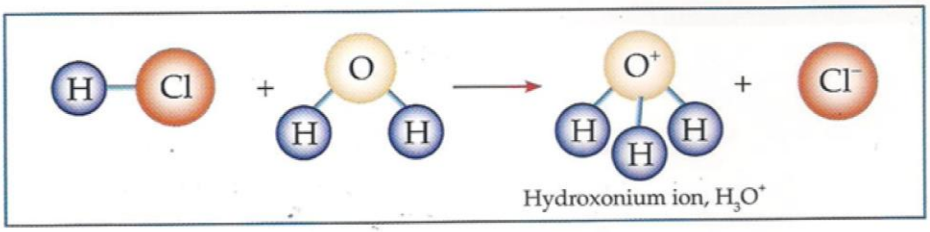
Acids

Acids – chemical substances that ionises in water to produce hydrogen ions, H^+ or hydroxonium ions, H_3O^+



Formation of hydroxonium ions

Acids

Role of water in acids
In the presence of water, acid show its acidic properties.

Basicity of acids
- Monoprotic acid
- Diprotic acid
- Triprotic acid

Uses of some acids

Benzoic acid
- Used to preserve food

Nitric acid
- Used in the manufacture of fertilisers, explosives, dyes and plastics

Sulphuric acid
- Used in the manufacture of paints, detergents, polymers, fertilisers
- Used as an electrolyte in lead-acid accumulator

Methanoic acid
- Used to coagulate latex in the rubber industries

Ethanoic acid
- The main component of vinegar

Chemical Properties of Acids

- Sour in taste
- pH values of less than 7
- Change colours of indicators
  - blue litmus paper to red
  - universal indicator to orange or red
  - methyl orange to red

Chemical properties of acids

❶ Acid + base → salt + water

$H_2SO_4(aq) + ZnO(s) \rightarrow ZnSO_4(aq) + H_2O(l)$

sulphuric acid, zinc oxide, zinc sulphate, water

❷ Acid + metal → salt + hydrogen gas

$2HCl(aq) + Mg(s) \rightarrow MgCl_2(aq) + H_2(g)$

hydrochloric acid, magnesium, magnesium chloride, hydrogen gas

❸ Acid + carbonate → salt + water + carbon dioxide

$2HNO_3(aq) + CuCO_3(s) \rightarrow Cu(NO_3)_2(aq) + H_2O(l) + CO_2(g)$

nitric acid, copper(II) carbonate, copper(II) nitrate, water, carbon dioxide

❶ Acids react with bases to form salts and water.

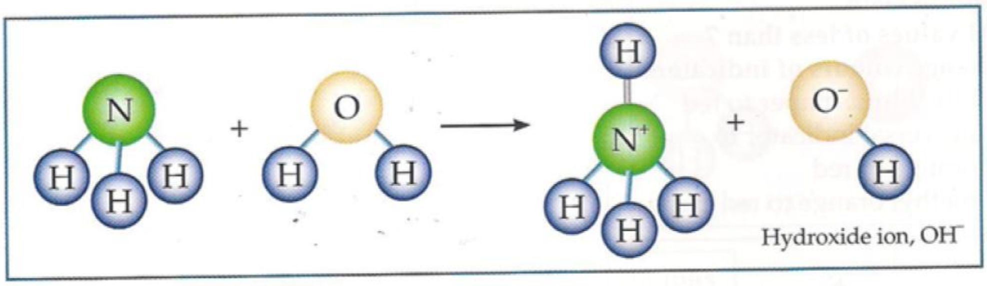
❷ Acids react with reactive metals to produce salts and hydrogen gas.

❸ Acids react with carbonates to produce salts, water and carbon dioxide.

Bases and Alkalis

Bases – chemical substances that can neutralise an acid to form a salt and water

Alkalis – bases that can dissolve in water to produce hydroxide ions, OH^-



Formation of hydroxide ions

Bases and alkalis

Role of water in alkalis
In the presence of water, an alkali shows its alkaline properties.

Uses of some bases

Magnesium hydroxide
- Used to make toothpaste, and gastric medicine

Sodium hydroxide
- Used to make soaps, detergents, fertilisers and bleaching agents

Ammonia
- Used to make fertilisers, nitric acid, and grease remover
- Used to keep latex in liquid form

Calcium hydroxide
- Used to make cement, lime water and to neutralise the acidity of soil

Aluminium hydroxide
- Used to make gastric medicine

Chemical Properties of Alkalis

- Bitter in taste and feel soapy
- pH values of more than 7
- Change colours of indicators
  - red litmus paper to blue
  - universal indicator to blue or purple
  - methyl orange to yellow

Chemical properties of alkalis

❶ **Alkali + acid → salt + water**

$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$

sodium hydroxide, hydrochloric acid → sodium chloride, water

❷ **Alkali + metal ion → insoluble metal hydroxide**

$2OH^-(aq) + Cu^{2+}(aq) \rightarrow Cu(OH)_2(s)$

hydroxide ion, copper(II) ion → copper(II) hydroxide (blue precipitate)

❸ **Alkali + ammonium salt → salt + water + ammonia gas**

$NaOH(aq) + NH_4Cl(aq) \rightarrow NaCl(aq) + H_2O(l) + NH_3(g)$

sodium hydroxide, ammonium chloride → sodium chloride, water, ammonia gas

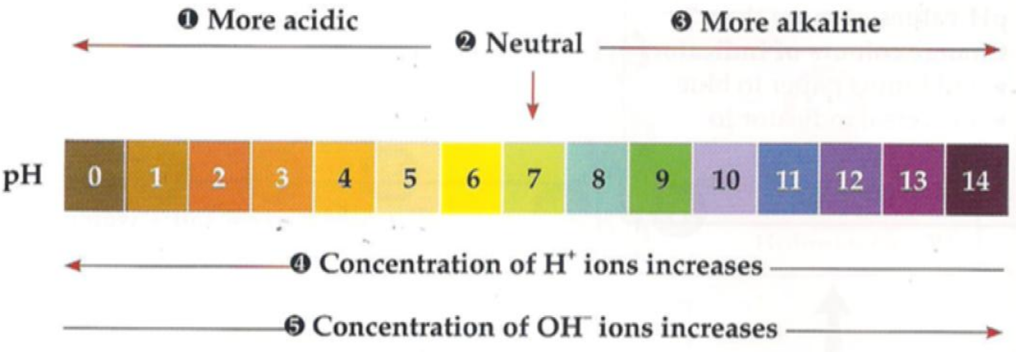
❶ Alkalis react with acids to form salts and water.

❷ Ammonia gas is liberated when a mixture of an alkali and an ammonium salt is heated.

❸ Most metal hydroxides are insoluble in water. Adding an alkali to most metal ion solutions (except Group 1 metal ions) will give a precipitate of an insoluble metal hydroxide.

The pH scale

pH scale – a set of numbers used to indicate the degree of acidity or alkalinity of a solution



❶ pH value less than 7 indicates an acidic solution.

❷ pH value equals to 7 indicates a neutral solution.

❸ pH value greater than 7 indicates an alkaline solution.

❹ The lower the pH value, the higher the concentration of H^+.

❺ The higher the pH value, the higher the concentration of OH^-.

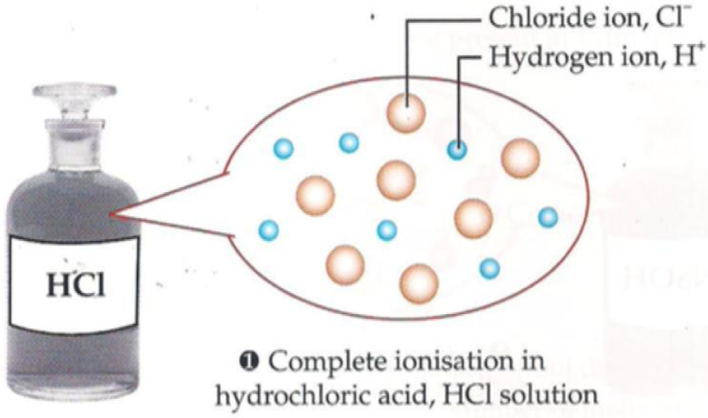
INSTANT FACT

The pH value of some substances are as follows:

pH 1 = concentrated hydrochloric acid, battery acid
pH 2 = hydrochloric acid secreted by stomach lining
pH 3 = lemon juice, vinegar, gastric acid
pH 4 = orange juice, grapefruit, soda
pH 5 = black coffee, soft drinking water
pH 6 = saliva, urine
pH 7 = pure water
pH 8 = sea water
pH 9 = baking soda
pH 10 = milk of magnesia, great salt lake
pH 11 = ammonia solution
pH 12 = soapy water
pH 13 = bleaches, oven cleaner
pH 14 = liquid drain cleaner

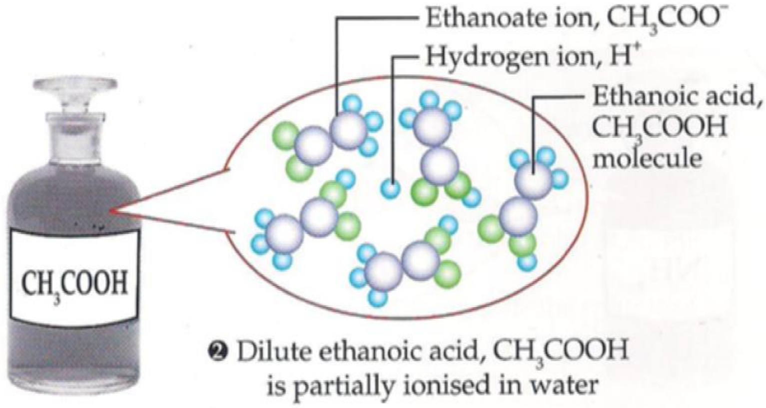
Strong and Weak Acids

Strong acid – an acid which ionises completely in water to produce hydrogen ions



❶ Complete ionisation in hydrochloric acid, HCl solution

Weak acid – an acid which is only partially ionised in water



❷ Dilute ethanoic acid, CH_3COOH is partially ionised in water

❶
- Hydrochloric acid is a strong acid.
- All the hydrogen chloride molecules that dissolve in water ionise completely into hydrogen ions and chloride ions.

$$HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$$

- There are no hydrogen chloride molecules in the acid.

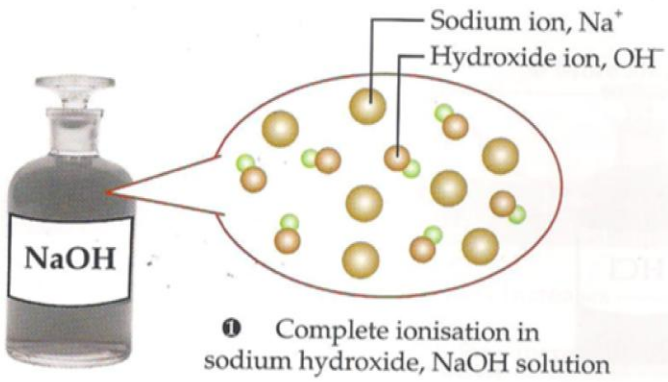
❷
- Ethanoic acid is a weak acid.
- Out of every 100 ethanoic acid molecules, only one of them ionises in water to form hydrogen ion and ethanoate ion.

$$CH_3COOH(aq) \rightleftharpoons H^+(aq) + CH_3COO^-(aq)$$

- The ethanoic acid molecules are still present in the acid. The ions combine again to form the original acid molecules.

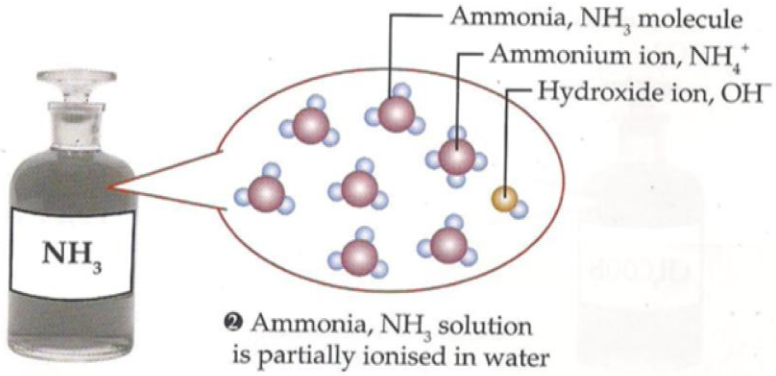
Strong and Weak Alkalis

Strong alkali – an alkali that ionised completely in water to produce hydroxide ion



❶ Complete ionisation in sodium hydroxide, NaOH solution

Weak alkali – an alkali which is only partially ionised in water



❷ Ammonia, NH_3 solution is partially ionised in water

❶
- Sodium hydroxide is a strong alkali.
- All the sodium hydroxide molecules that dissolve in water ionise completely into hydroxide ions and sodium ions.

$$NaOH(aq) \rightarrow Na^+(aq) + OH^-(aq)$$

❷
- Ammonia is a weak alkali.
- Only a small amount of ammonia molecules are ionised in water to form hydroxide ion and ammonium ion.

$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

- The ammonia molecules are still present in the alkali. The ions combine again to form the molecules.

Concentration of Acids and Alkalis

Concentration – the quantity of solute in a given volume of solution, which is usually 1 dm^3

Molarity – the number of moles of solute that are present in 1 dm^3 of solution

$$\text{❶ Molarity (mol dm}^{-3}) \underset{\div \text{ Molar mass}}{\overset{\times \text{ Molar mass}}{\rightleftarrows}} \text{❷ Concentration (g dm}^{-3})$$

❶ Concentration ($g\ dm^{-3}$)

$$= \frac{\text{Mass of solute (g)}}{\text{Volume of solution (dm}^3)}$$

❷ Molarity ($mol\ dm^{-3}$)

$$= \frac{\text{Number of moles of solute (mol)}}{\text{Volume of solution (dm}^3)}$$

WORKED EXAMPLES

1 The concentration of nitric acid, HNO_3 is 126 g dm^{-3}. What is its molarity?
[Relative atomic mass: H, 1; N, 14; O, 16]

Molar mass of HNO_3
$= 1 + 14 + 3(16)\ g\ mol^{-1}$
$= 63\ g\ mol^{-1}$

Molarity of HNO_3
$= \dfrac{126\ g\ dm^{-3}}{63\ g\ mol^{-1}}$
$= 2.0\ mol\ dm^{-3}$

2 How many moles of solute are in 20 cm^3 of solution with a molarity of 0.4 mol dm^{-3}?

- 0.4 mol dm^{-3} of a solution contains 0.4 moles of solute in 1 dm^3 solution.
- 20 cm^3 solution equals to 0.02 dm^3 solution

∴ 0.02 dm^3 contains
$= 0.02 \times 0.4$ moles of solute
$= 0.008$ moles of solute

3 Calculate the volume of a 4 mol dm^{-3} solution containing 2 moles of solute?

4 moles of solute are contained in 1 dm^3 solution
∴ 2 moles of solute are contained in
$= \dfrac{1\ dm^3}{4\ \text{moles}} \times 2$ moles
$= 0.5\ dm^3$
$= 500\ cm^3$

Preparation of Standard Solutions

A standard solution – a solution where its concentration is accurately known

❶ Calculate the mass of solute needed → ❷ Weigh out the exact mass of solute needed → ❸ Dissolve the solute in a small amount of distilled water → ❹ Transfer the dissolved solute into a suitable volumetric flask → ❺ Add enough water to the required volume

❶ The molar mass of the solute is determined and the mass of the solute is calculated.

❷ Weigh out the amount of the solute that has been calculated.

❸ The solute is dissolved in a small amount of distilled water and the solute is swirled to dissolve the solid.

❹ The dissolved solute is transferred into a suitable volumetric flask.

❺ Water is added to the required volume. A stopper is put and the solution in the volumetric flask is shaked well. A standard solution is ready.

WORKED EXAMPLES

1 Calculate the amount of sodium hydroxide to be used for the preparation of 100 cm^3 of sodium hydroxide solution with a concentration of 2.0 mol dm^{-3}.

Molar mass of NaOH
$= 23 + 16 + 1 = 40$ g

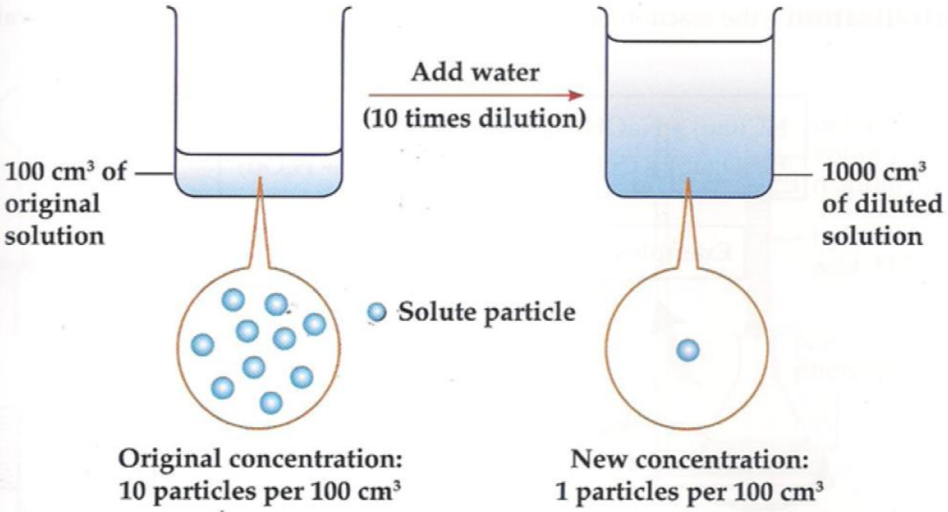
Mass of NaOH required
= Number of mole NaOH × Molecular mass of NaOH

$$= \frac{MV}{1000} \times 40 \text{ g}$$

$$= \frac{2.0}{1000} \times 100 \times 40 \text{ g}$$

$$= 8.0 \text{ g}$$

Dilution



$$M_1 \times V_1 = M_2 \times V_2$$

M_1 = molarity of the solution before water is added
V_1 = volume of the solution before water is added
M_2 = molarity of the solution after water is added
V_2 = volume of the solution after water is added

- During dilution, the amount of dissolved solute is fixed. The amount of solvent (water) is increased.
- As a result, the concentration of the solution will be decreased.

WORKED EXAMPLES

1 Calculate the volume of 2.0 mol dm^{-3} sulphuric acid, H_2SO_4 needed to prepare 100 cm^3 of 1.0 mol dm^{-3} sulphuric acid, H_2SO_4.

The volume of H_2SO_4 needed

$= \dfrac{1.0 \times 100}{2.0}$

$= 50\ cm^3$

Neutralisation

Neutralisation – the reaction of an acid and a base or alkali to form a salt and water

$$HCl(aq) + NaOH(aq) \longrightarrow NaCl(aq) + H_2O(l)$$
$$H_2SO_4(aq) + CuO(aq) \longrightarrow CuSO_4(aq) + H_2O(l)$$

Examples of neutralisation reactions

Neutralisation

Ionic equation for neutralisation

$$H^+(aq) + OH^-(aq) \longrightarrow H_2O(l)$$

Applications of neutralisation in daily life

Soil treatment

- Quick lime (calcium oxide) and slaked lime (calcium hydroxide) is added to the soil to neutralise the excess acid.

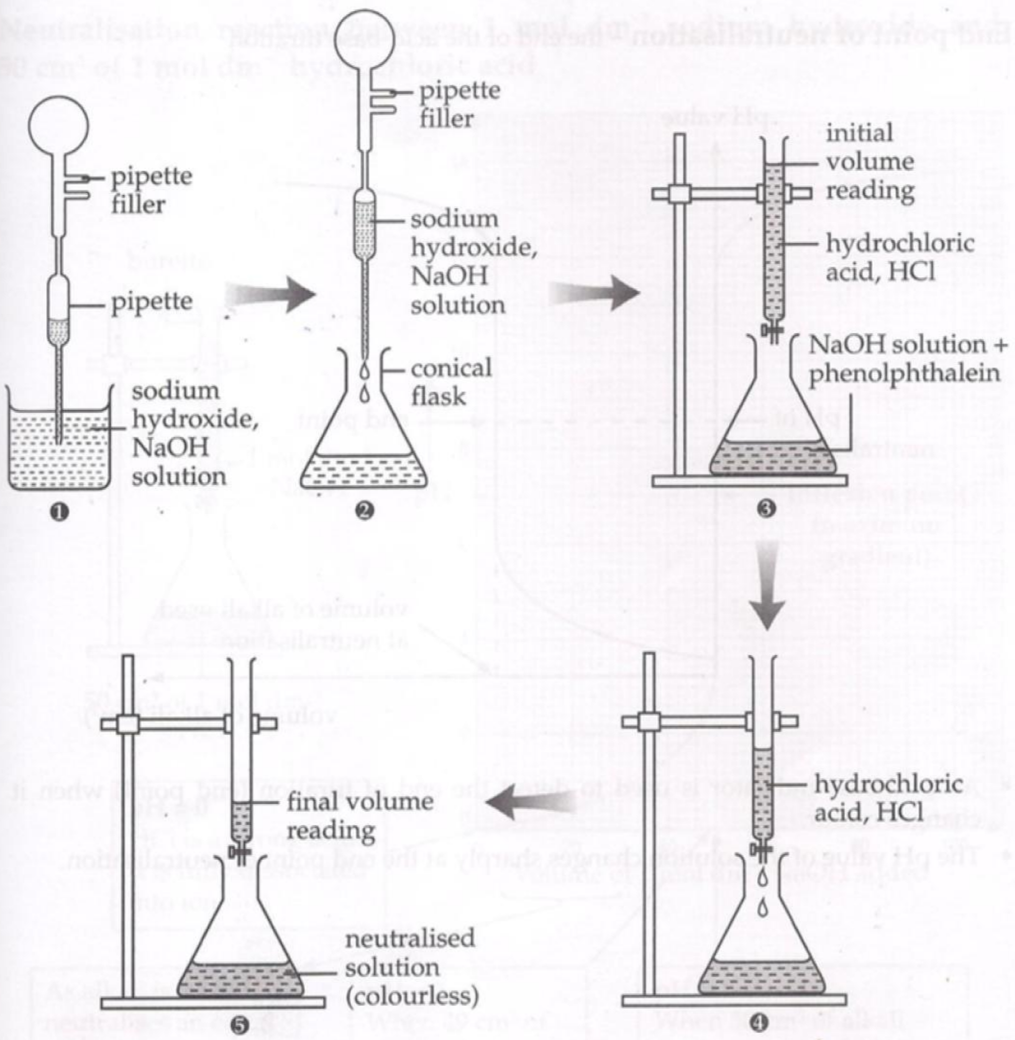
Industries

- Acidic effluent is treated with quick lime before discharged.
- Acidic gas (SO_2) is neutralised with quick lime before discharged.

Baking powder

- Baking powder contains bicarbonate of soda and a weak acid.
- When water is added, the acid is reacting on the carbonate and gives out carbon dioxide, which raises the cake.

Acid-base Titration



❶ A pipette is used to draw up 25.0 cm^3 of sodium hydroxide, NaOH solution.

❷ The NaOH solution is transferred into a conical flask.

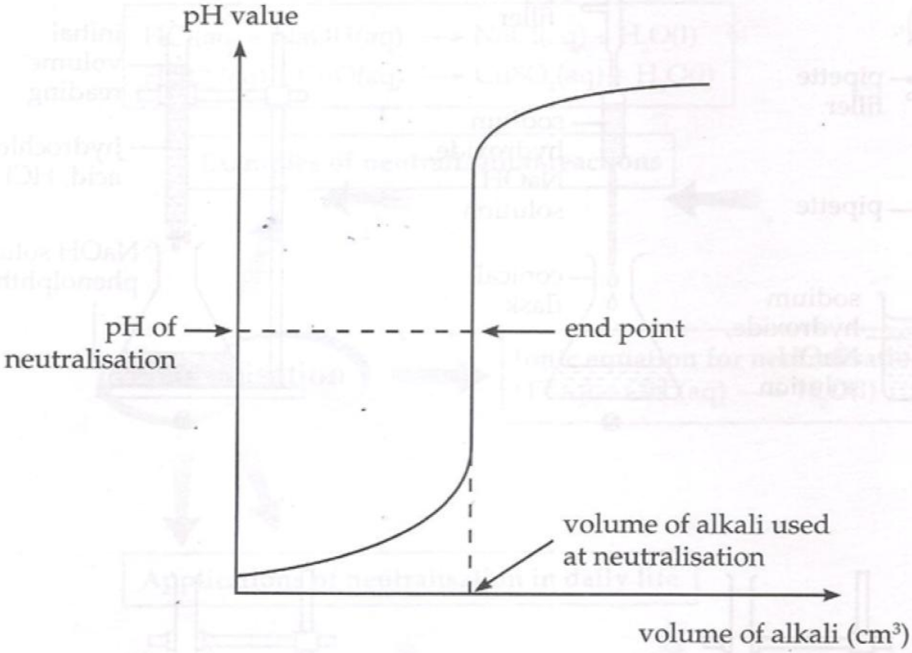
❸ Two to three drops of phenolphthalein is added to NaOH solution. A burette is filled with hydrochloric acid, HCl. The initial burette reading is recorded.

❹ HCl is added drop by drop into the alkali solution. The contents of the flask is swirled.

❺ HCl is added continuously until the indicator changes colour. The final burette reading is recorded.

End Point of Neutralisation

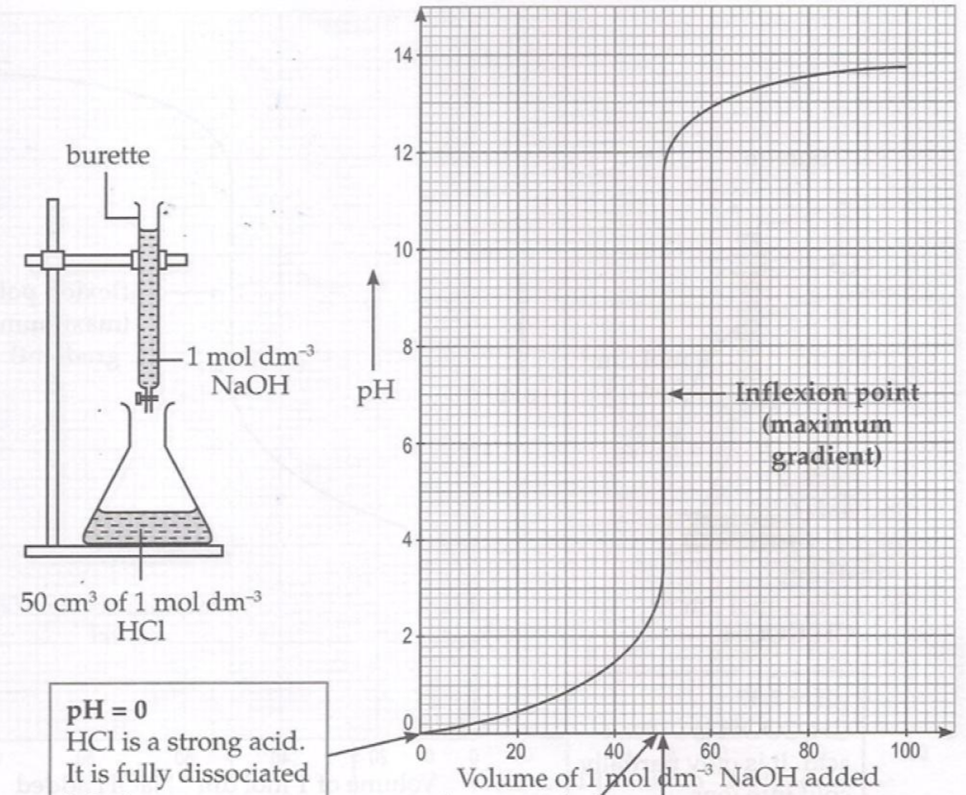
End point of neutralisation – the end of the acid-base titration



- An acid-base indicator is used to detect the end of titration (end point) when it changes colour.
- The pH value of the solution changes sharply at the end point of neutralisation.

Neutralisation between Strong Acid and Strong Alkali

Neutralisation reaction between 1 mol dm^{-3} sodium hydroxide and 50 cm^3 of 1 mol dm^{-3} hydrochloric acid



pH = 0
HCl is a strong acid. It is fully dissociated into ions.

As alkali is added, it neutralises an equal volume of acid to form salt and water. The remaining acid is diluted by the increased volume of water. The concentration of H^+ ions decreases and the pH increases.

pH = 2
When 49 cm^3 of alkali have been added, only 1 cm^3 of acid remains unneutralised. This 1 cm^3 of acid is in 99 cm^3 of solution so it is diluted about 100 times.

pH = 7
When 50 cm^3 of alkali have been added, the acid is completely reacted leaving salt and water. This is indicated by the inflexion point. The alkali added from now on has nothing to react with. The pH rises towards a final value of 14.