NCEA Chemistry 2.1

Quantitative Analysis AS 91161

What does this Internal Assessment involve?

Carry out quantitative analysis, including an acid-base titration

Demonstrate comprehensive understanding 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. (require application of relationships such as n=m/M and c=n/V)

Aiming for Excellence – all below is required

- ☐ *Recoverable data from the titration is recorded.*
- ☐ *At least three titres must fall within a range of 0.2 mL*
- ☐ *The average titre value used is within 0.2 mL of the expected outcome.*
- ☐ *Average value is calculated using only concordant titres*
- ☐ *The concentration of the unknown solution is correctly calculated using c=n/V*
- ☐ *The concentrations calculated must have correct units and uses 3 significant figures consistently.*
- ☐ *All stoichiometric calculations using n=m/M correct, with units and 3 sgf.*

What do I have to help me in the Internal Assessment?

You will have an acid and base solution provided, one will be unknown – this is the solution you will be calculating the concentration for. Equipment and Indicator will be provided, along with a balanced equation for the acid-base neutralisation, and *c=n/V* + *n=m/M* formula for calculations.

What is stoichiometry?

"Stoichiometry is founded on the law of conservation of mass: where the total mass of the reactants equals the total mass of the products" An equation is a representation of the ratio of reactants and products in relation to each other, at equilibrium. *"This means that if the amounts (mass) of the separate reactants are known, then the amount of the product can be calculated. Conversely, if one reactant has a known quantity (mole) and the quantity of the products can be empirically determined, then the amount of the other reactants can also be calculated."* Wikipedia

The Mole

Because atoms and molecules are so small to practically use as a quantity, we use the unit of a mole. The number of particles in a substance is measured in moles. *1 mole of particles = 6.02214 x* 10^{23} *particles for any substance! called Avogadro's number.* Balanced equations show the number of moles present for each species in the reaction.

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.

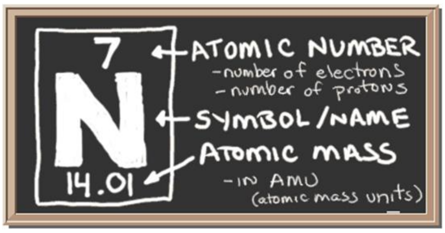
For example 1 mole of Carbon (Ar = 12.01) is 12.01g

Converting number of particles to amount of Moles (n) and Molar Mass

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

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

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

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)

We use the following formula 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.

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

m - Mass is measured in grams (g)

μ - Molar Mass is measured in gmol^{-1}

n - Moles are measures in mols

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

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.

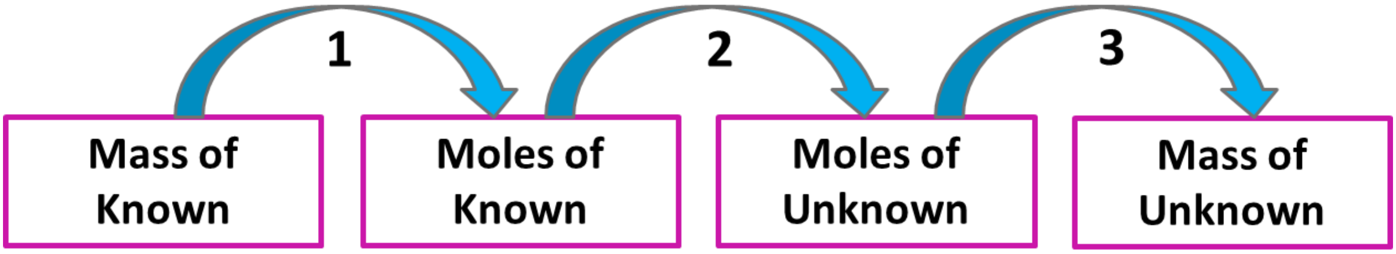
$$N_2 + 3H_2 \rightarrow 2NH_3$$

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

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.

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

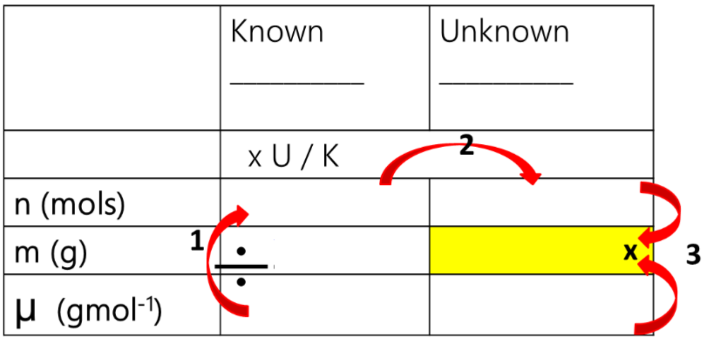


$$N_2 + 3H_2 \rightarrow 2NH_3$$

- ☐ Question asks for moles of H_2 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 mass of H_2 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

This can be used to keep a track of each step



	Known ________	Unknown ________
	x U / K	
n (mols)		
m (g)	÷	x
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) mass is from the question
↗ ↑ ↖ molar mass added up from periodic table or given
Moles mass molar mass add up each atom's molar mass in molecule

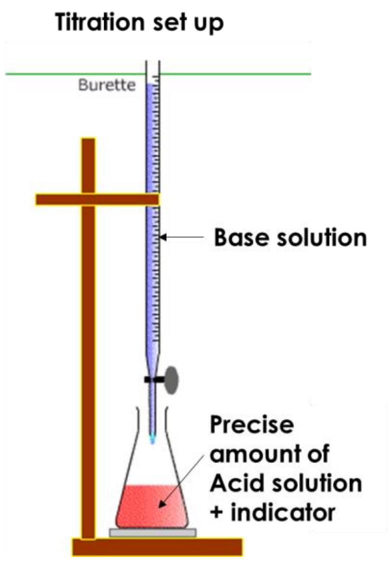
Step two:
Calculate mols of Unknown:
n(Unknown) = n (known) x $\frac{U}{K}$ ← Unknown mols from equation e.g **6** CO_2 mols = 6
← Known mols from equation
↑
From Step One

Step three:
Calculate mass of Unknown (answer in g)
m(U) = n(U) x μ (U)
↑ ↖ molar mass calculated by adding up molar mass from each atom
From Step Two

Volumetric Analysis

Volumetric analysis will involve a titration.

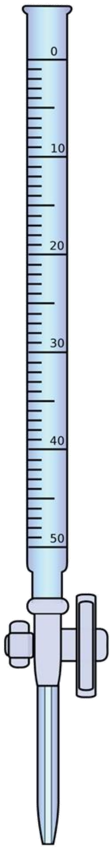
- ☐ In a titration, a solution, of unknown concentration, is typically titrated (added) from a burette into a flask.
- ☐ The flask typically contains a known amount of solution. A pipette is used to measure a precise set volume called an aliquot.
- ☐ In an acid-base titration the end point of the titration 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 equipment - Pipette (Diji Pipette)

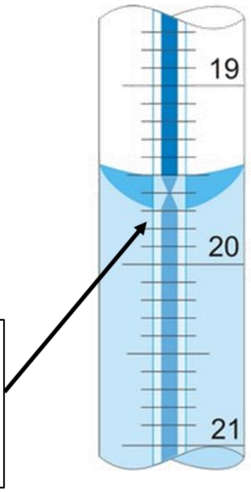
- ☐ calibrated to provide an exact volume of acid into the flask.
- ☐ clean and rinsed with solution to be pipetted.
- ☐ reading from the bottom of the meniscus on the red line of the pipette.
- ☐ In 20mL or 10mL volumes
- ☐ Pull the handle up to draw in solution and push down to release

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

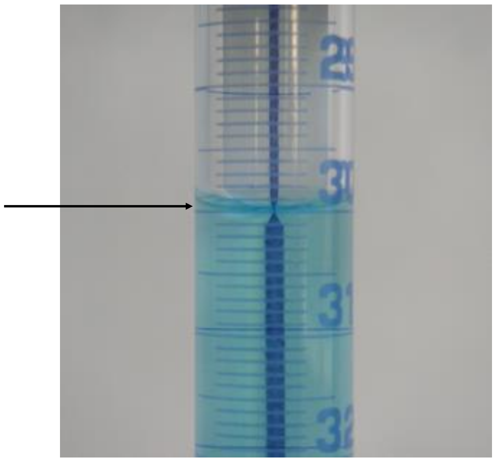
29ml

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.

Indicator selection

Before starting the titration a suitable pH indicator must be chosen. The endpoint of the reaction, when all the acid and base have neutralised, 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

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 <u>0.0100L</u>

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 <u>not</u> 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})

We use the formula below 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.

$$c = n / v$$

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

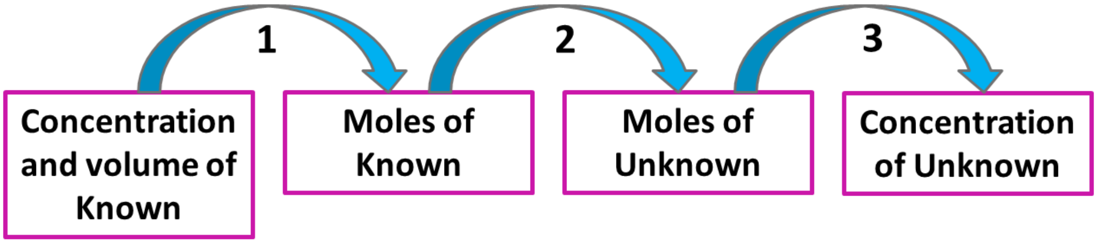
v - volume is measured in L

n - moles are measures in mols

Answering titration c = n/v Calculations

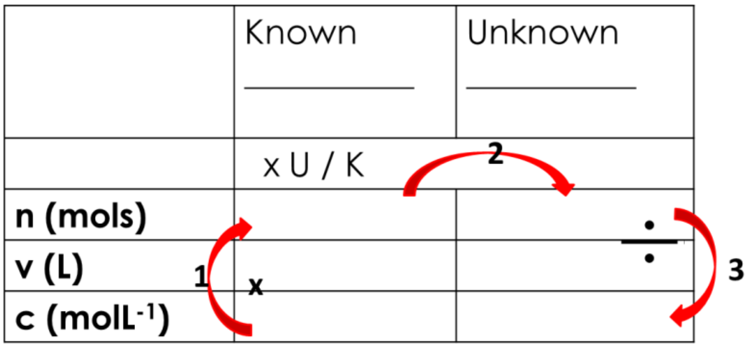
Make sure all of your titration volumes are written clearly in a data table and only concordant data is used to calculate the volume of the average titre. This value in mL must be changed into L to use in the titration concentration calculation

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



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. 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 ← Unknown mols from equation e.g **2** NaOH mols = 2
K ← Known mols from equation
From Step One

Step three:

Calculate concentration of Unknown (answer in molL^{-1})
c(U) = n(U) / v (U) ← volume from burette or pipette (L)
From Step Two

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 $3.62 \text{ x } 10^{-3} = 3.62 \div 1000 = 0.00362$

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

Titration calculations part ONE c = n/v

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
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
$c(Na_2CO_3) = 2.10 \times 10^{-3}$ mol / 0.0250L
$c(Na_2CO_3)$ = 0.0839 $molL^{-1}$ or 8.39×10^{-2} $molL^{-1}$