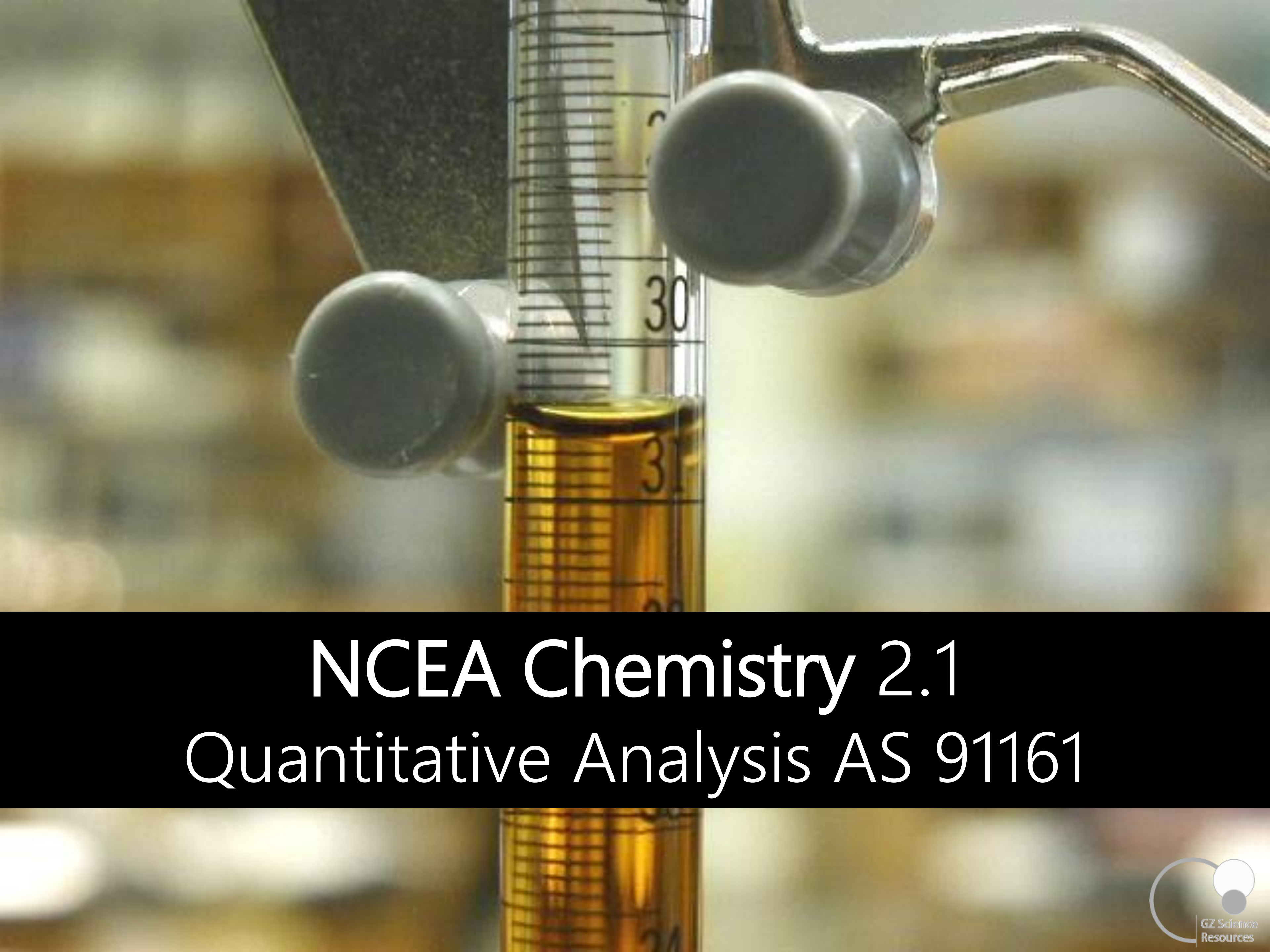

NCEA Chemistry 2.1

Quantitative Analysis AS 91161

GZ Science Resources

What is this NCEA Achievement Standard?

When a student achieves a standard, they gain a number of credits. Students must achieve a certain number of credits to gain an NCEA certificate (80 for Level 2)

The standard you will be assessed on is called **Chemistry 2.1 Carry out quantitative analysis**

It will be internally (in Class) assessed as part of a **Examination with a practical component** and will count towards **4 credits** for your Level 2 NCEA in Chemistry

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What are the main steps required in this Internal Assessment?

AS91161 Carry out quantitative analysis

Interpretation of evidence for Achieved

Carry out quantitative analysis involves:

- Collecting **titration data** that contains at least three titre values that fall within a range of 0.4 mL; the average titre value must be within 0.8 mL of the expected outcome

- Solving quantitative problems that use the relationships *n=m/M* and *c=n/V* to **calculate one variable given the other two** (the relationships are not given). Molar masses for substances may be provided. Calculations must be carried out using appropriate procedures (not provided).

Interpretation of evidence for Merit

Carry out in-depth quantitative analysis involves:

- ❑ Collecting **titration data** that contains at least three titre values that fall within a range of <u>0.4 mL</u>; the average titre value must be within <u>0.5 mL</u> of the expected outcome

- ❑ Solving quantitative problems that involve at **least two steps** and require application of relationships such as $n=m/M$ and $c=n/V$. Titration calculations must be carried out correctly using **only concordant titre** values.

Standard of Excellence

Interpretation of evidence for Excellence

Carry out comprehensive quantitative analysis involves:

- ❑ Collecting titration data that contains at least three titre values that fall within a range of 0.2 mL; the average titre value must be within 0.2 mL of the expected outcome

- ❑ Solving quantitative problems that involve **more than two steps**, and the use of stoichiometric principles. Answers to calculations must demonstrate **correct units** and appropriate use of significant figures (**3sgf**).

The Mole and Atomic Mass

The number of particles in a substance is measured in moles (unit n)

1 mole of particles = 6.02214 x 10^{23} ***particles*** *for any substance!*

The mass of 1 mole of each element in grams, is equivalent to the relative Atomic Mass (Ar), which is an average of the isotopes mass in the proportions of isotopes found on Earth, and approximates to the number of protons and neutrons in the atom.

For example 1 mole of Carbon (Ar = 12.01) is 12.01g

Converting number of particles to amount of Moles (n)

If the actual number of particles is known (atoms, ions or molecules) then the amount, n, is easily calculated since

$$n = \frac{\text{number of particles}}{6.02 \times 10^{23}}$$

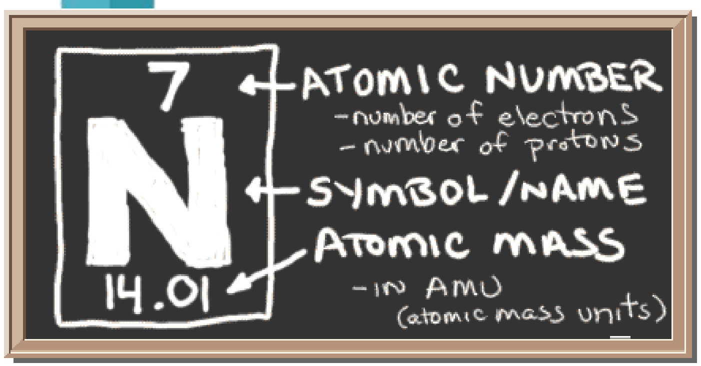
For example 12×10^{24} sodium ions is equivalent to

$$\frac{12 \times 10^{24}}{6.02 \times 10^{23}}$$

= 20 mol of sodium ions.

Calculating the Molar Mass μ

The *molar mass* is given as the *mass* of a given element or compound in grams (g), and divided by the amount, in moles, of the substance (mol). The unit for Molar Mass is, therefore, $gmol^{-1}$



Molar mass is calculated by adding up the **atomic mass** (or mass number) or each individual atom

The atomic mass used at L2 Chemistry is provided on a standardised periodic Table, also provided in all Examinations. This will be the correct value to use for calculations.

Calculating Molar Mass of a compound

1. Identify how many of each atom	2. Write a sum using the molar mass for each atom	3. Calculate the total
e.g. H_2SO_4 2 H 1 S 4 O	2 x M(H) + M(S) + 4 x M(O) (2 x 1) + 32 + (4 x 16)	$M(H_2SO_4)$ = 98 $gmol^{-1}$
e.g. CuSO4.5H2O 1 Cu 1 S 9 O 10 H	M(Cu) + M(S) + 9 x M(O) + 10 x M(H) 63.5 + 32 + (9 x 16) + (10 x 1)	$M(CuSO_4.5H_2O)$ =249.5 $gmol^{-1}$

Calculating number of moles (n)

$$n = m / \mathcal{M}$$

We use the formula above to calculate the number of moles present of a substance when given the **mass of the substance** and the **molar mass** (atomic mass) from the Periodic Table.

m - Mass is measured in grams (g)

$\mathcal{M}$ - Molar Mass is measured in gmol^{-1}

n - Moles are measures in mols

https://www.acs.org/content/acs/en/education/outreach/outreach-graphics.html

One step calculations Example

EXAMPLE

Calculate the amount (in moles) of methane, CH_4, in 12.5 g of the gas?

$M(CH_4) = 16.0 \text{ g mol}^{-1}$

$n = m / \mathcal{M}$

1) Write down the formula and rearrange if necessary

$n(CH_4) = m/ \mu$

2) Write in the values (with units) underneath and calculate

$n(CH_4) = 12.5\text{g}/16.0\text{g mol}^{-1}$

$n(CH_4) = 0.781\text{mol}$

Stoichiometry - Equations and calculating moles

A **balanced equation** will be given, which shows each substance with its lowest common number of moles in relationship to the other substances.

$$N_2 + 3H_2 \rightarrow 2NH_3$$

In the equation above **1 mole** of nitrogen gas (N_2) will react with **3 moles** of hydrogen gas (H_2) to form **2 moles** of ammonia (NH_3)

Of course the actual amount of moles you have in any reaction will depend on the mass you start with but the ratios of the other substances **will remain the same as in the equation**

For example: the number of moles of NH_3 produced will always be 2 x the number of moles of N_2 and 2/3 x the number of H_2

What is Stoichiometry? It is an area of chemistry that involves using relationships between reactants and/or products in a chemical reaction to determine quantitative data.

Known and unknown values and mole ratios

In a question that requires you to calculate either mass or moles of substance – that substance is referred to as the **unknown** (U)

The substance that the mass is given for is referred to as the **known** (K)

When you need to calculate the mass or moles of an unknown you will need to multiply the moles of the known by a **mole ratio** from the equation.

The mole ratio is **x U / K** and the values of these are from the **balanced equation.**

$$N_2 + 3H_2 \rightarrow 2NH_3$$

For example in the equation above if H_2 was the unknown (3 moles in equation) and $NH_3$was the known (2 moles in equation) then:

moles of hydrogen = moles of ammonia x 3/2

Scientific Notation and Significant figures

A number converted to Scientific notation is written in **two parts**:
Just the **digits** (with the decimal point placed after the first digit), followed by
× 10 to a power that puts the decimal point where it should be
(i.e. it shows how many places to move the decimal point).
A negative number of power shifts the decimal place to the right

In this example, 0.00362 is written as **3.62×10^{-3}**,
because $3.62 \times 10^{-3} = 3.62 \div 1000 = 0.00362$

The Significant figures required in this standard are 3

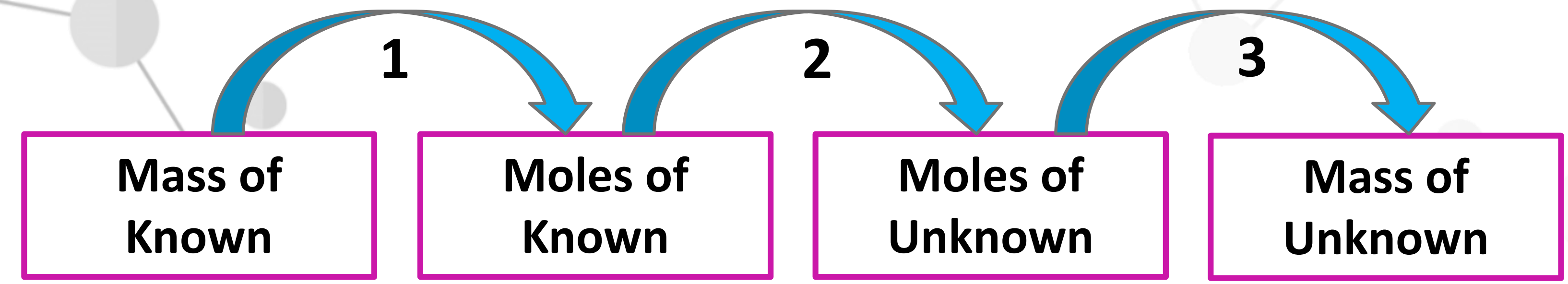
3.60 0.360 0.0360 and 0.00360 are examples of 3 significant figures

Notice that a 0 before the first whole number **does not** count as a significant figure (it is only a place holder) but a 0 after a whole number is regarded as a significant figure.
3 significant figures must be rounded if the original number given is longer

Answering partial n = m/M Calculations

The step that you begin and stop at depends on what information the question provides and what they want you to calculate. For example if the question provides the number of moles of a known and asks for the moles of the unknown only step 2 is required.

$n(K) = m(K) / \mu(K)$ $n(U) = n(K) \times U/K$ $m(U) = n(U) \times \mu(U)$



$$N_2 + 3H_2 \rightarrow 2NH_3$$

- Question asks for <u>moles of H_2</u> if moles of N_2 is given as 0.250mol . N_2 is Known (K) and H_2 is Unknown (U) so **only step 2 is required**. $n(H_2) = 0.025 \times U/K = 0.025 \times 3/1$
- Question asks for <u>mass of H_2</u> if moles of N_2 is given as 0.025mol. **Step 2 and 3 are required**. (note step one is not required as moles of known already given)

Recording Grid

	Known ______	Unknown ______
	x U / K	2
n (mols)		
m (g) 1	÷	x 3
μ ($gmol^{-1}$)		

1. n(K) = m(K) / μ (K)

2. n(U) = n(K) x U/K

3. m(U) = n(U) x μ (U)

Equations and mole ratios n = m/M Calculation Steps

Step One:

> You need to establish which chemical /compound in an equation is the Known (K) – this will be the one that has information about it's mass. Write K above this in the equation.
> Establish which is the unknown (U). This will be the compound/chemical in the equation that the question is asking you to find the mass for. Write a U above this in the equation.
> Calculate the n(mols) of **Known**

n(K) = m(K) / μ (K)

n(K) ← Moles; m(K) ← mass; μ (K) ← molar mass

mass is from the question
molar mass added up from periodic table or given
add up each atom's molar mass in molecule

Step two:

Calculate mols of Unknown:

n(Unknown) = n (known) x $\frac{U}{K}$

U ← Unknown mols from equation e.g **6** CO_2 mols = 6
K ← Known mols from equation

n (known) ↑ From Step One

Step three:

Calculate mass of Unknown (answer in g)

m(U) = n(U) x μ (U)

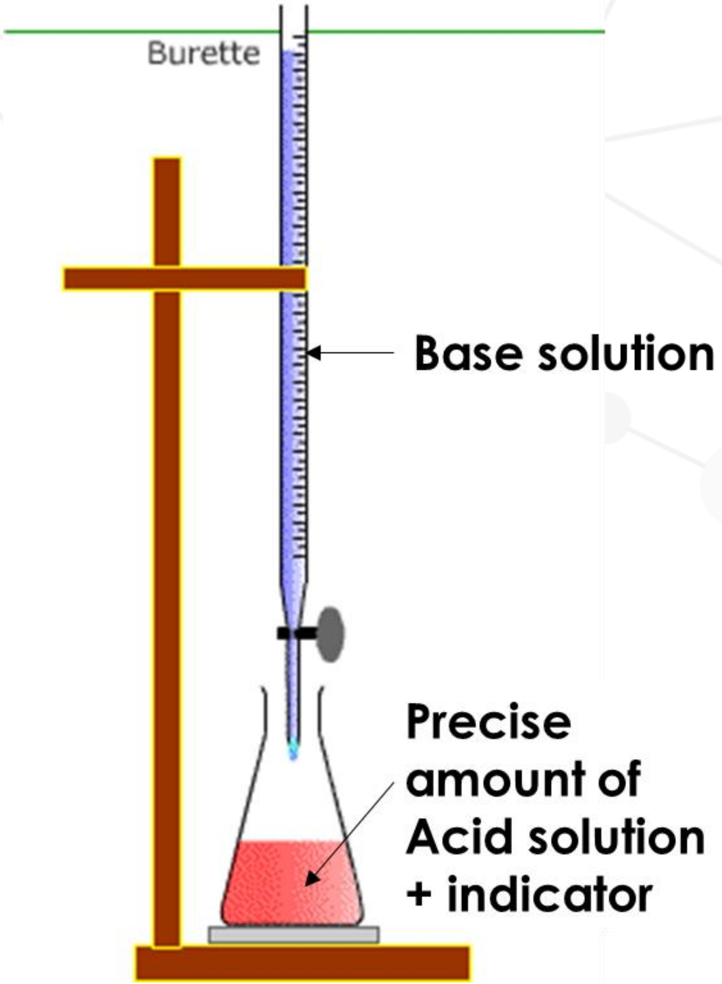
n(U) ↑ From Step Two

μ (U) ← molar mass calculated by adding up molar mass from each atom

Volumetric analysis will involve a titration.

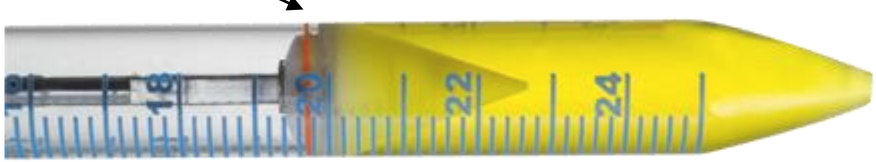
- In a titration, a solution, of unknown concentration, is typically titrated (added) from a burette into a flask.
- The flask typically contains a known amount of solution. A pipette is used to measure a precise set volume called an aliquot.
- In an acid-base titration the end point of the titration is reached when there is a neutralisation. Indicator (usually phenolphthalein) is added into the flask and a colour change (lasting more than 10 seconds) will indicate a neutralisation
- Using c=n/v and a balanced equation, the concentration of the solutions can be calculated.

Titration set up

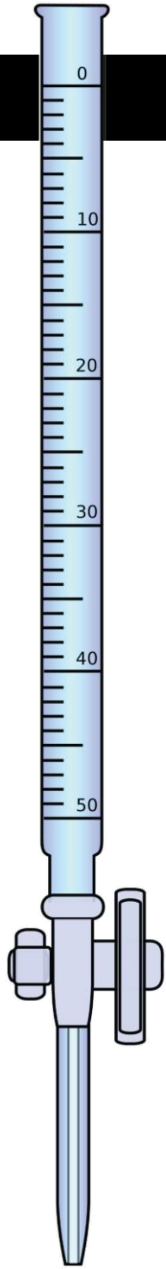


Titration equipment - Pipette (Diji Pipette)

- Calibrated to provide an exact volume of acid into the flask.
- Clean and rinsed with solution to be pipetted.
- Reading from the bottom of the meniscus on **the red line of the pipette.**
- In 20mL or 10mL volumes
- Pull the handle up to draw in solution and push down to release

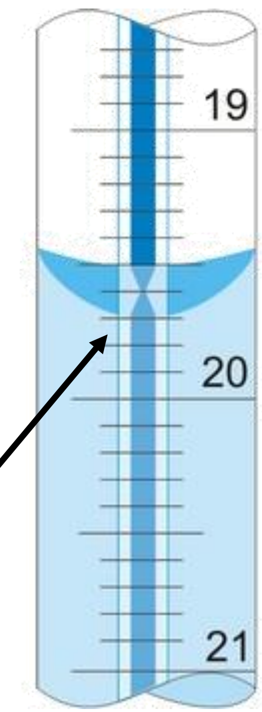


Titration equipment - Burette



- The burette must be cleaned and rinsed with small amount of solution that will go into it.
- The volume of the solution in the burette is read from the bottom of the meniscus. Volume is recorded before and after the titration.
- The volume of solution delivered by the burette is called a **titre**.

The **bottom of the meniscus** must be used for measurement. Avoid parallax error by reading close up and at eye level to the line



Reading the burette

Reading is to be taken from the bottom of the meniscus curve.

a) Read the ml

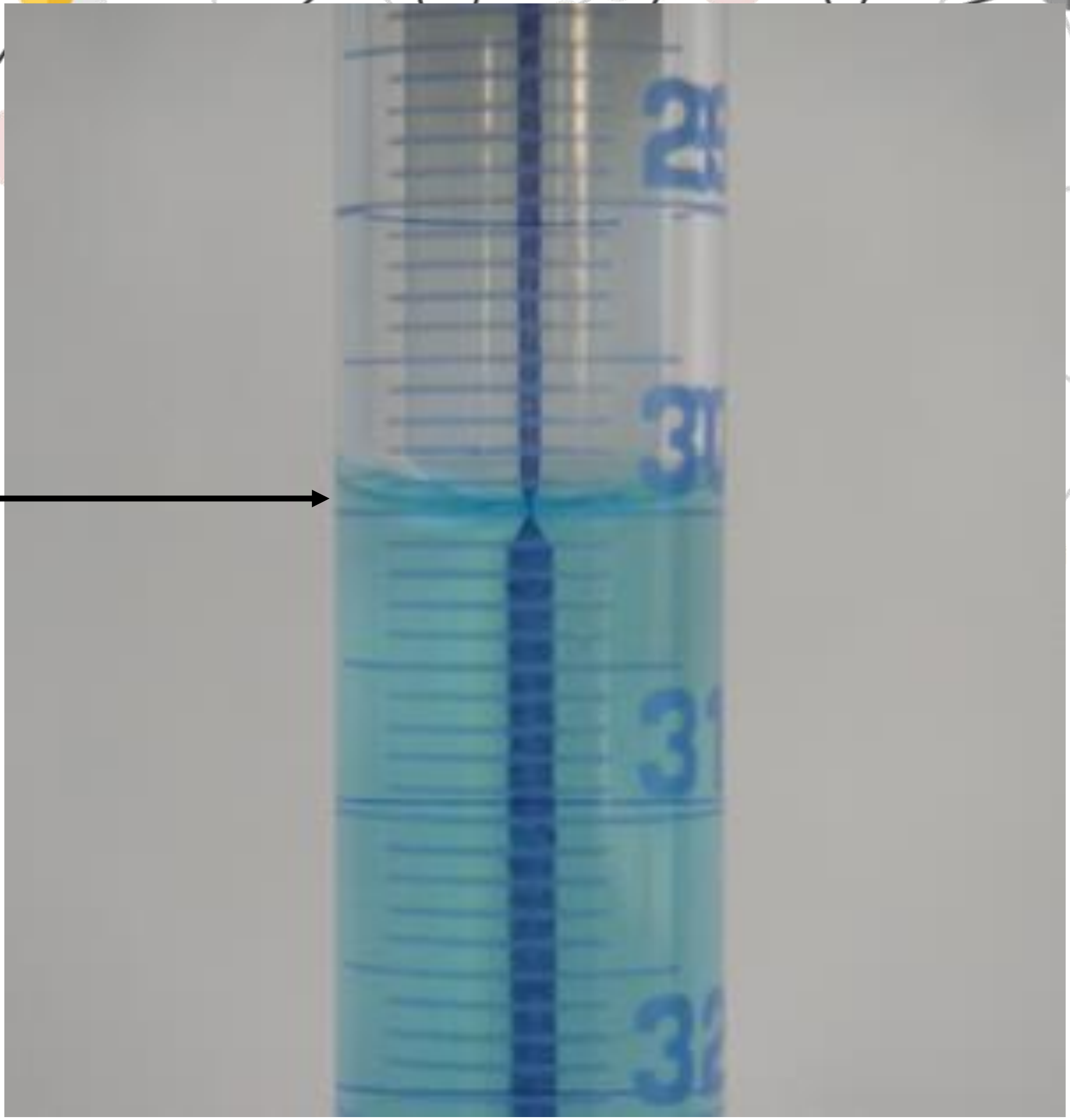
29ml

b) Read the 1/10 of ml

29.9ml

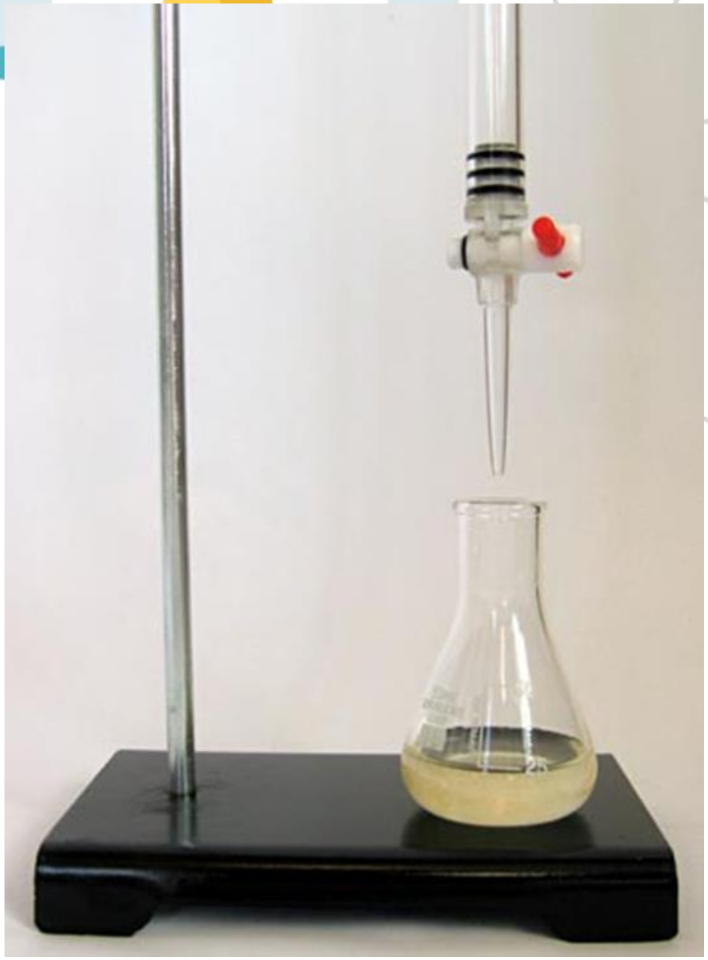
c) Divide the 1/10ml up into 0.00, 0.02, 0.04…0.08 and read to closest

29.98ml



Titration equipment - conical flask

- The flask is rinsed with **distilled water** before use.
- A aliquot of solution (unknown or known concentration) placed into the flask from the pipette.
- A few drops of indicator are placed into the flask – you will be instructed as to what indicator to use.
- The flask is swirled during the titration.

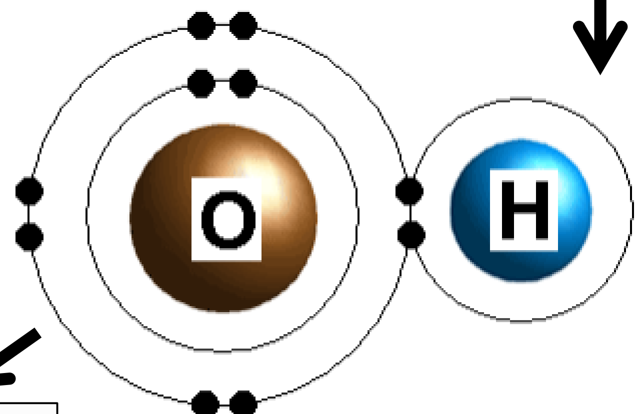


During neutralisation reactions hydrogen ions combine with hydroxide ions to form water molecules

From an acid

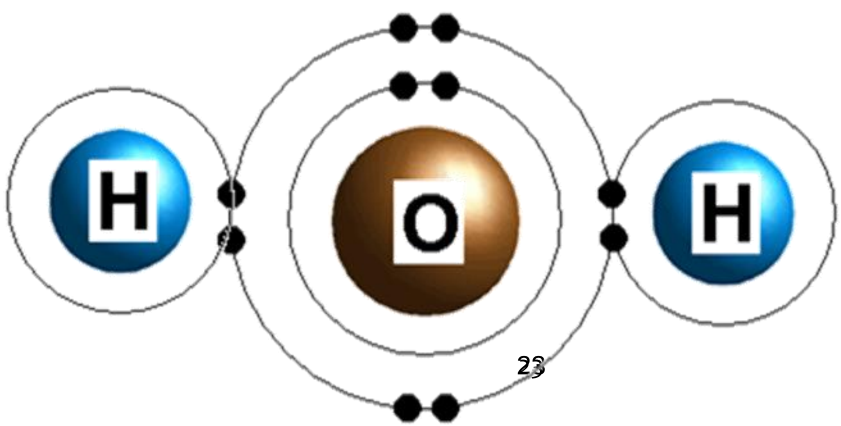
From a base

Hydrogen ion
1 proton
0 electrons
= +1 charge



Hydroxide:
9 protons
10 electrons
= -1 charge

Neutralisation



Water
10 protons
10 electrons
= 0 charge

Indicator selection

Before starting the titration a suitable pH indicator must be chosen. The **endpoint of the reaction**, when all the products have reacted, will have a pH dependent on the relative strengths of the acids and bases. The pH of the endpoint can be roughly determined using the following rules:
A strong acid reacts with a strong base to form a neutral (pH=7) solution.
A strong acid reacts with a weak base to form an acidic (pH<7) solution.
A weak acid reacts with a strong base to form a basic (pH>7) solution.
When a weak acid reacts with a weak base, the endpoint solution will be basic if the base is stronger and acidic if the acid is stronger. If both are of equal strength, then the endpoint pH will be neutral.

A suitable indicator should be chosen, that will experience a change in colour close to the end point of the reaction.

Indicator	**Acid**	**Base**	**pH range**
Methyl Orange	Red	Yellow	3.1 - 4.4

Phenolphthalein	Colourless	Pink	8.3 - 10.0

Standard solutions

A **standard solution** is a solution whose concentration is known accurately. Its concentration is usually given in $molL^{-1}$. When making up a standard solution it is important that the correct mass of substance is accurately measured and all of this is successfully transferred to the volumetric flask used to make up the solution.

Making a $1molL^{-1}$ of NaCl solution

a) Calculate the mass of 1mole of NaCl

m (NaCl) = n x M

m (NaCl) = 58.5g

b) Determine the volume of the volumetric flask being used and mass of substance added.

1L flask = 1mol

100mL flask = 1/10mol

c) Weigh and add substance to the volumetric flask with wash bottle

d) Continue filling flask with distilled water to line – bottom of meniscus must touch line

Titration method

1. First, the burette should be **rinsed** with the base solution, the pipette with the acid solution, and the conical flask with distilled water.

2. Secondly, a known volume of the acid solution should be taken with the pipette and placed into the conical flask, along with a small amount of the suitable indicator chosen. The burette should be filled to the top of its scale with the base with a funnel. Remove the funnel after the burette is filled. **Record the starting volume.**

3. The base solution should then be allowed out of the burette, into the conical flask. At this stage we want a rough estimate of the amount of this solution it took to neutralise the acid solution. Let the solution out of the burette until the indicator changes colour and then record the value on the burette. **This is the first titre and should be excluded from any calculations.**

4. Perform **at least three more titrations,** this time more accurately, taking into account roughly of where the end point will occur. Record of each of the readings on the burette at the end point. **Endpoint is reached when the indicator just changes colour for more than 10 seconds.**

Three titres must be concordant to 0.2ml to gain Excellence (0.4ml Merit and Achieved)

Recording Titrations

1. Read your instructions carefully. Understand clearly which solution (acid) goes into the conical flask and which goes into the burette (base). Make sure you convert all volumes into litres i.e. 10ml aliquots from a pipette is 0.0100L

2. Record the given concentration on your sheet

Concentration of known (*i.e. standard sodium hydroxide*) solution = ___________ $molL^{-1}$

3. Rule up a table to record your titrations. Titre = final reading – start reading

	initial titration	1st titration	2nd titration	3rd titration	4th titration
Final reading					
Start reading					
titre					

Concordant titres

1. At least 3 titrations must be within 0.2ml of each other to be concordant at Excellence level

2. Any titres not falling within this range must be discarded and not used in the average.

3. If more there are more than 3 concordant titres within this range they will be included in the average calculation

EXAMPLE

successive titrations – 24.50 mL, 23.25 mL, 23.35 mL and 23.28 mL.

23.35mL – 23.25mL = 0.10ml

This difference is less than 0.2ml allowed, and 23.28 falls within this range so all three are used. 24.50mL falls outside this range so is discarded.

v = (23.35mL + 23.28mL + 23.25mL) ÷ 3 = 23.29mL = **0.0233L**

Calculating concentration of solutions ($molL^{-1}$)

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$$c = n / v$$

We use the formula above to calculate the concentration of a unknown substance when given the **concentration of a known solution** when a titration has reached end point.

The **moles of each** substance is found in a balanced equation.

c - concentration is measured in $molL^{-1}$

v - volume is measured in L

n - moles are measures in mols

https://www.acs.org/content/acs/en/education/outreach/outreach-graphics.html

Answering titration c = n/v Calculations

Make sure **all of your titration volumes are written clearly** in a data table and **only concordant data** is used to calculate the volume of the average titre. This value in **mL must be changed into L** to use in the titration concentration calculation

n(K) = c(K) x v (K)

n(U) = n(K) x U/K

c(U) = n(U) / v (U)

Concentration and volume of Known → **1** → **Moles of Known** → **2** → **Moles of Unknown** → **3** → **Concentration of Unknown**

All steps must be followed with each, calculation (and equation) written down as **3 significant figures** consistently.

The entire calculation can done continuously on a calculator with the final answer of the **concentration of the unknown written down as 3sgf and units of $molL^{-1}$**

Highlight your final answer and make sure it appears to be a sensible answer. If you have time go through the calculation again quickly to check.

Recording Grid

	Known ________	Unknown ________
	x U / K	
n (mols)		
v (L)		
c (molL^{-1})		

1 x **2** **3** ÷

1. n(K) = c(K) x v (K)

2. n(U) = n(K) x U/K

3. c(U) = n(U) / v (U)

Titration Calculation Steps   n = c x v

Step One: (After the titration) You need to establish which acid /base in an equation is the Known (K) – this will be the one that you are given the concentration. Write K above this in the equation.

Establish which is the unknown (U). This will be the acid/base in the equation that you need to find the concentration for. Write a U above this in the equation.

Calculate the n(mols) of **Known**

n(K) = c(K) x v (K)

Moles ↗ concentration ↑ volume ↖

volume is from the titration (burette or pipette)

Concentration is given by the teacher

Step two:

Calculate mols of Unknown:

n(Unknown) = n (known) x U / K

From Step One → n (known)

U ← Unknown mols from equation e.g **2** NaOH mols = 2

K ← Known mols from equation

Step three:

Calculate concentration of Unknown (answer in $molL^{-1}$)

c(U) = n(U) / v (U)

From Step Two → n(U)

v (U) ← volume from burette or pipette (L)

Titration calculations part ONE c = n/v

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EXAMPLE

A standard solution of 0.180 mol L^{-1} hydrochloric acid was titrated against 25.0 mL samples of a solution of sodium carbonate. The following volumes of hydrochloric acid solution were used in successive titrations – 24.50 mL, 23.25 mL, 23.35 mL and 23.28 mL.

The equation for the reaction is

$$Na_2CO_3 + 2\,HCl \rightarrow 2\,NaCl + CO_2 + H_2O$$

Use this information to determine the concentration of the sodium carbonate solution.
Give your answer to three significant figures.

1. Select concordant titres ~~24.50 mL~~, 23.25 mL, 23.35 mL and 23.28 mL.

2. Calculate average titre and convert from mL to L

Ave = 23.29mL = 0.0233L 3sgf

Titration calculations Part TWO c = n/v

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3. Calculate the n(mols) of **Known**

n(K) = c(K) x v (K) volume is from the titration (burette or pipette)

Concentration is given by the teacher (HCl)

n(HCL) = 0.180 mol L^{-1} x 0.0233L

n(HCl) = 0.00419mol or in standard form 4.19×10^{-3} mol

4. Calculate mols of Unknown: (from equation)

n(Unknown) = n (known) x U / K

n(Unknown) = n (known) x U / K

n(**Na_2CO_3**) = 4.19×10^{-3} mol x 1/2

n(**Na_2CO_3**) = 2.10×10^{-3} mol

5. Calculate concentration of Unknown (answer in molL^{-1})

c(U) = n(U) / v (U) volume from burette or pipette (L) 25mL = 0.0250L

c(**Na_2CO_3**) = 2.10×10^{-3} mol / 0.0250L

c(**Na_2CO_3**) = 0.0839 molL^{-1} or 8.39×10^{-2} molL^{-1}