National 5 Chemistry

Unit 1 – Chemical Changes and Structure
Summary Notes

Success Criteria

✓	I am confident that I understand this and I can apply this to problems
?	I have some understanding but I need to revise this some more
×	I do not understand this and I need help with it

I will be successful if I can…		Self-Evaluation		
1	State the factors that affect the rate of a reaction	✓	?	x
2	Define the term catalyst	✓	?	x
3	Describe the relationship between different factors and the rate of a reaction	✓	?	x
4	Calculate the average rate of a reaction using the appropriate units	✓	?	x
5	Describe how the rate of a reaction varies as a reaction proceeds	✓	?	x
6	Identify the end point of a reaction on a reaction rate graph	✓	?	x
7	Name the subatomic particles that are found in an atom	✓	?	x
8	Describe subatomic particles in terms of their location, mass and charge	✓	?	x
9	Use atomic number and mass number to determine the number of protons, neutrons and electrons in an atom	✓	?	x
10	Explain why an atom is electrically neutral	✓	?	x
11	Describe how elements are organised in the periodic table	✓	?	x
12	Discuss the names and properties of Group 1, 7 and 0 elements	✓	?	x
13	Write the electron arrangement of the first 20 elements using the databook	✓	?	x
14	Draw the electron arrangement diagrams for the first 20 elements	✓	?	x
15	Write the nuclide notation for a given element	✓	?	x
16	Define the term isotopes	✓	?	x
17	Define the term relative atomic mass (RAM)	✓	?	x
18	Use a given equation to calculate the relative atomic mass (RAM)	✓	?	x
19	Identify which isotope is the most abundant from given data	✓	?	x
20	Describe how a covalent bond is formed	✓	?	x
21	State the type of atoms that can form a covalent bond	✓	?	x
22	Draw diagrams showing the sharing of electrons between two atoms	✓	?	x
23	Identify the shape of covalent molecules	✓	?	x
24	Discuss the differences between the structure and properties of a covalent network and discrete covalent molecular substance	✓	?	x

25	Describe how an ionic bond is formed	✓	?	x
26	State the type of atoms that can form an ionic bond	✓	?	x
27	Explain how ions are formed	✓	?	x
28	State the type of compounds which form ionic lattice structures	✓	?	x
29	Describe the properties (melting point, boiling point, conductivity, solubility) associated with different types of bonding	✓	?	x
30	Write the molecular formula for a given compound	✓	?	x
31	Write the ionic formula for a given compound	✓	?	x
32	Write a balanced molecular equation, including state symbols	✓	?	x
33	Calculate the gram formula mass (GFM) of a compound from its molecular formula	✓	?	x
34	Use the equation n=CV to calculate the number of moles, concentration or volume of a substance dependent on the information provided	✓	?	x
35	Use the equation n=m/GFM to calculate the number of moles or mass of a substance dependent on the information provided	✓	?	x
36	Calculate the percentage composition of an element in a compound given the formula	✓	?	x
37	State the definition of pH	✓	?	x
38	Discuss the pH scale	✓	?	x
39	Give examples of everyday acids and bases	✓	?	x
40	State whether a soluble non-metal oxide / metal oxide will form an acidic / alkaline solution when dissolved in water	✓	?	x
41	Explain the dissociation of water, in terms of the ions present	✓	?	x
42	Discuss the relationship between the concentration of hydrogen ions and pH	✓	?	x
43	Explain what happens to pH when an acid / alkali is diluted with water	✓	?	x
44	State the definition of a neutralisation reaction	✓	?	x
45	Write balanced chemical equations for neutralisation reactions involving the reaction of acids with metal oxides, metal hydroxides and metal carbonates	✓	?	x
46	Identify the spectator ions in a neutralisation reaction equation	✓	?	x
47	Explain what can be investigated using a titration	✓	?	x
48	Describe why an indicator is used in a titration	✓	?	x
49	Carry out calculations from balanced chemical equations	✓	?	x

Key Area 1.1 Reaction Rates

Rate of Reaction

- The rate of a chemical reaction is a measure of how fast the reaction occurs
- The reaction rate is dependent on the reaction that is taking place

Variables Affecting Reaction Rate

- There are many variables that can affect the rate of a reaction
- The table below details how changing concentration, temperature and surface area can affect the rate of reaction

Variable	Change to Variable	Change to Reaction Rate
Concentration	Increase	Speeds up reaction
	Decrease	Slows down reaction
Temperature	Increase	Speeds up reaction
	Decrease	Slows down reaction
Surface Area	Increase	Speeds up reaction
	Decrease	Slows down reaction

Catalysts

- A catalyst is a substance which speeds up a reaction
- A catalyst remains chemically unchanged during the reaction and can be reused
    - The type of catalyst at the start of the reaction is the same at the end of the reaction.
    - The mass of the catalyst at the start of the reaction is the same at the end of the reaction.

Monitoring Reaction Rates

- The rate of a chemical reaction is how fast the reactants are being used up and how fast the products are being made
- The rate can therefore be determined by measuring
    - Changes in the concentration of the reactants or products
    - Changes in the mass of the reactants or products
    - Changes in the volume of the reactants or products

Calculating the Average Rate of Reaction

- The average rate of a reaction can be calculated using the following equation

$$\text{Average rate} = \frac{\text{Change in measurable quantity}}{\text{Change in time}}$$

- The change in measurable quantity can be read from a table of results or from a graph produced from the results
- The units of average rate changes dependent on the measurable quantity

Measurable quantity	Units	
mass	grams per second	gs^{-1}
volume	centimetres cubed per second	cm^3s^{-1}

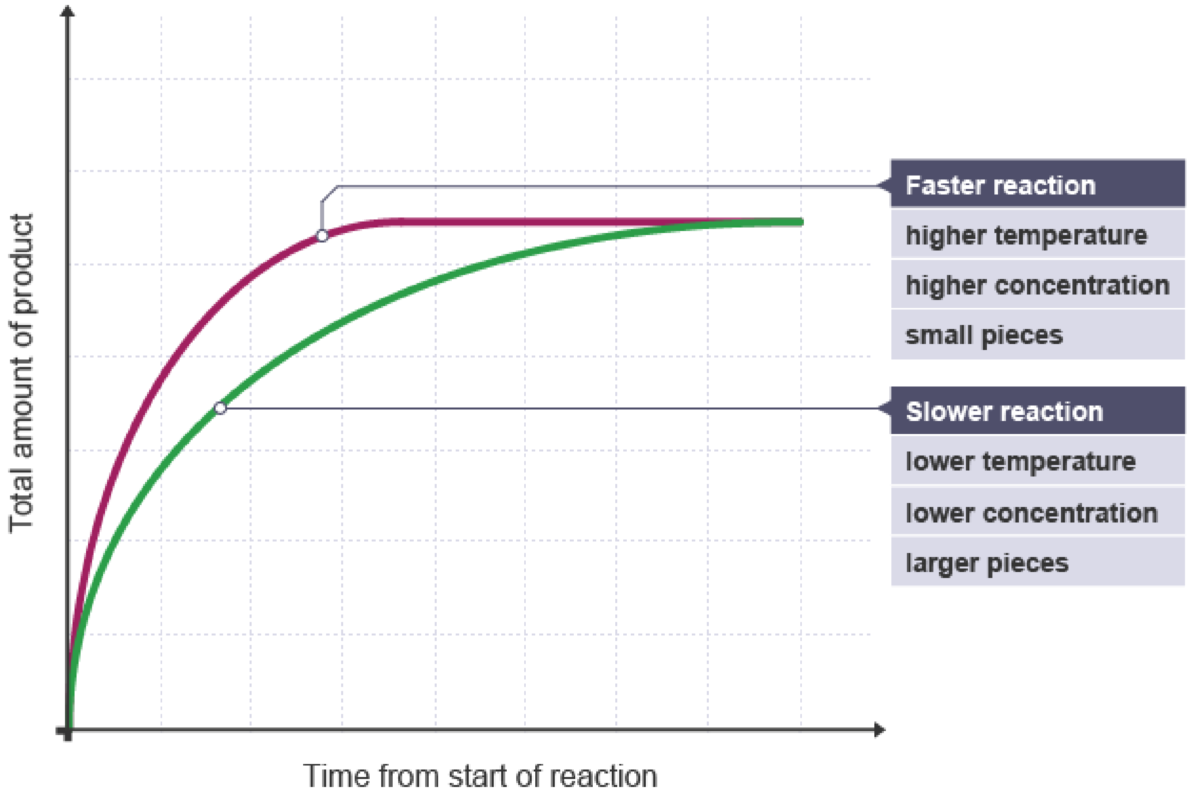
Rate of Reaction Graphs

- We can use recorded data from an experiment to create a reaction rate graph
    - The reaction rate is related to the gradient (slope) of the line
    - The reaction has stopped when the line is horizontal

- These graphs can be used to find out information about the reaction
    - When was the reaction the fastest?
    - How long did the reaction last?
    - What volume of gas was produced after a specified time?
    - What was the total volume of gas produced in the reaction?

- To compare reactions, multiple experiments can be plotted on the same graph
    - The variable being measured in the experiments must be the same
    - The use of a catalyst, increased/decreased temperatures, increased/decreased concentrations, increased/decreased surface area can be seen by comparing reaction rate graphs

- The example graph below shows the comparison between a faster and slower reaction
    - The steeper gradient of the purple line shows clearly that this is the faster reaction
    - The end point of each reaction can be clearly observed
    - The total amount of product produced is consistent independent on the rate of the reaction



Key Area 1.2 Atomic Structure and Bonding

The Periodic Table

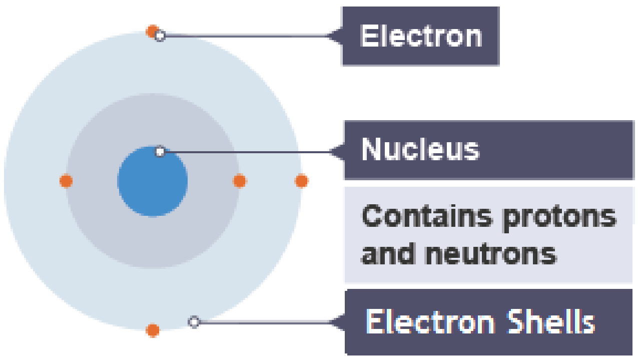
- 118 known elements are found in the Periodic Table
    - An element is a substance which contains only one type of atom
    - Each element has a different symbol and atomic number

- The Periodic Table is arranged in horizontal rows called periods and vertical columns called groups
    - The elements are arranged by atomic number and based on their chemical properties

- Elements in the same group of the Periodic Table have similar chemical properties
    - The alkali metals are all soft and reactive metals that will react with water to produce an alkaline solution (Group 1)
    - The halogens are all reactive non-metal elements (Group 7)
    - The noble gases are all colourless and extremely unreactive elements (Group 0)

The Structure of the Atom

- Atoms are made up of three subatomic particles; protons, neutrons and electrons
    - Protons and neutrons are found in the central nucleus
    - Electrons are found in the electron shells/energy levels outside the nucleus
    - This is shown in the diagram below.



- Each of the subatomic particles has an associated chare and relative mass
    - These are summarised in the table below
    - The nucleus of an atom will have the highest mass
    - Protons are positively charged particles
    - Electrons are negatively charged particles
    - Neutrons are electrical neutral particles
    - Atoms are electrically neutral as the number of positive protons equals the number of negative electrons.

Particle	Position	Charge	Relative Mass (AMU)
Electron	Electron Shell	-1	Almost zero
Proton	Nucleus	+1	1
Neutron	Nucleus	0	1

Atomic Number and Mass number

- Each element in the periodic table has a different atomic number
    - The atomic number is equal to the number of protons in an atom
    - From the atomic number you can work out the number of electrons in an atom as there must be the same number of electrons and protons

- Each element in the periodic table has a mass number
    - The mass number is equal to the total number of protons and neutrons
        - Number of neutrons = Mass number – Atomic number

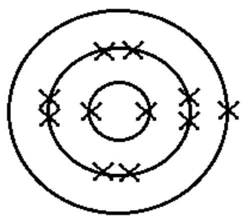
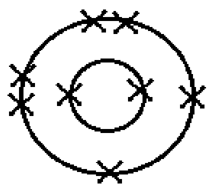
- The atomic number and mass number of an element can be shown using nuclide notation
    - The elemental symbol is shown as found on the periodic table
    - To the lower left of the symbol the atomic number is shown
    - To the upper left of the symbol the mass number is shown

Electron Arrangements

- The electrons within an atom are organised into different shells/levels
- Each shell/level has a certain number of electrons that can be added to that shell/level

Shell/Level	Number of electrons
1	**2**
2	**8**
3	**8**
4	**2**

- The electron arrangements of different atoms can be found on page 6 of the databook
- The electron arrangement of an atom can be represented using numbers of a diagram
    - Examples are shown below

Element	Number of electrons	Electron arrangement	Electron arrangement diagram
Sodium	11	2,8,1	
Oxygen	8	2,6	

Isotopes

- Isotopes are atoms with the same atomic number but different mass number
- Each has the same number of protons but a different number of neutrons
    - The carbon atoms shown below are isotopes

$$^{12}_{6}C \qquad ^{14}_{6}C$$

	C-12	C-14
Atomic Number	6	6
Mass Number	12	14
Protons	6	6
Electrons	6	6
Neutrons	6	8

Relative Atomic Mass (RAM)

- Elements are made up of isotopes
    - The mass given in the databook is the relative atomic mass (RAM)
- The relative atomic mass is calculated from the masses of all the isotopes of an element taking into account the percentage proportion of each
- There are two isotopes of chlorine, shown below
    - The RAM of chlorine is 35.5, therefore chlorine-35 must be more abundant because the mass number is closer to the RAM

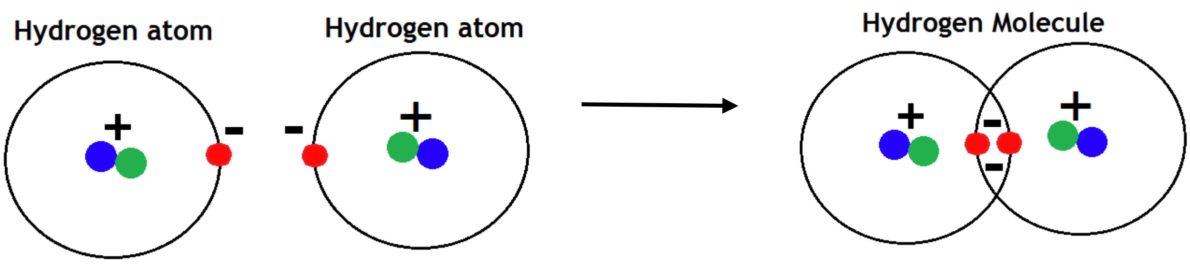
$$^{35}_{17}Cl \qquad ^{37}_{17}Cl$$

Bonding

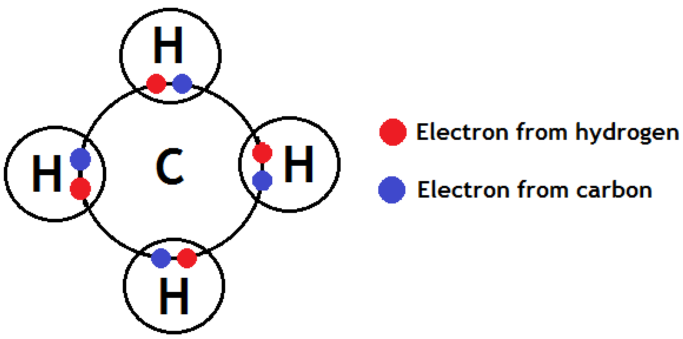
- An atom can bond with other atoms in order to achieve a stable electron arrangement
    - A stable electron arrangement is achieved when an atom has full outer electron shells/levels
    - An atom can lose, gain or share electrons to achieve a stable electron arrangement
- There are different types of bonds that atoms can form with other atoms
    - Covalent bonds
    - Ionic bonds

Covalent Bonds

- A covalent bond is a shared pair of electrons between two non-metal atoms
    - The shared pair of electrons is attracted to the positive nuclei of both atoms
- Covalent bonds are strong
- Atoms that form covalent bonds form molecules
- A diatomic molecule can be formed when two of the same atom form a covalent bond
    - There are seven diatomic elements
    - Iodine (I_2), bromine (Br_2), chlorine (Cl_2), fluorine (F_2), oxygen (O_2), nitrogen (N_2) and hydrogen (H_2)
    - I Bring Clay For Our New House
- Examples of covalent bond are shown below
    - Hydrogen (H_2)
        - Each hydrogen atom has one outer electron
        - The hydrogen atoms share their electrons to create the covalent bond
        - When bonded, each hydrogen atom has a full outer shell



    - Methane (CH_4)
        - The carbon atom has four outer electrons and the hydrogen atoms each have one outer electron
        - Each hydrogen atom can share its electron with the carbon atom to create 4 pairs of electrons
        - When bonded, each hydrogen atom and the carbon atom have full outer shells



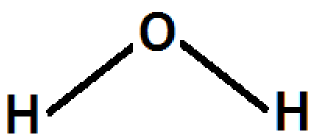
- More than one covalent bond can be formed between two atoms when multiple electrons are shared
    - Two covalent bonds between two atoms is termed a double bond e.g. diatomic oxygen (O=O)
    - Three covalent bonds between two atoms termed a triple bond e.g. diatomic nitrogen (N≡N)

- Covalent substances can take two forms
  - Covalent molecular
  - Covalent Network

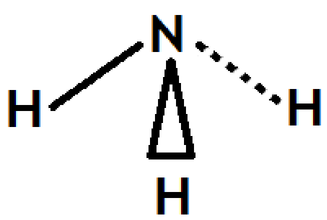
- Covalent molecules can form a variety of different shapes

  - Linear
    - A molecule will have a linear shape when it has one atom bonded to two other atoms OR one atom bonded to one other
    - All diatomic molecules are linear in shape
    - An example of a liner molecule is hydrogen fluoride (HF)

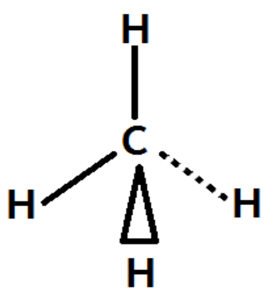
  - Angular
    - A molecule will have an angular shape when it has one atom bonded to two other atoms
    - An example of an angular molecule is water (H_2O)



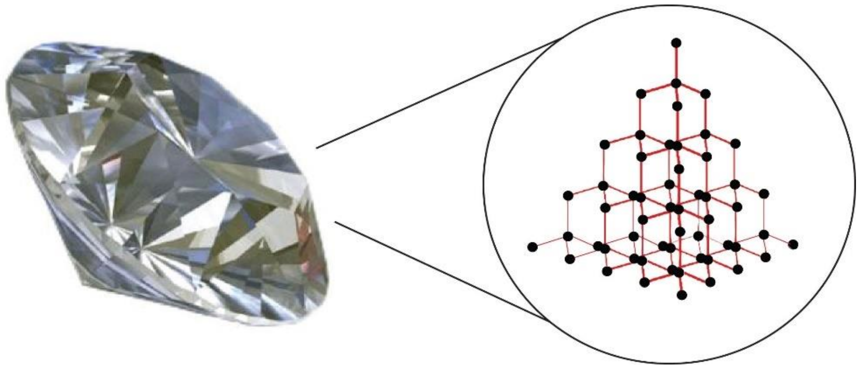
  - Trigonal Pyramidal
    - A molecule will have a trigonal pyramidal shape when it has one atom bonded to three other atoms
    - An example of a trigonal pyramidal molecule is ammonia (NH_3)



  - Tetrahedral
    - A molecule will have a tetrahedral shape when it has one atom bonded to four other atoms
    - An example of a tetrahedral molecule is methane (CH_4)



- A few covalent substances can form covalent networks
    - Boron, carbon, silicon, silicon carbide and silicon dioxide can form covalent networks
    - For example, diamond is formed from a covalent network containing only carbon atoms covalently bonded together



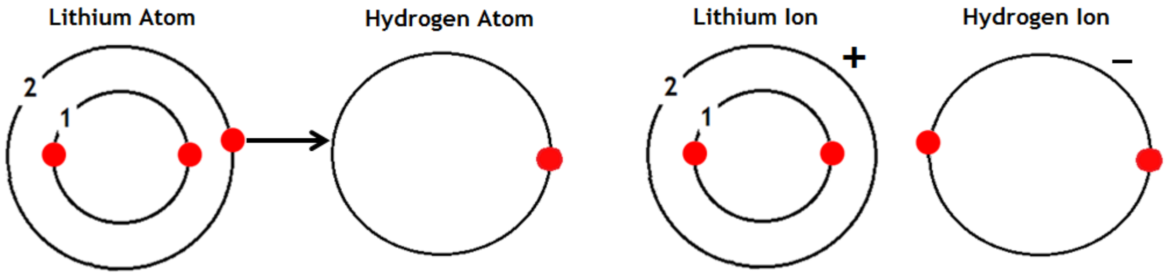
- Substances containing covalent molecular structures and covalent networks have different properties and these are summarised in the table below
    - By using experimental procedures to test the properties of a substance, it is possible to determine if it has a discrete molecular or network structure

Property	Covalent molecular	Covalent network
Melting point	Low	High
Boiling point	Low	High
Conductivity	Does not conduct (except graphite)	Does not conduct

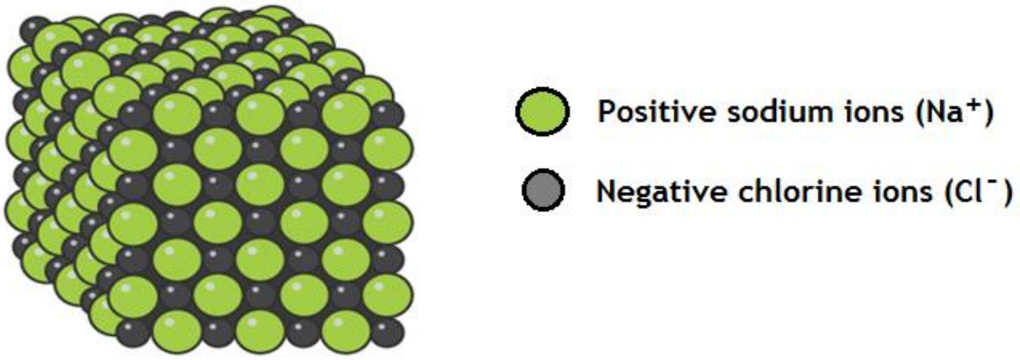
- Covalent molecular substances have strong covalent bonds within the molecule and weak attractions between the molecules
    - resulting in a low melting point and boiling point
    - can be soluble in a range of different solvents
- Covalent network structure have strong covalent bonds through the structure
    - resulting in a high melting point and boiling point
    - considered insoluble

Ionic Bonds

- Ionic bonds are formed between a metal and a non-metal atom
    - Electrons are transferred from one atoms to another forming two ions
    - Ions are formed when an atom loses or gains electrons
    - The metal atom loses electrons to form a positive ion and a non-metal atom gains electron to form a negative ion
    - The ionic bond is formed at the positive and negative ions are electrostatically attracted to one another
- Ionic bonds are formed between lithium and hydrogen to form lithium hydride (LiH)
    - The outer electron of lithium is transferred to the outer shell of hydrogen
    - This results in the formation of a positive lithium ion and a negative hydrogen ion



- Ionic compounds form lattice structures of oppositely charged ions
  - A lattice is a regular arrangement of ions
  - Every positive ion is surrounded by negative ions
  - Every negative ion is surrounded by positive ions
  - For example, sodium chloride (NaCl)



- Ionic compounds also have a distinct set of properties that are summarised in the table below

Property	Ionic Lattice
Melting point	High
Boiling point	High
Conductivity	Does not conduct when solid Conducts when molten or in solution

- Many ionic compounds are soluble in water
- Ionic compounds conduct electricity when molten or in solution as the ions are free to move as a result of the lattice structure breaking down
  - The free ions create a flow of charge

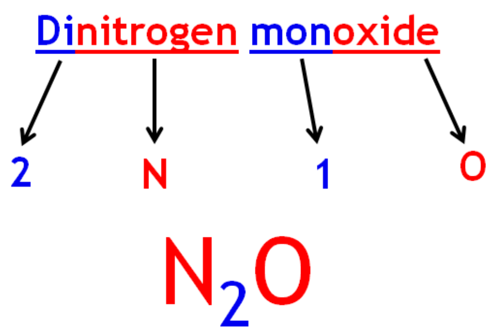
Key Area 1.3 Formulae and Reaction Quantities

Molecular Formulae

- The molecular formula of a compound indicates the number of each element present in the compound
    - Elements are represented by their symbol and the number of atoms of that element present in the **compound** is represented by a small subscript number
- The name of a compound can contain prefixes that give information about the formula

Number of atoms	Prefix
1	mono
2	di
3	tri
4	tetra

- For example, dinitrogen monoxide



Valency

- The valency of an atom can be described as the number of bonds an atom can make
- Elements in the same group of the Periodic Table have the same valency
- The valency of an atom can be determined by its group number, summarised in the table below

Group Number	1	2	3	4	5	6	7	0
Valency	1	2	3	4	3	2	1	0

- The valency of the transition metal elements are variable
    - The valency of the transition metal atom will be indicated in the name of the compound using Roman numerals, summarised in the table below

Roman numeral	I	II	III	IV	V	VI	VII
Valency	1	2	3	4	5	6	7

Writing Molecular Formula

- The SVSDF system is used to write a molecular formula

1. SYMBOL	Write the symbols for the elements in the compound
2. VALENCY	Write the valency of each element beneath the symbol
3. SWAP	Swap the valencies
4. DIVIDE	If the valency can be simplified, divide them both by the smaller of the two numbers
5. FORMULA	Write the molecular formula for the compound

- Writing the molecular formula for potassium oxide using this system is detailed below

1. SYMBOL	K	O
2. VALENCY	1	2
3. SWAP	2	1
4. DIVIDE	2	1
5. FORMULA	**K_2O**	

- Writing the molecular formula for copper (II) oxide using this system is detailed below

1. SYMBOL	Cu	O
2. VALENCY	2	2
3. SWAP	2	2
4. DIVIDE	1	1
5. FORMULA	**CuO**	

Formulae of compounds containing group ions

- Group ions contain two or more atoms
- The formula for the common group ions are in the databook
- The valency of the group ion is the same as the number of charges on the group ion
- Writing the molecular formula for magnesium nitrate using this system is detailed below

1. SYMBOL	Mg	NO_3
2. VALENCY	2	1
3. SWAP	1	2
4. DIVIDE	1	2
5. FORMULA	**$Mg(NO_3)_2$**	

The nitrate ion is a one negative ion, therefore, it has a valency of one

Ionic Formula

- The ionic formula of a compound indicates the number of each type of ion is present in an ionic compound or one containing group ions
  - A positive ion is represented by a +
  - A negative ion is represented by a –

- The charge on an element is the same as the valency of that atom
  - In an ionic compound, the metal atom will form a positive ion and the non-metal will form a negative ion
- The charge on a group ion is the same as that detailed in the databook
- Overall, the compound should have an equal number of positive and negative ions to ensure the atom is neutral
- Writing the ionic formula for sodium chloride is detailed below

1. SYMBOL	Na	Cl
2. VALENCY	1	1
3. SWAP	1	1
4. DIVIDE	1	1
5. FORMULA	**$Na^{+}Cl^{-}$**	

Sodium is a metal with a valency of 1 (sodium is in Group 1), therefore, the ion has a + charge

Chlorine is a non-metal with a valency of 1 (chlorine is in Group 7), therefore, the ion has a - charge

- Writing the ionic formula for calcium nitrate is detailed below

1. SYMBOL	Ca	NO_3
2. VALENCY	2	1
3. SWAP	1	2
4. DIVIDE	1	2
5. FORMULA	**$Ca^{2+}(NO_3^{-})_2$**	

Calcium is a metal with a valency of 2 (calcium is in Group 2), therefore, the ion has a 2+ charge

The nitrate ion has a – charge, as found in the databook

- Writing the ionic formula for ammonium phosphate is detailed below

1. SYMBOL	NH_4	PO_4
2. VALENCY	1	3
3. SWAP	3	1
4. DIVIDE	3	1
5. FORMULA	**$(NH_4^+)_3PO_4^{3-}$**	

The ammonium ion has a + charge, as found in the databook

The phosphate ion has a 3- charge, as found in the databook

Chemical Equations

- A chemical equation can be used to describe a reaction, showing the chemicals which react (reactants) and the chemicals which are produced (products)

reactants $\longrightarrow$ **products**

- The state symbols of the reactants and products must also be included
  - solids (s)
  - liquids (l)
  - aqueous solutions (aq)
  - gases (g)

- For example, the reaction of sodium with water to produce sodium hydroxide and hydrogen

1. Word equation	sodium + water	$\longrightarrow$	sodium hydroxide + hydrogen
2. Formula equation	$Na + H_2O$	$\longrightarrow$	$NaOH + H_2$
3. State symbols	$Na(s) + H_2O(l)$	$\longrightarrow$	$NaOH(aq) + H_2(g)$

Balanced Chemical Equations

- A balanced equation shows the same number and type of atoms on each side of the equation
- For example, the reaction of copper with oxygen to produce copper oxide

1. Word Equation copper + oxygen $\longrightarrow$ copper oxide
2. Formula equation $Cu + O_2 \longrightarrow CuO$
3. State Symbols $Cu(s) + O_2(g) \longrightarrow CuO(s)$

- This equation is UNBALANCED, there are unequal numbers of each type of atom on each side
  - On the reactant side there is one copper atom and two oxygen atoms
  - On the reactant side there is one copper atom and one oxygen atom
  - You can multiply reactant or product molecules/atoms to balance the equation

reactants	products
1 Cu	1 Cu
2 O	1 O

1. Multiply the copper oxide by 2 to balance the oxygen atoms

$$Cu(s) + O_2(g) \longrightarrow 2CuO(s)$$

reactants	products
1 Cu	2 Cu
2 O	2 O

2. You must now multiply the copper by 2 on the reactant side of the equation to balance the copper atoms
   - This creates the balanced chemical equation

$$2Cu(s) + O_2(g) \longrightarrow 2CuO(s)$$

reactants	products
2 Cu	2 Cu
2 O	2 O

- Another example is the reaction of butene with oxygen to produce carbon dioxide and water

1. Word Equation butene + oxygen $\longrightarrow$ carbon dioxide + water
2. Formula equation $C_4H_8 + O_2 \longrightarrow CO_2 + H_2O$
3. State Symbols $C_4H_8(l) + O_2(g) \longrightarrow CO_2(g) + H_2O(l)$

- This equation is UNBALANCED

reactants	products
4 C	1 C
8 H	2 H
2 O	3 O

1. Multiply the carbon dioxide on the product side by 4 to balance the carbon atoms

$$C_4H_8(l) + O_2(g) \longrightarrow 4CO_2(g) + H_2O(l)$$

reactants	products
4 C	4 C
8 H	2 H
2 O	9 O

2. You must now multiply the water on the product side by 4 to balance the hydrogen atoms

$$C_4H_8(l) + O_2(g) \longrightarrow 4CO_2(g) + 4H_2O(l)$$

reactants	products
4 C	4 C
8 H	8 H
2 O	12 O

3. You must now multiply the oxygen on the reactant side by 6 to balance the oxygen atoms
   - This creates the balanced chemical equation

$$C_4H_8(l) + 6O_2(g) \longrightarrow 4CO_2(g) + 4H_2O(l)$$

reactants	products
4 C	4 C
8 H	8 H
12 O	12 O

Gram Formula Mass (GFM)

- The gram formula mass (GFM) of a substance is known as the mass of one mole
  - The unit of gram formula mass is grams (g)
  - The relative atomic masses of the elements present in a compound can be used to calculate the gram formula mass
- For example, calculate the gram formula mass (GFM) of calcium bromide ($CaBr_2$).

1. Identify the number of atoms of each element

   (1 x Ca) + (2 x Br)

2. Replace the symbols with the relative atomic masses (RAM)

   (1 x 40) + (2 x 80)

3. Calculate

   GFM = 200g

- For example, calculate the gram formula mass (GFM) of butanol (C_4H_9OH).

1. Identify the number of atoms of each element

   (4 x C) + (10 x H) + (1 x O)

2. Replace the symbols with the relative atomic masses (RAM)

   (4 x 12) + (10 x 1) + (1 x 16)

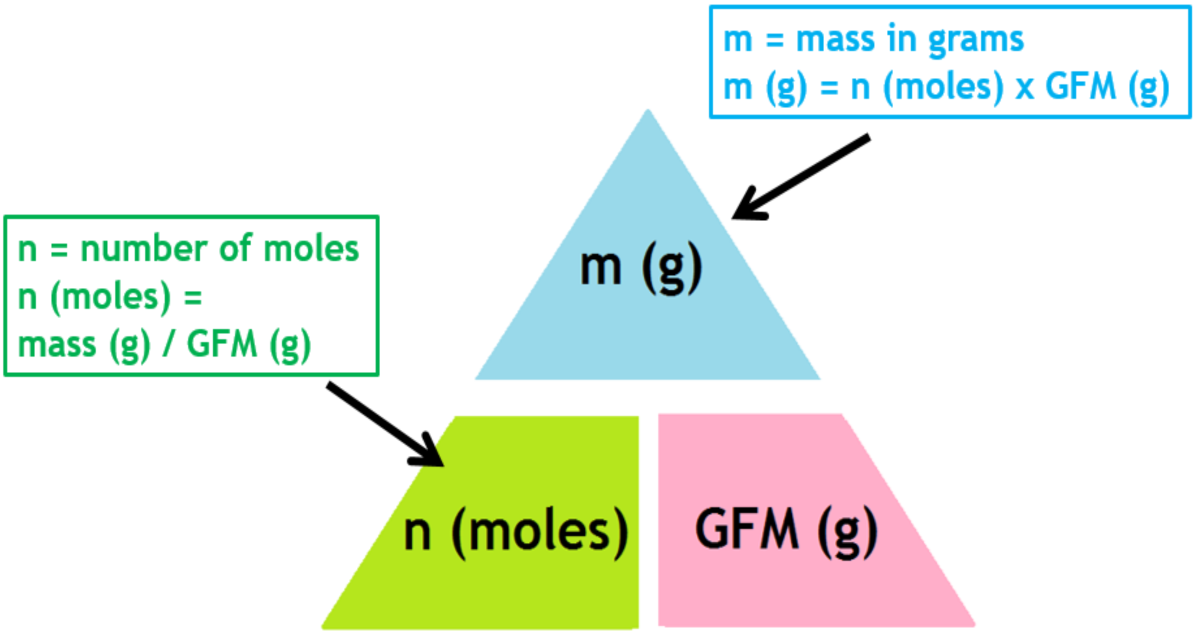
3. Calculate

   GFM = 74g

The Mole

- A mole is a unit of measurement used in chemistry
  - 1 mole is equal to the gram formula mass (GFM)
- There are two formulae that can be used to calculate the number of moles of a substance
  - These are most commonly used in the form of formula triangles

1. This triangle can be used to calculate number of moles or mass dependent on the information given in a question

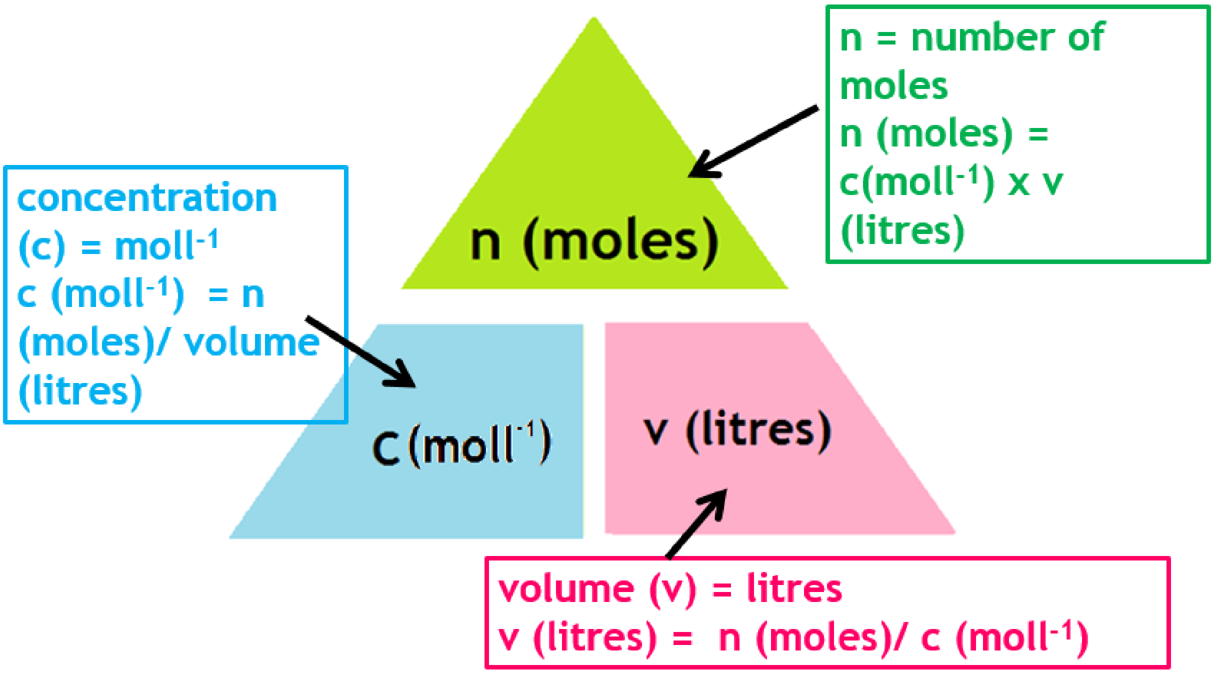


- For example, calculate the number of moles present in 25g of calcium carbonate ($CaCO_3$)

  - Equation used — n (moles) = m (g) / GFM (g)
  - Calculate GFM — (1 x Ca) + (1 x C) + (3 x O)
    (1 x 40) + (1 x 12) + (3 x 16)
    = 100g
  - What do you know — n = ?
    m = 25g
    GFM = 100g
  - Equation — n = m/GFM
    = 25g/100g
    = 0.25moles

- For example, calculate the mass of 3 moles of sodium oxide (Na_2O)
  - Equation used — m (g) = n (moles) x GFM (g)
  - Calculate GFM — (2 x Na) + (1 x O)
    (2 x 23) + (1 x 16)
    = 62g
  - What do you know — n = 3 moles
    m = ?
    GFM = 62g
  - Equation — m = n x GFM
    = 3 moles x 62g
    = 186g

2. This triangle can be used to calculate number of moles, concentration or volume of a solution dependent on the information given in a question



- For example, calculate the number of moles in 2 litres of 1.5moll^{-1} magnesium chloride
  - Equation used — n (moles) = c (moll^{-1}) x v (l)
  - What do you know — n = ?
    c = 1.5moll^{-1}
    v = 2l
  - Equation — n = c x v
    = 1.5moll^{-1} x 2l
    = 3 moles

- For example, calculate the concentration of the solution formed when 0.25 moles of calcium hydroxide are dissolved in $500cm^3$ of water
  - Equation used   c ($moll^{-1}$) = n (moles) / v (l)
  - What do you know   n = 0.25moles
    c = ?
    v = $500cm^3$= 500/1000 = 0.5l
  - Equation   c = n / v
    = 0.25moles/0.5litres
    = 0.5 $moll^{-1}$
- For example, calculate the volume required to create a $1moll^{-1}$ solution of sodium hydroxide using 2 moles of solid sodium hydroxide
  - Equation used   v (l) = n (moles) / c ($moll^{-1}$)
  - What do you know   n = 2 moles
    c = $1moll^{-1}$
    v = ?
  - Equation   v = n (moles)/ c($moll^{-1}$)
    = 2moles/$1moll^{-1}$
    = 2l

Percentage Composition

- The percentage composition of a compound indicates the percentage of each type of element in the compound
- Percentage composition can be calculated using the following steps
    1. Write the molecular formula for the compound
    2. Calculate the gram formula mass of the compound
    3. Write the mass of each element present
    4. Calculate the percentage of a specific element by dividing the mass of the element by the gram formula mass of the compound
- For example, the percentage composition of ammonium nitrate is shown below

Step 1 ammonium nitrate

S	NH_4	NO_3
V	1	1
S	1	1
D	1	1
F	NH_4NO_3	

Step 2 GFM = (2xN) + (4xH) + (3xO)

GFM = (2x14) + (4x1) + (3x16)

GFM = 80g

Step 3 2 x N = 28g

4 x H = 4g

3 x O = 16g

Step 4 %N = 28/80 x 100 = 35%

%H = 4/80 x 100 = 5%

%O = 48/80 x 100 = 60%

- The total percentage should always equal 100%

Key Area 1.4 Acids and Bases

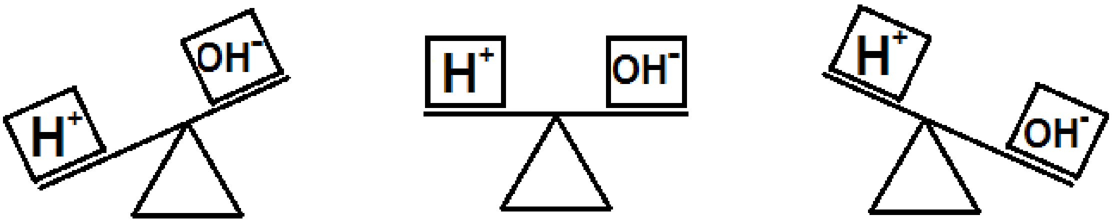
Dissociation of Water

- Water molecules can break down into hydrogen and hydroxide ions
  - This is a reversible reaction
  - A mixture of hydrogen ions, hydroxide ions and water molecules will be present at any one time
  - The reaction is shown below

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

water molecule hydrogen ion hydroxide ion

- Dependent on the concentration of hydrogen ions an acidic, alkaline or neutral solution can be produced
  - When the number of hydrogen and hydroxide ions are equal, a neutral solution is formed e.g. water
  - When the number of hydrogen ions is greater than the number of hydroxide ions, an acidic solution is formed e.g. hydrochloric acid
  - When the number of hydrogen ions is less than the number of hydroxide ions, an alkaline solution is formed e.g. sodium hydroxide

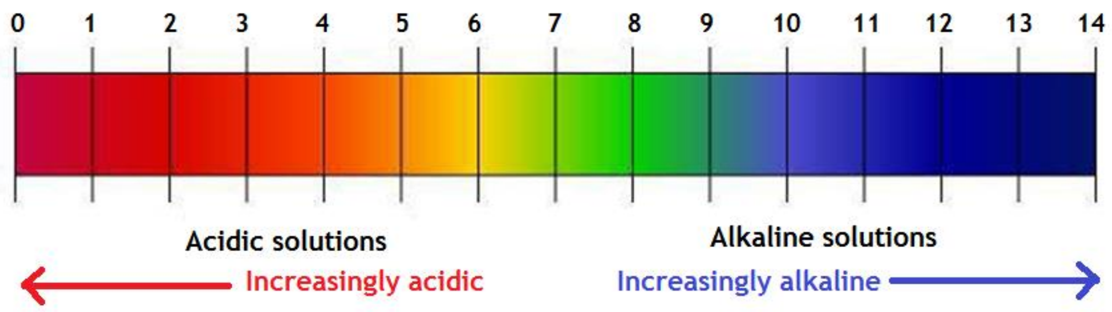


acidic solution neutral solution alkaline solution

Acids and Bases

- The concentration of hydrogen ions present in a solution determines if it is an acid or an alkali
  - pH is a measure of the hydrogen ion concentration present
  - Most common pH values range between 0 and 14
  - Acids have a pH below 7
  - Alkalis have a pH above 7
  - Water and neutral solutions have a pH equal to 7

- The pH of a solution can be tested using pH paper, universal indicator or a pH probe
- pH paper and universal indicator show a different colour dependant on the pH of a solution
  - The associated colours can be shown on a pH scale



Diluting Acids and Alkalis

- Adding water to an acid or alkali will change its pH
- Water is mostly water molecules so adding water to an acid or base reduces the concentration of ions in the solution
- When an acidic solution is diluted with water
  - The concentration of H+ ions decreases
  - The pH of the solution increases towards 7
  - To make the pH change by 1, a tenfold dilution is required
- When an alkaline solution is diluted with water
  - The concentration of H+ ions increases
  - The pH of the solution decreases towards 7
  - To make the pH change by 1, a tenfold dilution is required

Forming Acids and Alkalis

- Water soluble oxides can be dissolved in water to produce acids or alkalis
  - Metal oxides dissolve in water to produce metal hydroxides which are alkaline
    - There is an increase in the concentration of hydroxide ions
  - Non-metal oxides dissolve in water to produce acidic solutions
    - There is an increase in the concentration of hydrogen ions

Names and Formulae

- It is important to know the names and formulae of common acids and bases
  - Some of these are noted in the tables below

Name of Acid	Formula	Ionic
Hydrochloric acid	HCl	H^+Cl^-
Sulfuric acid	H_2SO_4	$2H^+(SO_4)^{2-}$
Nitric acid	HNO_3	$H^+NO_3^-$

Name of Base	Formula	Ionic
Sodium hydroxide	$NaOH$	Na^+OH^-
Calcium hydroxide	$Ca(OH)_2$	$Ca^{2+}\ 2OH^-$
Magnesium hydroxide	$Mg(OH)_2$	$Mg^{2+}\ 2OH^-$

Neutralisation

- Neutralisation is the type of reaction that takes place when a base is added to an acid
  - A neutralisation reaction results in the pH of the acids increasing towards 7, becoming neutral
- Water and a salt are always formed as a result of a neutralisation reaction

Naming Salts

- It is possible to name the salt from the type of acid and base used in the reaction
  - The first part of the name is always the metal present in the base
  - The second part of the name is dependent on the acid used
    - If hydrochloric acid is used, a chloride salt is formed
    - If nitric acid is used, a nitrate salt is formed
    - If sulfuric acid is used, a sulfate salt is formed
- Examples are detailed in the table below

Base	Acid	Salt
sodium hydroxide	hydrochloric acid	sodium chloride
magnesium oxide	sulfuric acid	magnesium sulfate
calcium carbonate	nitric acid	calcium nitrate

Neutralisation Chemical Equations

- A base is a substance that neutralises an acid including metal oxides, metal hydroxides and metal carbonates
- It is important that balanced chemical equations can be written for each type of neutralisation reaction

1. Metal oxides
   - General equation: acid + metal oxide $\longrightarrow$ salt + water
   - For example, the reaction of magnesium oxide and sulfuric acid forming magnesium sulfate and water

     sulfuric acid + magnesium oxide $\longrightarrow$ magnesium sulfate + water
     $H_2SO_4(aq) + MgO(s) \longrightarrow MgSO_4(aq) + H_2O(l)$

2. Metal hydroxides
   - General equation: acid + metal hydroxide $\longrightarrow$ salt + water
   - For example, the reaction of sodium hydroxide and hydrochloric acid forming sodium chloride and water

     hydrochloric acid + sodium hydroxide $\longrightarrow$ sodium chloride + water
     $HCl(aq) + NaOH(aq) \longrightarrow NaCl(aq) + H_2O(l)$

3. Metal carbonates
    - General equation: acid + metal carbonate $\longrightarrow$ salt + water + carbon dioxide
    - For example, the reaction of calcium carbonate and nitric acid forming calcium nitrate, water and carbon dioxide

    nitric acid + calcium carbonate $\longrightarrow$ calcium nitrate + water + carbon dioxide
    $HNO_3(aq) + CaCO_3(s) \longrightarrow Ca(NO_3)_2(aq) + H_2O(l) + CO_2(g)$
    $2HNO_3(aq) + CaCO_3(s) \longrightarrow Ca(NO_3)_2(aq) + H_2O(l) + CO_2(g)$

Neutralisation Ionic Equations

- Equations can be written showing the ions involved in a neutralisation reaction
    - Ions that remain the same on the reactant and product side of the equation are known as spectator ions
    - Spectator ions can be eliminated from these equations to show the reacting species
- For example, the reaction of lithium hydroxide and hydrochloric acid forming lithium chloride and water

    hydrochloric acid + lithium hydroxide $\longrightarrow$ lithium chloride + water
    $HCl(aq) + LiOH(aq) \longrightarrow LiCl(aq) + H_2O(l)$
    $H^+(aq) + Cl^-(aq) + Li^+(aq) + OH^-(aq) \longrightarrow Li^+(aq) + Cl^-(aq) + H_2O(l)$

    - The lithium ion and the chlorine ion are the same on both sides of the equation
    - These ions can be eliminated as they are spectator ions
    - The equation showing the reacting species would be as follows:

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

- For example, the reaction of calcium carbonate and sulfuric acid forming calcium sulfate, water and carbon dioxide

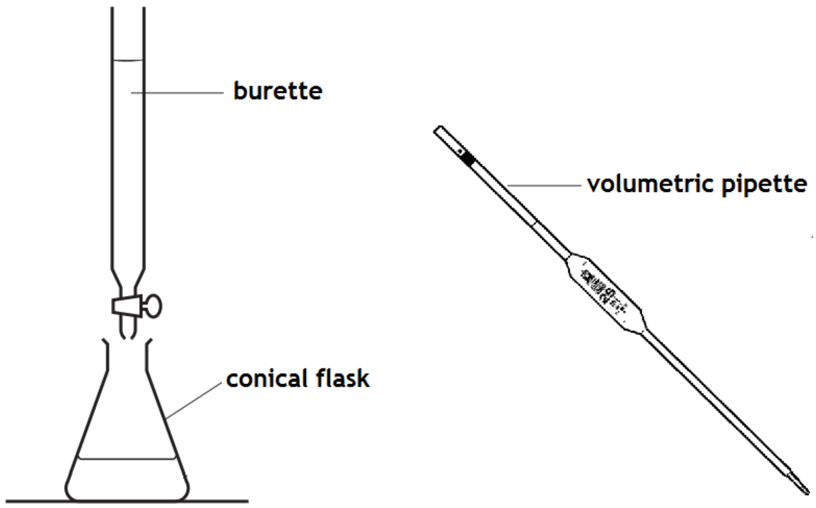
    nitric acid + calcium carbonate $\longrightarrow$ calcium sulfate + water + carbon dioxide
    $H_2SO_4(aq) + CaCO_3(s) \longrightarrow CaSO_4(aq) + H_2O(l) + CO_2(g)$
    $2H^+(aq) + SO_4^{2-}(aq) + Ca^{2+}CO_3^{2-}(s) \longrightarrow Ca^{2+}(aq) + SO_4^{2-}(aq) + H_2O(l) + CO_2(g)$

    - The calcium ion and the sulfate ion are the same on both sides of the equation
    - These ions can be eliminated as they are spectator ions
    - The equation showing the reacting species would be as follows:

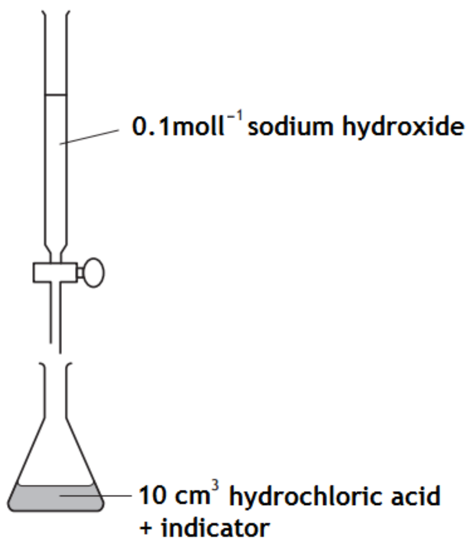
    $2H^+(aq) + CO_3^{2-}(s) \longrightarrow H_2O(l) + CO_2(g)$

Titrations

- Titration is an analytical technique used to determine the accurate volumes involved in chemical reactions such as neutralisation
    - An indicator is normally used to show the endpoint of the reaction
    - Titrations can be used to determine the concentration of a solution
- The most important pieces of apparatus require to carry out a titration include a burette, volumetric pipette and conical flask
    - The set up for a titration is shown below



- The base is added to the burette, ensuring the burette is filled and a specific volume of acid is measured using the volumetric pipette and added to the conical flask
- Universal indicator is added to the acid to make the end point of the reaction clearer
- To carry out the neutralisation and determine the exact volume of base required to neutralise the acid, the base is added drop wise to the acid
    - The end point of the reaction occurs when the indicator turns from red (acidic) to green (neutral)
- For example, the experiment used to calculate the volume of 0.1moll^{-1} sodium hydroxide required to neutralise 10cm^3 hydrochloric acid would be set up as shown below



Average Volume

- Titrations are repeated to ensure the reliability of the results
  - An average volume must be calculated
  - The results from a rough titration are never used in an average calculation
  - The results are presented in a table, an example is shown below

	Rough Titre	1st Titre	2nd Titre
Initial burette reading (cm^3)	0.0	0.0	0.0
Final burette reading (cm^3)	20.5	19.9	20.1
Volume used (cm^3)	20.5	19.9	20.1

- To calculate the average volume, only the 1st and 2nd titre results are used
  - Average volume (cm^3) = (1st Titre + 2nd Titre) / 2
    = (19.9 + 20.1) / 2
    = $20cm^3$

Calculations from Equations

- It is possible to calculate the concentration/ volume/ mass of a reactant or product required in a reaction
  - A balanced chemical equation is required
  - The mole calculations
- The following steps are used

1. Write a balanced molecular equation
2. Circle the two compounds mentioned in the question
3. Write the molar ratio
4. Calculate the number of moles of the substance you have been given information about
5. Use the molar ratio to state the number of moles of the compound you are trying to find
6. Calculate what you are being asked in the question

- An example is shown below

  Question: $16cm^3$ of $0.1moll^{-1}$ hydrochloric acid was required to neutralise $10cm^3$ of sodium carbonate. The equation for the reaction is

  $$2HCl + Na_2CO_3 \longrightarrow 2NaCl + CO_2 + H_2O$$

  Calculate the concentration in moll-1 of the sodium carbonate solution.

1. Balanced Chemical Equation

$$2HCl + Na_2CO_3 \longrightarrow 2NaCl + CO_2 + H_2O$$

2. Circle the two compounds mentioned in the question
    - Hydrochloric acid and sodium carbonate are mentioned in the question

$$2HCl + Na_2CO_3 \longrightarrow 2NaCl + CO_2 + H_2O$$

$v = 16cm^3$
$c = 0.1moll^{-1}$

$v = 10cm^3$
$c = ?$

3. Write the molar ratio

$2HCl : Na_2CO_3$
2 moles : 1 mole

4. Calculate the number of moles of the substance you have been given information about

$n = v \times c$
$n = 0.016 \times 0.1$
$n = 0.0016$ moles of HCl

5. Use the molar ratio to state the number of moles of the compound you are trying to find

$2HCl : Na_2CO_3$
2 moles : 1 mole
0.0016 moles : 0.0008 moles of Na_2CO_3

6. Calculate the concentration

$n = v \times c$
$c = n/v$
$c = 0.008/0.01$
$c = \underline{\underline{0.08\ moll^{-1}}}$