

Titration Theory

What are they?

In its simplest form '*doing a titration*' (titrimetric analysis) is a practical method for **determining the concentration** of a solution of a **known compound**.

It usually involves reacting this solution with the solution of another chemical, the **accurate concentration** of which **is known**.

Consider the following general example.



In this example, $A_{(aq)}$ could represent a solution of an **acid** and $B_{(aq)}$ could represent a solution of a **base**. Now imagine that you are asked **to find out the concentration of B**.

According to the chemical equation shown above, we know that **B** reacts with **A** in a **1:1 ratio**. We also know that we can find out exactly how much **A** is needed to neutralise **B** as it will make the indicator (phenolphthalein, methyl orange or litmus) change colour (the end point) when we have added just enough **A** to **B**.

Chemical we are adding
(normally in **burette**)

Chemical we are **investigating**
(normally in **conical flask**)

We will write:

Concentration of **A** as c_A

and Concentration of **B** as c_B

Volume of **A** as V_A

and Volume of **B** as V_B

number of moles of **A** as n_A

and number of moles **B** as n_B

Remember we are trying to work out the concentration of B (c_B)

- At the start of the titration, **we decide** the volume of the unknown, **B** (V_B). This is usually 25.0 cm^3 . It is measured out into a conical flask using an accurate **pipette**.
- We can only determine the concentration of **B** (c_B) if we can find out the number of moles of **B**, (n_B) that were in the 25.0 cm^3 sample we measured out in step one.
- According to the chemical equation**, the number of moles of **B** (n_B) that we neutralise must be the same as the number of moles of **A** (n_A) that we add from the **burette** (ratio 1:1)
i.e. $n_B = n_A$
So, we can solve the problem if we can find out n_A
- By doing the titration**, we find the volume of added **A** (V_A) which is added from the burette (the titre value). The concentration of **A** (c_A) **which we know at the start** is then used to calculate the number of moles of **A** (n_A) that has been added to neutralise **B**.
- Now that we have worked out n_A , and we know that this must be the same value as n_B , we can now calculate c_B which is **the thing that we were trying to find out** by doing the titration.



$$c_B = \frac{n_B}{V_B}$$

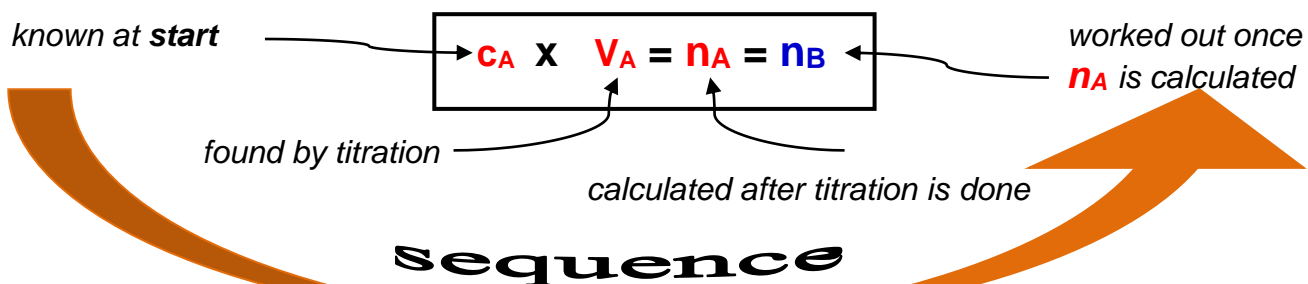
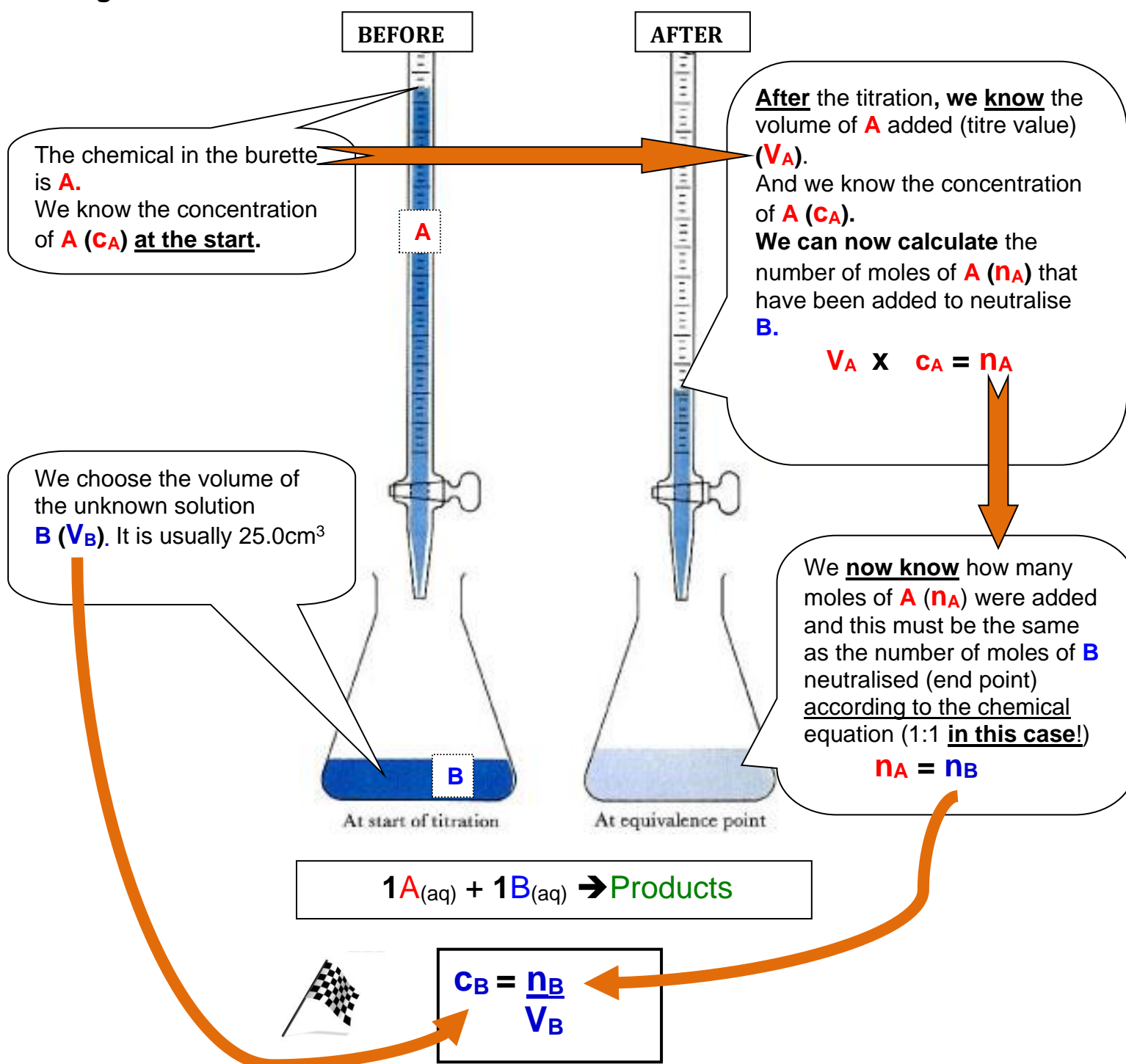


Diagram to Illustrate Process



A worked example:

You are asked **determine the concentration of a solution of sodium hydroxide** (we will call this, **B**).

You carry out a titration using a **volume** of 25.0cm³ of the sodium hydroxide **B** in the conical flask.

You carry out a titration using some hydrochloric acid (in the burette) which is labelled with its **concentration** 0.100 mol/dm³ (we will call this, **A**).

You find, by accurate titration, that you need an average **volume** of 21.50 cm³ of hydrochloric acid to just make your indicator change colour.

1. What you **do know at the start** (before doing the titration)

volume of **B** (V_B) = _____ cm³ **and** concentration of **A** (C_A) = _____ mol/dm³

2. What you know **after the titration**

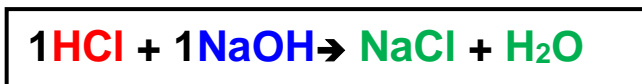
volume of **A** as (V_A) = _____ cm³

3. What you can **now calculate** after the titration?

$$n_A = V_A \times C_A$$

number of moles of **A** (n_A) = _____ mol

4. What you can deduce from the chemical equation



ratio of **A** : **B** = _____ : _____

5. What you can deduce about the number of moles **B**, (n_B)

number of moles of **B**, (n_B) = _____ mol

6. Now you can calculate the concentration of **B**, (C_B)!

$$C_B = \frac{n_B}{V_B}$$



concentration of **B**, (C_B) = _____ mol/dm³



You can apply this same sequence to any titration. The names of the chemicals may differ but the same theory applies. It isn't only applied to neutralisation reaction, too!

The same general sequence can be used for determining the **unknown concentration** of any solution. Let's call this compound **U** (for **unknown**). You need to find a reaction where the unknown, **U**, reacts with a solution whose **concentration is known**. Let's call this compound, **K** (for **known**).

1. What you **do know at the start** (before doing the titration)

volume of **U** (V_U) = _____ cm^3 **and** concentration of **K** (c_K) = _____ mol/dm^3

2. What you know **after the titration**

volume of **K** as (V_K) = _____ cm^3

3. What you can **now calculate** after the titration

$$n_K = V_K \times c_K$$

number of moles of **K** (n_K) = _____ mol

Don't forget to divide V by 1000 if necessary!

4. What you can deduce from the chemical equation



ratio of **K : U** = x____ : y____

5. What you can deduce about the number of moles **U**, (n_U)

number of moles of **U**, (n_U) = _____ mol

6. Now you can calculate the concentration of **U**, (c_U)!

$$c_U = \frac{n_U}{V_U}$$



concentration of **U**, (c_U) = _____ mol/dm^3



Don't forget to divide V by 1000 if necessary!

All titration calculations are basically the same!

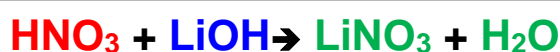
Try to apply this sequence to the following examples. Each problem is progressively less 'scaffolded':

- a) You are asked **determine the concentration of a solution of lithium hydroxide** (we will call this, **B**).

You carry out a titration using a **volume** of 25.0cm³ of the lithium hydroxide **B** in the conical flask.

You carry out a titration using some nitric acid (in the burette) which is labelled with its **concentration** 0.100 mol/dm³ (we will call this, **A**).

You find, by accurate titration, that you need a **volume** of 27.30 cm³ of nitric acid to just make your phenolphthalein indicator change colour.



- b) You are asked **determine the concentration of a solution of potassium hydroxide**.

You carry out a titration using a **volume** of 25.0cm³ of the **potassium hydroxide**.

You run the titration using some sulfuric acid (in the burette) which is labelled with its **concentration** 0.200 mol/dm³.

You find that you need a **volume** of 27.30 cm³ of sulfuric acid to reach the end point (the methyl orange indicator turns from yellow to red). What is the **concentration of the solution of potassium hydroxide**?



- c) By titration, it was found that 19.25cm³ of hydrochloric acid (concentration 0.150mol/dm³) was needed to neutralise 25.0cm³ of barium hydroxide solution (formula Ba(OH)₂!). Calculate the concentration of the barium hydroxide solution. You will need to write a balanced equation for the reaction.