

2.1.4 Acids

An acid releases H^+ ions in aqueous solution

The most common strong acids are :
Hydrochloric (HCl), sulphuric (H_2SO_4) and nitric (HNO_3) acid;
Ethanoic acid CH_3COOH is a weak acid

There are several definitions of acids we use in chemistry. One we use later in the course is the Bronsted- Lowry acid which is defined as a proton (H^+) donor

Bases and Alkalis

Bases neutralise acids. Common bases are metal oxides, metal hydroxides and ammonia.

The Bronsted- Lowry base is defined as a proton (H^+) acceptor

An Alkali is a soluble base that releases OH^- ions in aqueous solution;
The most common alkalis are sodium hydroxide (NaOH), potassium hydroxide (KOH) and aqueous ammonia (NH_3)

A base readily accepts H^+ ions from an acid:
eg OH^- ions accepts an H^+ ion forming H_2O
 NH_3 accepts an H^+ ion forming NH_4^+ ion

Strong and weak acids

Strong acids **completely dissociate** when dissolved in water

Weak acids only **slightly dissociate** when dissolved in water, giving an equilibrium mixture

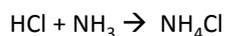
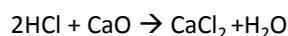
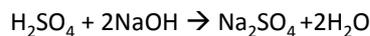
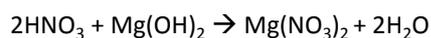
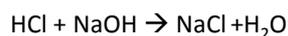
Neutralisation Reactions

Neutralisation reaction form salts

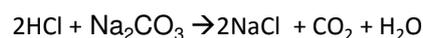
A **Salt** is formed when the H^+ ion of an acid is replaced by a metal ion or an ammonium ion

Common Neutralisation Reaction Equations

ACID + BASE → SALT + WATER



Acid + Carbonate → Salt + Water + Carbon Dioxide



Observations : In carbonate reactions there will be Effervescence due to the CO_2 gas evolved and the solid carbonate will dissolve

Titration

The method for carrying out the titration

- rinse equipment** (burette with acid, pipette with alkali, conical flask with distilled water)
- pipette 25 cm³ of alkali into conical flask**
- touch surface of alkali with pipette** (to ensure correct amount is added)
- adds acid solution from burette**
- make sure the jet space** in the burette **is filled** with acid
- add a few drops of indicator** and refer to colour change at end point
- phenolphthalein [pink (alkali) to colourless (acid): end point pink colour just disappears] [use if NaOH is used]
- methyl orange [yellow (alkali) to red (acid): end point orange] [use if HCl is used]
- use a white tile underneath the flask to help observe the colour change
- add acid to alkali whilst **swirling the mixture** and **add acid dropwise at end point**
- note burette reading** before and after addition of acid
- repeats titration** until **at least 2 concordant results** are obtained- two readings within 0.1 of each other

Working out average titre results

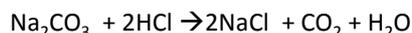
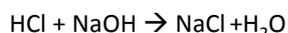
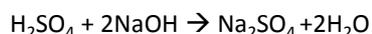
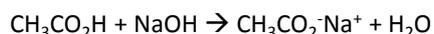
Only make an average of the concordant titre results

If **2 or 3 values are within 0.10cm³** and therefore **concordant** or close then we can say results are accurate and **repeatable** and **the titration technique is good/ consistent**

Recording results

- Results should be clearly recorded in a table
- Result should be recorded in full (i.e. both initial and final readings)
- Record titre volumes to 2dp (0.05 cm³)**

Common Titration Equations



Titration mixtures

If titrating a mixture to work out the concentration of an active ingredient it is necessary to consider if the mixture contains other substances that have acid base properties. If they don't have acid base properties we can titrate with confidence.

Testing batches

In quality control it will be necessary to do titrations/testing on several samples as the amount/concentration of the chemical being tested may vary between samples.

Safely dealing with excess acid

Sodium hydrogen carbonate (NaHCO₃) and calcium carbonate (CaCO₃) are good for neutralising excess acid in the stomach or acid spills because they are not corrosive and will not cause a hazard if used in excess. They also have no toxicity if used for indigestion remedies but the CO₂ produced can cause wind. Magnesium hydroxide is also suitable for dealing with excess stomach acid as it has low solubility in water and is only weakly alkaline so not corrosive or dangerous to drink (unlike the strong alkali sodium hydroxide). It will also not produce any carbon dioxide gas.

Safety precautions

Acids and alkalis are corrosive (at low concentrations acids are irritants)

Wear eye protection and gloves

If spilled immediately wash affected parts after spillage

If substance is unknown treat it as potentially toxic and wear gloves.

If the jet space is not filled properly prior to commencing the titration it will lead to errors if it then fills during the titration, leading to a larger than expected titre reading.

A conical flask is used in preference to a beaker because it is easier to swirl the mixture in a conical flask without spilling the contents.

Indicators are generally weak acids so we only add a few drops of them. If too much is added it will affect the titration result

Distilled water can be added to the conical flask during a titration to wash the sides of the flask so that all the acid on the side is washed into the reaction mixture to react with the alkali. It does not affect the titration reading as water does not react with the reagents or change the number of moles of acid added.

More complicated titration calculations- taking samples

Example 1: A 25.0cm³ sample of vinegar was diluted in a 250cm³ volumetric flask. This was then put in a burette and 23.10cm³ of the diluted vinegar neutralised 25.0 cm³ of 0.100 M NaOH. What is the concentration of the vinegar in gdm⁻³ ?



Step 1: work out amount, in mol, of sodium hydroxide
 amount = conc x vol
 = 0.10 x 0.025
 = 0.00250 mol

Step 2: use balanced equation to give moles of CH₃CO₂H
 1 moles NaOH : 1 moles CH₃CO₂H
 So 0.00250 NaOH : 0.00250 moles CH₃CO₂H

Step 3 work out concentration of diluted CH₃CO₂H in 23.1 (and 250 cm³) in moldm⁻³

conc = amount/Volume
 = 0.00250 / 0.0231
 = 0.108 mol dm⁻³

Step 4 work out concentration of original concentrated CH₃CO₂H in 25cm³ in moldm⁻³

conc = 0.108 x 10 = 1.08 mol dm⁻³

Step 5 work out concentration of CH₃CO₂H in original concentrated 25 cm³ in gdm⁻³

conc in gdm⁻³ = conc in mol dm⁻³ x Mr
 = 1.08 x 60 = 64.8 g dm⁻³

Example 2. An unknown metal carbonate reacts with hydrochloric acid according to the following equation.
 $\text{M}_2\text{CO}_3(\text{aq}) + 2\text{HCl}(\text{aq}) \rightarrow 2\text{MCl}(\text{aq}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$
 A 3.96 g sample of M₂CO₃ was dissolved in distilled water to make 250 cm³ of solution. A 25.0 cm³ portion of this solution required 32.8 cm³ of 0.175 mol dm⁻³ hydrochloric acid for complete reaction. Calculate the Mr of M₂CO₃ and identify the metal M

1. Calculate the number of moles of HCl used

amount = conc x vol
 = 0.175 x 0.0328
 = 0.00574 mol

2. Work out number of moles of M₂CO₃ in 25.0 cm³ put in conical flask

use balanced equation to give moles of M₂CO₃
 2 mol HCl : 1 mol M₂CO₃
 So 0.00574 NaOH : 0.00287 moles M₂CO₃

3. Calculate the number of moles M₂CO₃ acid in original 250 cm³ of solution

Moles in 250cm³ = 0.00287 x 10
 = 0.0287

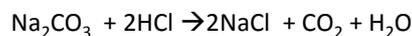
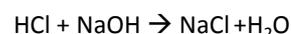
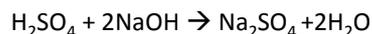
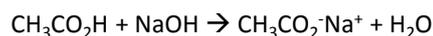
4. work out the Mr of M₂CO₃

Mr = mass / amount
 = 3.96 / 0.0287 = 138.0

5. Work out Ar of M = $\frac{138-12-16 \times 3}{2}$

Ar of M = 39 M = potassium

Common Titration Equations



Example 3

950 mg of impure calcium carbonate tablet was crushed. 50.0 cm³ of 1.00 mol dm⁻³ hydrochloric acid, an excess, was then added. After the tablet had reacted, the mixture was transferred to a volumetric flask. The volume was made up to exactly 100 cm³ with distilled water. 10.0 cm³ of this solution was titrated with 11.1cm³ of 0.300 mol dm⁻³ sodium hydroxide solution.

What is the percentage of CaCO₃ by mass in the tablet?

1. Calculate the number of moles of sodium hydroxide used

amount = conc x vol
 = 0.30 x 0.0111
 = 0.00333 mol

2. Work out number of moles of hydrochloric acid left in 10.0 cm³

use balanced equation to give moles of HCl
 1 mol NaOH : 1 mol HCl
 So 0.00333 NaOH : 0.00333 moles HCl

3. Calculate the number of moles of hydrochloric acid left in 100 cm³ of solution

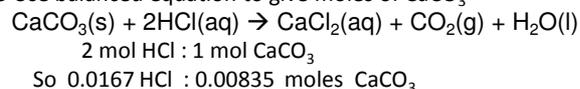
Moles in 100cm³ = 0.00333 x 10
 = 0.0333

4. Calculate the number of moles of HCl that reacted with the indigestion tablet.

In original HCl 50.0 cm³ of 1.00 mol dm⁻³ there is 0.05 moles

moles of HCl that reacted with the indigestion tablet. = 0.05 - 0.0333 = 0.0167

5 Use balanced equation to give moles of CaCO₃



6. work out the mass of CaCO₃ in original tablet

mass = amount x Mr
 = 0.00835 x 100 = 0.835 g

percentage of CaCO₃ by mass in the tablet = 0.835/0.950 x 100 = 87.9 %

Uncertainty

Readings and Measurements

Readings

the values found from a single judgement when using a piece of equipment

Measurements

the values taken as the difference between the judgements of two values (e.g. using a burette in a titration)

In general, if uncertainty is not indicated on apparatus, the following assumptions are made:

For an analogue scale-

The uncertainty of a reading (one judgement) is at least ± 0.5 of the smallest scale reading.

The uncertainty of a measurement (two judgements) is at least ± 1 of the smallest scale reading.

- If the apparatus has a digital scale, the uncertainty is \pm the resolution of the apparatus in each measurement

Calculating Apparatus Uncertainties

Each type of apparatus has a sensitivity uncertainty

- balance ± 0.001 g (if a 3 d.p. balance)
- volumetric flask ± 0.1 cm³
- 25 cm³ pipette ± 0.1 cm³
- burette (start & end readings and end point) ± 0.10 cm³

Calculate the percentage error for each piece of equipment used by

$$\% \text{ uncertainty} = \pm \frac{\text{uncertainty}}{\text{Measurement made on apparatus}} \times 100$$

e.g. for burette

$$\% \text{ uncertainty} = 0.10 / \text{average titre result} \times 100$$

To calculate the maximum percentage apparatus uncertainty in the final result add all the individual equipment uncertainties together.

Uncertainty of a measurement using a burette.

If the burette used in the titration had an uncertainty for each reading of ± 0.05 cm³ then during a titration two readings would be taken so the uncertainty on the titre volume would be ± 0.10 cm³.

To decrease the apparatus uncertainties you can either decrease the sensitivity uncertainty by using apparatus with a greater resolution (finer scale divisions) or you can increase the size of the measurement made.

Reducing uncertainties in a titration

Replacing measuring cylinders with pipettes or burettes which have lower apparatus uncertainty will lower the error

To reduce the uncertainty in a burette reading it is necessary to make the titre a larger volume. This could be done by: increasing the volume and concentration of the substance in the conical flask or by decreasing the concentration of the substance in the burette.

If looking at a series of measurements in an investigation the experiments with the smallest readings will have the highest experimental uncertainties.

Reducing uncertainties in measuring mass

Using a more accurate balance or a larger mass will reduce the uncertainty in weighing a solid
Weighing sample before and after addition and then calculating difference will ensure a more accurate measurement of the mass added.

Calculating the percentage difference between the actual value and the calculated value

If we calculated an Mr of 203 and the real value is 214, then the calculation is as follows:

Calculate difference $214 - 203 = 11$

$$\% = 11 / 214 \times 100$$
$$= 5.14\%$$

If the %**uncertainty** due to the apparatus < percentage difference between the actual value and the calculated value then there is a discrepancy in the result due to other errors.

If the %**uncertainty** due to the apparatus > percentage difference between the actual value and the calculated value then there is no discrepancy and all errors in the results can be explained by the sensitivity of the equipment.