What is Chemistry?
Chemistry is the branch of **Natural Science** that deals with how substances react with one another under certain given conditions.It is a central science, having strong interactions with biology, medicine, earth and environmental sciences, physics, and mathematics.

Branches of Chemistry/Areas of Study of Chemistry
There are several branches of chemistry. Here is a list of the main branches of chemistry, with an overview of what each branch of chemistry studies.

Biochemistry- Biochemistry is the branch of chemistry concerned with the chemical reactions that occur inside living organisms.

Agro chemistry - This branch of chemistry may also be called agricultural chemistry. It deals with the application of chemistry for agricultural production, food processing, and environmental remediation as a result of agriculture.

Analytical Chemistry - Analytical chemistry is the branch of chemistry involved with studying the properties of materials or developing tools to analyze materials.

Chemical Engineering - Chemical engineering involves the practical application of chemistry to solve problems.

Electrochemistry- Electrochemistry is the branch of chemistry that involves the study of chemical reactions in a solution at the interface between an ionic conductor and an electrical conductor. Electrochemistry may be considered to be the study of electron transfer, particularly within an electrolytic solution.

Environmental Chemistry - Environmental chemistry is the chemistry associated with soil, air, and water and of human impact on natural systems.

Food Chemistry - Food chemistry is the branch of chemistry associated with the chemical processes of all aspects of food. Many aspects of food chemistry rely on biochemistry, but it incorporates other disciplines as well.

General Chemistry- General chemistry examines the structure of matter and the reaction between matter and energy. It is the basis for the other branches of chemistry.

Inorganic Chemistry - Inorganic chemistry is the branch of chemistry that deals with the structure and interactions between inorganic compounds, which are any compounds that aren't based in carbon-hydrogen bonds.

Kinetics - Kinetics examines the rate at which chemical reactions occur and the factors that affect the rate of chemical processes.

Medicinal Chemistry - Medicinal chemistry is chemistry as it applies to pharmacology and medicine.

Organic Chemistry - This branch of chemistry deals with the chemistry of carbon and living things.

Physical Chemistry - Physical chemistry is the branch of chemistry that applies physics to the study of chemistry. Quantum mechanics and thermodynamics are examples of physical chemistry disciplines.

Polymer Chemistry - Polymer chemistry or macromolecular chemistry is the branch of chemistry that examines the structure and properties of macromolecules and polymers and finds new ways to synthesize these molecules.

Theoretical Chemistry - Theoretical chemistry applies chemistry and physics calculations to explain or make predictions about chemical phenomena.

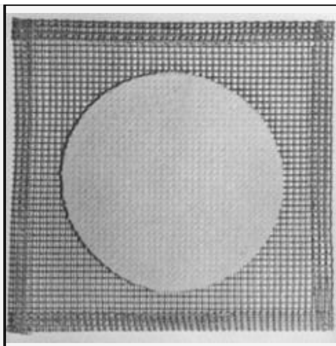
CHEMISTRY LABORATORY APPRATUS

Chemistry laboratory apparatus are pieces of equipment that Scientists(Chemists) use to do experiments in a laboratory.

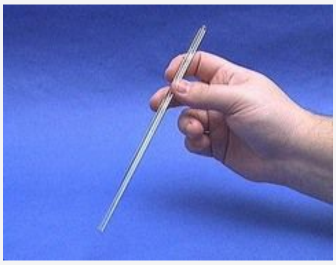
 **Medicine dropper**: Used to transfer liquids	 **Bunsen Burner**: used for heating	 **Beaker**: Holds liquids; Used for heating liquids; Not a measuring device

 **Test Tube**: Container for reactions	 **Test Tube Rack**: Hold test tubes	 **Forceps**: Used to pick up substances in the lab
 **Spatula or Scoopula**: Used to transfer solids	 **Tongs/Crucible Tong**: Used to pick up and hold substances; For moving materials; For use with crucibles	 **Beaker Tongs**: For moving hot beakers
 **Test Tube Brush**: Used to clean glassware	 **Thermometer:** Used for measuring temperature at which chemical reactions take place.	 **Clamp Stand**: Used to clamp/hold apparatus.

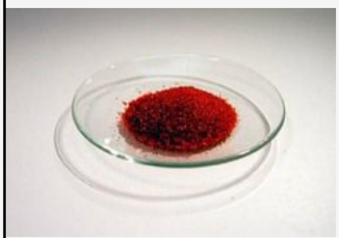
Erlenmeyer Flask:
For heating and holding reactions

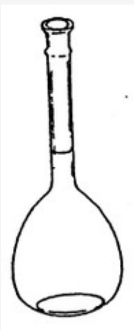

Wire Gauze:
Support used to hold glassware when being heated


Test Tube Clamp/Tongs:
Used to hold a test tube while heating


Stirring Rod:
Used to agitate liquids or mixtures

Crucible and Cover:
For heating small amounts at high temperatures

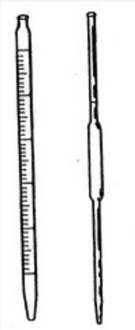

Watch Glass:
Used as a cover or sample plate


Volumetric flask:
is used to measure one specific volume. They are mostly used in mixing solutions where a one litre or one half a litre is needed.


Graduated (measuring) Cylinder:
Used to measure approximate volumes of liquids or solutions.


Mortar and Pestle Mortar and Pestle:
For crushing solids

Evaporating Dish:
Used to evaporate liquids from a mixture

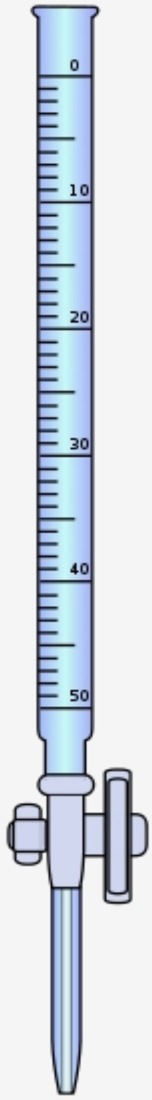


Pipette: Used to measure fixed volume of liquids or solutions. Transfer measured substances into another vessel

Separating funnel: Used to separate immiscible liquids.

Funnel:
Liquid transfer; Separation techniques

Pipette Filler: Used to fill a pipette with a solution.



Burette: Used to measure accurate volume of liquids or solutions.

Round and Flat bottomed flasks respectively: Used for heating and holding reactions

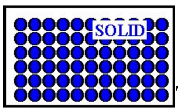
States of Matter
Matter is anything that exists, occupies space and has weight.
Matter has three states:
1. Gas
2. Liquid
3. Solid
These are physical states of matter. The three states of one matter may have different physical properties while their chemical properties are same. Water exists in three physical states: solid (ice), liquid and gas (steam) has same chemical properties.

Kinetic Theory of Matter
The Kinetic theory was presented to explain the properties of gases and is called kinetic theory of gases. But this theory was also able to explain the composition of liquid and solid state of matter. So it is called **Kinetic Theory of Matter**.
According to Kinetic Theory of matter:
1. All matter is composed of atoms, molecules or ions.
2. These particles have kinetic energy due to which they are in the state of motion.
3. In gaseous state, these particles move in a straight line. They collide with one another and with the walls of container. In liquids the rate of their movement is very small but in solids, there is to and fro motion only.
4. Generally material particles can have three types of movements, i.e. translational (moving in a straight line), rotational (moving round) and vibrational (moving to and fro).

Three Basic Units of Matter
The three basic units of matter are **atoms**, **molecules** and **ions**.

SOLID
The state of matter which has **definite (fixed) shape** and **volume** is called solid.

Properties of Solids
1. Definite (fixed) Volume and Shape
The**cohesive forces** in solid substances are so **verystrong** that they keep their particles arranged in fixed positions. In solid particles are **very close** to each other. So due to **restrict movements** of particles, the solids have definite volume and shape.



The particle model of a solid

2.Motion (movement) of Particles
The solid particles have **vibrational motion** only because these particles are held in fixed position by **very strong** cohesive forces.

3. Effect of Heat
The physical state of solid substance can be changed by heating. On heating solid is converted to liquid and gaseous state. **Heat increases** the kinetic energy of the particles and

they start vibrating at **higher frequency**. At a particular temperature the vibrational motions become fast that they overcome the cohesive forces and solid melts to liquid.

4. Melting Point
The temperature at which the solid is converted to liquid on heating is called **melting point.** At melting point, the particles of solid **lose their means position** and their arrangement. The solid collapses and turns to liquid.

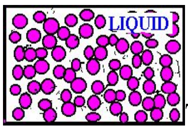
5. Sublimation
The conversion of some solids directly into gaseous state or from gaseous state directly into solid state is called **sublimation.** Iodine crystals, ammonium chloride andnaphthalene are some of the substances that change directly into vapour (gaseous) state upon heating.

LIQUID
The state of matter having definite (fixed) volume but indefinite (no fixed) shape is called liquid.

Properties of Liquid

1. Volume
Liquids have definite volume. In liquid particles are close to one another and have cohesive forces among the particles. Due to the presence of cohesive forces, liquids have definite volume and keep their level as well.

2. Shape
Liquids do not have any specific shape (no fixed shape). They adopt the shape of the container. The molecules of liquid are able to move within a container. Due to this **random motion** the molecules of liquid do not have fixed position and as a result, a liquid does not have any specific shape.



The particle model of a liquid

- **Liquids usually flow freely** despite the forces of attraction between the particles but liquids are not as 'fluid' as gases.
- Liquids are **not readily compressed** because there is so little 'empty' space between the particles, so increase in pressure has only a tiny effect on the volume of a solid, and you need a huge increase in pressure to see any real contraction in the volume of a liquid.

3. Evaporation
Conversion of liquid into its vapours at **any temperature** is called evaporation. The molecules of liquid come to the surface of liquid and escape by overcoming cohesive forces. So liquid is converted to vapours at **all temperature**.

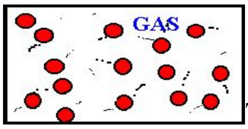
4. Boiling Point
The temperature of a liquid at which its vapour pressure becomes equal to the atmospheric pressure is called **boiling point.**Using a 'primitive' definition, boiling point is the temperature at which a liquid turns into a gas.

GAS

The state of matter which does not have definite shape and no definite volume is called gaseous state.

Properties of Gaseous State

1. Indefinite (no fixed) Volume and no Fixed Shape
In gaseous state, the molecules have **insignificant or weak cohesive** forces among themselves. They move very fast in all possible directions. As a result, a gas neither has fixed shape nor a fixed volume.



The particle model of a gas

- A gas is **compressible** due to **enough space** between the particles

2. Kinetic Energy of the Particle of a Gas
Gas particles have very high kinetic energy as compared to liquid and solid state.

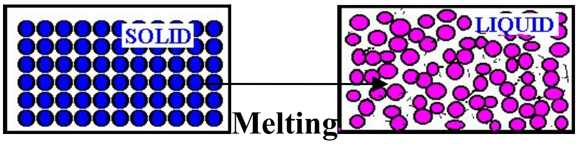
3. Pressure
The molecules of a gas are in the state of random motion. The molecules of gas not only collide so often with one another but also with the walls of the container in which they are enclosed. Due to their often or high collision, the velocity of the molecules changes every moment. The pressure exerted by gas is also due to the collision of its molecules with the walls of the container.

4. Elastic Collision
The collision of gas molecules is elastic in nature which means that the total energy of the colliding molecules remains the same before and after the collision.

Changes of States of matter: solid<=> liquid<=> gas

A change of state means an interconversion between two states of matter, namely gas <=> liquid <=> solid.

- e.g. **1**. the change of matter from solid to liquid : solid ==> liquid is**melting or fusing**



2. the change of matter from liquid to gas: liquid ==> gas/vapour (vapor) is **boiling, evaporation or vapourisation (vaporisation).**

- the **temperatute** at which solid changes into liquid is called **melting point**

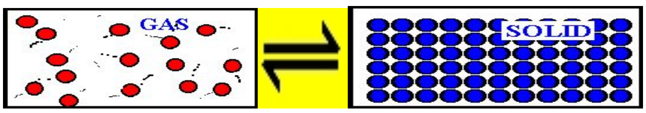
3. the change of matter from gas to liquid: gas/vapour (vapor) ==> liquid is **condensation, liquefaction/liquefying**

- the temperature at which liquid turns into gas/vapour is called **boiling point**.

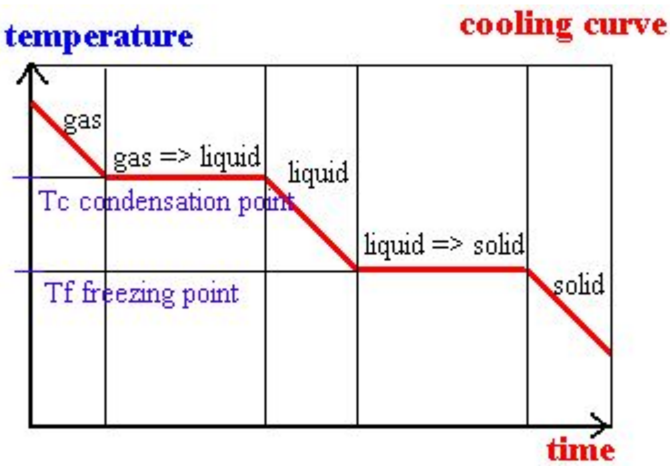
4. the change of matter from liquid to solid: liquid ==> solid is **freezing, solidifying or crystallising.**

- the temperature at which liquid turns into solid is called **freezing point.**

5. The change of matter directly from soild to gas and from gas to solid without passing through liquid state: solid ==> gas; and gas==> solid is **sublimation.**



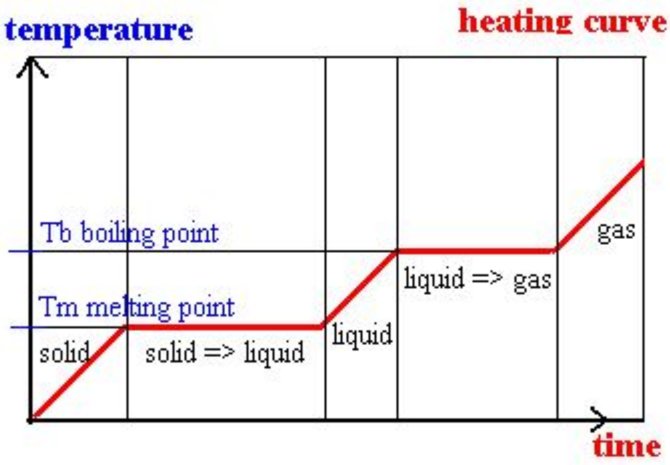
Cooling and Heating Curves



2f(i) Cooling curve: Note the temperature **stays constant** during the **state changes** of condensing at temperature Tc, and freezing/solidifying at temperature Tf. This is because all the heat energy removed on cooling at these temperatures (the latent heats or enthalpies of state change), allows the strengthening of the inter-particle forces without temperature fall (the heat loss is compensated by the exothermic increased intermolecular force attraction). In between the 'horizontal' state change sections of the graph, you can see the energy 'removal' reduces the kinetic energy of the particles, lowering the temperature of the substance.

A cooling curve summarises the changes:

gas ==> liquid ==> solid



2f(ii)Heating curve: Note the temperature stays constant during the state changes of melting at temperature Tm and boiling at temperature Tb. This is because all the energy absorbed in heating at these temperatures (the latent heats or enthalpies of state change),goes into weakening the inter-particle forces without temperature rise (the heat gain equals the endothermic/heat absorbed energy required to reduce the intermolecular forces). In between the 'horizontal' state change sections of the graph, you can see the energy input increases the kinetic energy of the particles and raising the temperature of the substance.

A heating curve summarises the changes:

solid ==> liquid ==> gas

DIFFUSION

The movement of molecules from a region of higher concentration to a region of lower concentration is known as **Diffusion**.

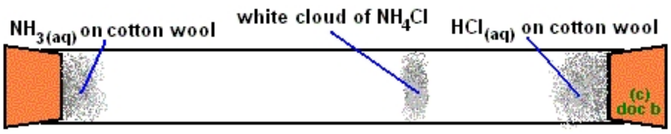
If the concentration of molecules at a particular place is higher, they start moving towards a place where their concentration is lower. When the concentration of molecules at both the places becomes equal the process of diffusion stops.

Diffusion in Gases

The molecules of one gas can diffuse easily into the molecules of other gas. For example if an open bottle of a perfume is kept in a room, its smell will spread uniformly throughout the room. The liquid perfume present in the bottle volatilized slowly and its vapours diffuse throughout the room.

The two experiments shown below describe diffusion in gases.

Experiment 1



A long glass tube (2-4 cm diameter) is filled at one end with a plug of cotton wool soaked in **conc. hydrochloric acid** sealed in with a rubber bung (for health and safety!). A similar plug of **conc. ammonia solution** is placed at the other end. The soaked cotton wool plugs will give off **fumes** of **HCl** and **NH_3** respectively, and if the tube is left undisturbed and horizontal, despite the lack of tube movement, e.g. NO shaking to mix and the absence of convection, **a white cloud forms about $^{1}/_{3}$rd along from the conc. hydrochloric acid tube end**.

Explanation: What happens is the colourless gases, ammonia and hydrogen chloride, **diffuse down the tube** and **react to form fine white crystals** of the salt ammonium chloride.

Ammonia + hydrogen chloride ==> ammonium chloride

$NH_{3(g)} + HCl_{(g)} \Longrightarrow NH_4Cl_{(s)}$

Note the rule: **The smaller the molecular mass, the greater the average speed of the moleculesand vice versa**(but all gases have the same average kinetic energy at the same temperature).

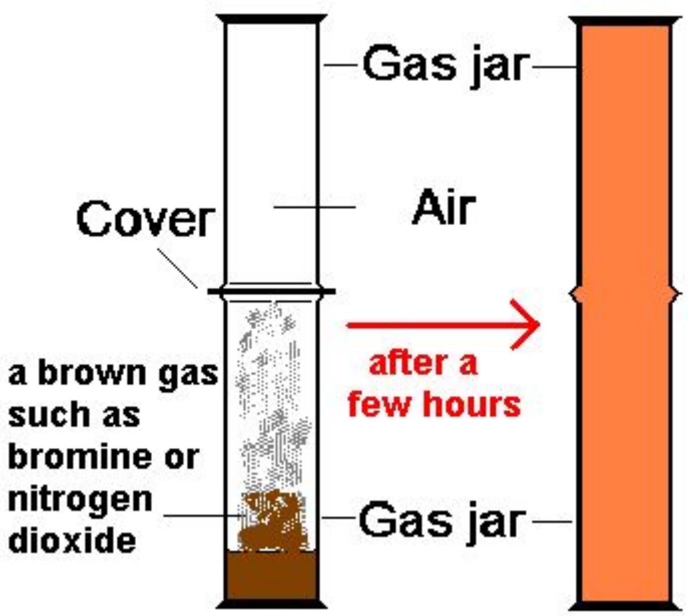
Therefore the smaller the molecular mass, the faster the gas diffuses.

e.g. M_r(**NH_3**) = 14 + 1x3 = **17**, moves **faster** than M_r(**HCl**) = 1 + 35.5 = **36.5**

AND that's why they meet nearer the HCl end of the tube!

So the experiment is not only **evidence for molecule movement**, it is also **evidence that molecules of different molecular masses move/diffuse at different speeds**.

Experiment 2



A **coloured gas, heavier than air** (greater density), is put into the bottom gas jar and a **second gas jar of lower density colourless air** is placed over it separated with a glass cover.

If the glass cover is removed then (i) the colourless air gases diffuses down into the coloured brown gas and (ii) bromine diffuses up into the air. The particle movement leading to mixing **cannot be due to convection because the more dense gas starts**

at the bottom!

No 'shaking' or other means of mixing is required. The **random movement of both lots of particles is enough to ensure that both gases eventually become completely mixed** by diffusion.

This is **clear evidence for diffusion** due to the random continuous movement of all the gas particles and, initially, the net movement of one type of particle from a higher to a lower concentration ('***down a diffusion gradient***'). When fully mixed, no further colour change distribution is observed BUT the random particle movement continues!

Law of Diffusion.
Hydrogen being lighter gas will diffuse faster than oxygen or carbon dioxide.

The natural **rapid and random movement** of the particles in all directions means that gases **readily 'spread' or diffuse**.

The net movement of a particular gas will be in the direction from lower concentration to a higher concentration, down the so-called diffusion gradient.

Diffusion is faster in gases than liquids where there is more space for them to move and diffusion is **negligible** in solids due to the close packing of the particles.

Diffusion is responsible for the spread of odours even without any air disturbance e.g. use of perfume, opening a jar of coffee or the smell of petrol around a garage.

The **rate of diffusion increases with increase in temperature as the particles gain kinetic energy and move faster**.

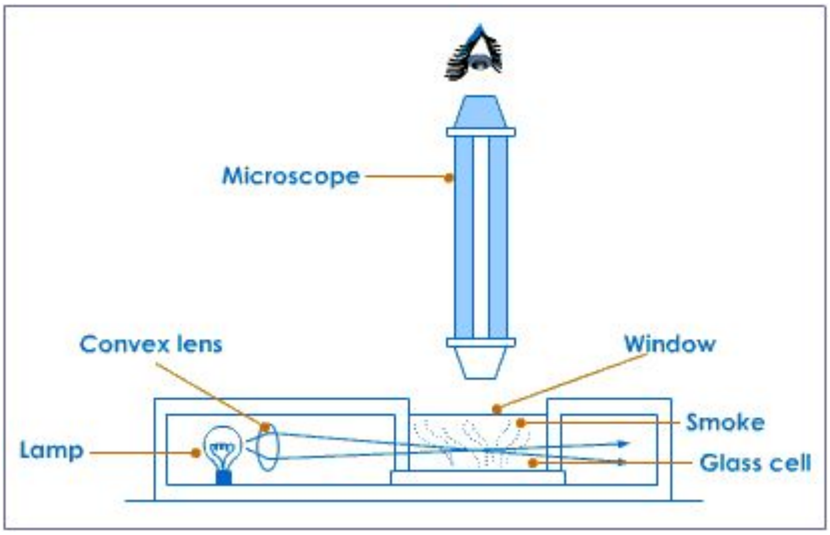
Diffusion in Liquids
Liquid molecules can also diffuse because they have free movement. Since the molecules of liquid move comparatively slowly than gas molecule, their rate of diffusion are also lesser than gases.

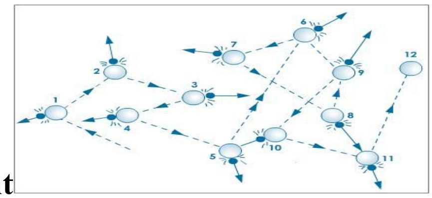
Brownian Motion /Brownian Movement
Robert Brown (1927) discovered this phenomenon:

Experiment

He was observing through a microscope some very tiny particles of pollen in suspension in water. To his surprise he saw that some of the smaller particles were moving about **continuously** in a **haphazard** way. It is due to the **bombardment** of tiny particles by the liquid molecules all around it. The direction of the resultant force is constantly changing. Hence the motion of the particles is completely random. Thus 'Brownian motion' is defined as the **random** or **zig zag motion** of the suspended molecules.

smoke viewed under a microscope



smoke experiencing **haphazard movement** 

Brownian motion can be demonstrated simply by releasing some smoke particles from burning cord into a small glass container and putting a cover plate to seal the smoke and air into the cell.

To investigate liquid molecular movement place some water with graphite particles suspended in it in the cell.

Now adjust the microscope slightly until you can see very bright specks. The particles of graphite (or smoke) scatter (reflect) the light shining on them and so appear as bright points of light darting about in a random or erratic motion. Note that the graphite (or smoke) particles are much larger than the water (or air) molecules. The particles can be seen by the light they scatter but the molecules themselves are too small to be seen.

The irregular movement of the visible particles of graphite (or smoke) is explained as being due to an uneven bombardment of the particles by the invisible molecules of water (or air). It is due to Brownian motion.

Diffusion is almost impossible in solids because the particles are too closely packed and strongly held together with no 'empty space' for particles to move through.

THE LANGUAGE OF CHEMISTRY

1. **Solvent**: It is a liquid substance in which a solute dissolves. It is the component of a solution in largest amount.
   example: the water.
2. **Solute**: A solid substance that dissolves in a solvent. It is the component of a solution in lesser amount.
   examples: salt in seawater(salt solution), sugar in sugar solution.
3. **Solution**: a homogeneous mixture of a solvent and a solute. *Examples:* salt solution; sugar solution; etc.
4. **Saturated Solution**: Is a solution with excess solute in it.
5. A **mixture:** is a material made up of two or more substances that are physically combined. These substances may be elements or compounds. They are usually easily separated by physical means
6. **Homogeneous mixture**: a mixture in which any two samples (substances) have the same composition and properties.
   examples: air (a gas); seawater (a liquid).
7. **Heterogeneous mixture**: a mixture containing substances that are not identical, *examples:* concrete; smoke.
8. **Aqueous solution**: a solution with water as the solvent.
9. **Crystallization**: The process of a solute coming out of solution as crystals.
10. An**atom:** isthe smallest particle of an element that can take part in a chemical reaction.
11. **A molecule:** is alarger particle formed by the chemical combination of two or more atoms. The molecule may be an **element** e.g. hydrogen formula H_2 (H-H, two atoms combined) or a **compound** e.g. carbon dioxide formula CO_2 (O=C=O, three atoms combined) and in each case the atoms are held together by **chemical bonds.**
12. **An element:** is a pure substance made up of only one type of atom, 92 occur naturally and can be 'summarised' in the **Periodic Table** (detailed notes) i.e. from element 1 hydrogen H to 92 uranium U.
13. **A compound:** is a chemical combination of two or more different elements on a fixed ratio. Compounds can be represented by a formula, which represents the whole number (integer) ratio of the atoms in a formula, and for molecules, a summary of all the atoms in one molecule. Examples:

    - **sodium chloride NaCl**, ionic compound, 2 elements, 1 of sodium and 1 of chlorine).
    - **methane CH_4,** covalent compound molecule, has 2 elements in it, 4 atoms of carbon and 1 atom of hydrogen*. The lines in the diagram of methane
    - **ethane C_2H_6**, two atoms of carbon combined with 6 atoms of hydrogen and note that two elements can form two different compounds because of different atom ratios.
    - **glucose $C_6H_{12}O_6$**(covalent compound molecule, 3 elements in it, 6 atoms of carbon, 12 of hydrogen and 6 of oxygen).
    - **carbon monoxide CO** (1C + 1O atoms), **carbon dioxide CO_2** (1C + 2O atoms), note again that two elements can form two different compounds because of different atom ratios.

14. **<u>Isotopes</u>**: Atoms of the same element with the same atomic number (proton) but with different numbers of neutrons and hence different mass numbers. Some isotopes are

unstable and emit particles or radiation over a period of time and are called **radioactiveisotopes**.

15. **Pure:** meansthat **only one substance** is present in the material and can be a pure element or compound.
16. **Chemical equation:** is an expression in symbols that describes precisely a particular chemical change.

eg the reaction in water between the alkali sodium hydroxide and the acid hydrochloric acid.

sodium hydroxide + hydrochloric acid ==> **sodium chloride + water** (word equation)

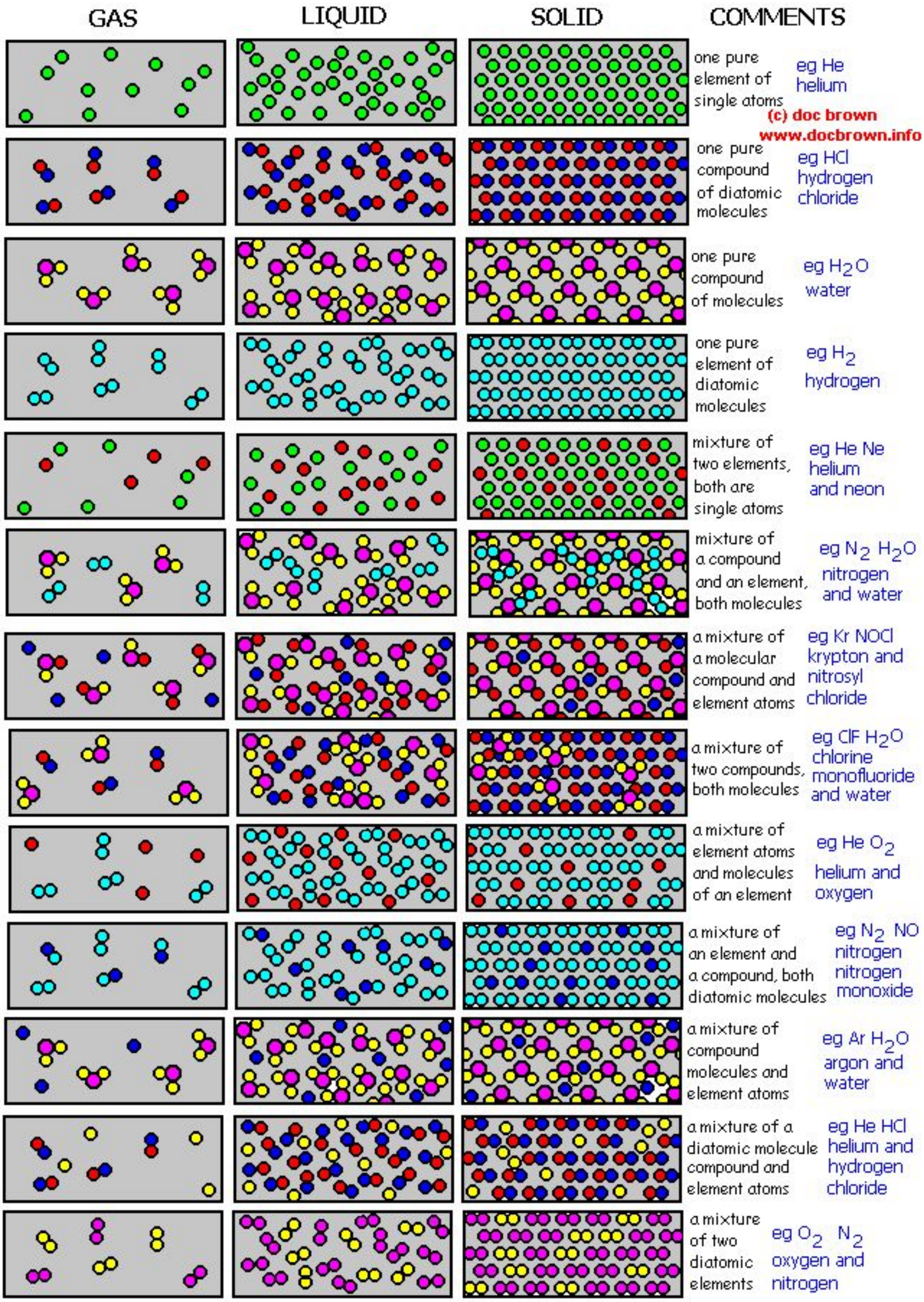
NaOH + HCl ==> **NaCl + H_2O** (chemical equation)

$NaOH_{(aq)}$ + $HCl_{(aq)}$==> **$NaCl_{(aq)}$ + $H_2O_{(l)}$** (chemical equation with state symbols)

Differences between a Mixture and a Compound

Mixture	**Compound**
The substances in it can be separated by physical means	The substances in it can be separated by chemical means
Its properties (e.g, colour, density) are the average of the substances in it	Its properties are quite different from those of the substances in it
Energy (heat, light or sound) is not usually given out or absorbed when a mixture is made	Energy is usually given out or absorbed when a compound is made
Its composition is variable: the substances can be present in any proportions by mass	Its composition is fixed: the elements are combined in fixed proportions by mass

Particle Picture examples of Elements, Compounds and Mixtures - useful visual images



Pure Substance

A Pure substance means that **only one substance** is present in the material and can be a pure element or compound.

Criteria of Purity

Criteria of purity refers to the physical properties (characteristics) of a pure substance.

- The simple physical tests for purity, and properties that can help identify a pure substance, is to measure the **boiling point,melting point and density**. Every puresubstance **melts and boils at a fixed temperature** and has a **fixed density** (though boiling point depends on the ambient air pressure).
    - If a liquid is **pure** it should **melt** and **boil** at a **constant temperature** and should have a **constant (fixed) density** e.g. water melts at 0^oc, boils at 100^oC and has a density of $1g/cm^3$.

Effects of Impurities

Impurities are substances contained in another substance. They make a substance impure.

Impurities **lower the melting point** of a substance, **raise the boiling point** of a substance and will either **lower or raise the density** of a substance depending on the nature and amount of impurities.

e.g. a water and salt mixture melts below 0^oC and butter, a mixture of fats, gradually melts more as the temperature rises on a hot summer's day.

A substance can be made pure and or / mixtures can be separated by using various techniques (methods) as discussed in the next topic.

<u>SEPARATION TECHNIQUES /METHODS</u>

1. Filtration

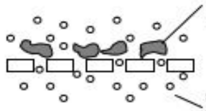
Dissolving or Dissolution

When a solid is dissolved into a liquid to form a homogeneous solution, the solid is known as the solute and the liquid is known as the solvent. The sugar solute dissolves in the water solvent to form the homogeneous sugar solution. It is interesting to note that sugar is soluble in water but not in organic solvents.

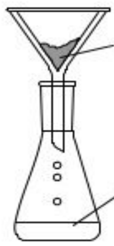
Suitable solvents must be used to dissolve different solutes. Water is the most common solvent used to dissolve most ionic compounds to form aqueous solution of the substances. Some ionic compounds such as calcium sulphate, barium sulphate, lead(II) sulphate, silver chloride, lead(II) chloride and lead(II) iodide and most carbonates however are insoluble in water. Lead(II) chloride and lead(II) iodide are soluble only in hot water. (Please refer to the section on solubility of compounds) Most organic compounds are insoluble in water but are highly soluble in organic solvents such as chloroform, tetrachloromethane and 1,1,1-trichloroethane.

Filtration

Filtration is suitable for separating mixtures whose solid components behave differently in a particular solvent – one component must be soluble and the other insoluble in it. A liquid which contains insoluble solid particles is called a suspension.



The solid mixture is first dissolved in a suitable solvent and the suspension poured through a filter which is usually made of paper. The filter paper has tiny holes through which the smaller molecules of the liquid are able to pass through as filtrate. The particles of the solid are large. They cannot pass through the holes and are trapped by the filter paper as residue.



The residues (insoluble solids) are trapped in the filter paper. The filtrate (liquid) passes through the filter paper and collects in the flask. The filtrate may be evaporated to obtain crystals of the solute in the filtrate. The solution may also be saturated by heating to half volume and allowing it to cool for crystals to form. The crystals are recovered via filtration.

Question: Explain why it is necessary to wash the residue with a little solvent?

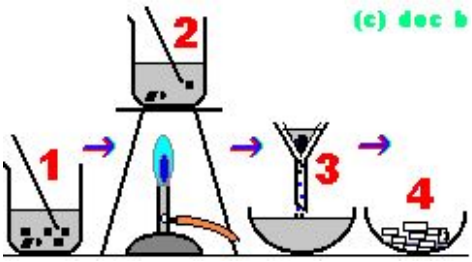
Some of the solute is adsorbed on the surfaces of the residue. Washing the residue with the solvent helps to flush down all these solute into the filtrate. The residue is thus cleaner. This also ensures a more complete separation of the mixture.

Filtration is employed in the purification of water. All solid impurities are first removed by filtration before the water is treated for harmful micro-organisms and

4

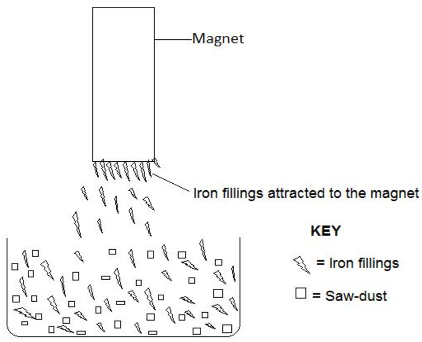
2. Crystallisation can mean a liquid substance changing to its solid form. However, **the term usually means what happens when the liquid from a solution has evaporated to a point beyond the solubility limit**. Then solid crystals will 'grow' out of the solution because the solution is too concentrated for all the solid to remain dissolved at that temperature. Crystallisation is often done from a hot concentrated solution, because most substance are more soluble in the hot liquid. Consequently on cooling a hot concentrated solution, crystals form as the solubility gets less and less.

The processes of crystallisation are demonstrated in the diagrams below.



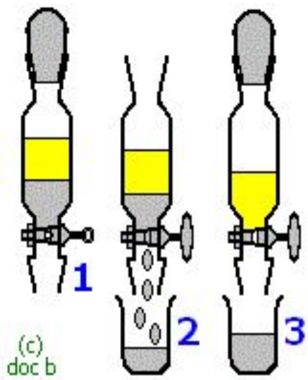
3. Magnetism

Magnetism is a technique used to separate a mixture of magnetic substance and non-magnetic substances (e.g. iron filings and saw dust). Magnetic substances (e.g., iron fillings) will be attracted to the magnet while non-magnetic substances (e.g. saw dust) will not be attracted to the magnet.



4. Separating funnel

If two liquids **do not mix completely**, they form two separate layers and are known as **immiscibleliquids** (e.g. oil or paraffin and water). This is illustrated in the diagram below, where the lower liquid will be more dense than the upper layer of the liquid and shows how you can separate these two liquids using a **separating funnel**.



5. Decantation

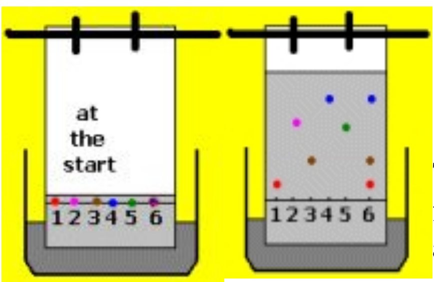
Decanting is the simplest possible way of separating a liquid (pure or a solution) from an insoluble solid which has a density greater than water (i.e. > 1.0 g/cm3). The solid-liquid mixture is allowed to stand e.g. in a beaker, until all the solid settles out to the bottom of the container. Then the liquid is carefully poured off to leave the insoluble solid behind. However it is inefficient e.g. a small amount of liquid is always left in the solid residue and very fine solid particles take some time to settle out and any disturbance of the liquid can mix them in with the liquid being poured off. Wine may be served in a decanter to leave the undesirable solids behind - no good for bits of cork though, they float!

6. Centrifuging

Centrifuges are devices or apparatus that can be used **to separate insoluble materials** (usually a solid) **from a liquid, where normal filtration does not work well** e.g. a suspension of very fine (tiny) solid particles. **The centrifuge** consists of carriage or glass tube holder, mounted on an electrically motor driven vertical axle. The carriage holds the balanced glass tubes of **equal amounts** of the solid-liquid mixture in each tube, all tubes initially in a horizontal position before the motor is switched on. The tube carriage is rotated at high speed safely in a **fully enclosed container**. Unbalanced tubes can break with the extra vibration and this situation has a 'knock on' effect, quite literally, as other tubes are likely to shatter with the erratic high speed unbalanced motion. High velocity glass fragments are not good for you! On **rapid rotation** of the carriage the tubes whirl round horizontally and the centrifugal force causes the **more dense** insoluble material particles to move outwards, separating from the liquid. When rotation ceases the solid particles end up at the 'bottom' of the glass tubes with the liquid above. After the **centrifuging operation** the liquid can be decanted off and the solid is left at the bottom of the glass tube. You might be interested in the solid, liquid or both products depending on the context. Centrifuges come in all sizes and centrifuge technology has many applications in the separation of mixtures and the purification of materials.

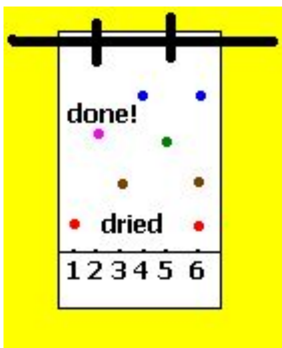
Uses-applications of centrifuging: In biology cells can be separated from fluids. A waste 'sludge' can be treated e.g. removing toxic solids from contaminated water from an industrial process. Milk can be separated from whey. Edible oils, wines and spirits can be cleaned or 'clarified' of solid impurities. Expensive oils and other fluids used as lubricants in machining metal parts in industry become contaminated with tiny metal fragments. The larger pieces of metal are easily removed by filtration or sedimentation (allowing to settle out) but the very fine metal particles can only be removed by using a centrifuge. This is likely to be a cheaper option than buying more machine fluid AND reducing pollution since the fluid is recycled leaving less waste to dispose off.

7. Paper Chromatography



This method of separation is used to see what coloured materials make up e.g. a food dye analysis.

The material to be separated e.g. a food dye (6) is dissolved in a solvent and carefully spotted onto chromatography paper or a thin layer of a white mineral material on a glass sheet. Alongside it are spotted known colours on a 'start line' (1-5).



The paper is carefully dipped into a solvent, which is absorbed into the paper and rises up it. The solvent may be water or an organic liquid like an alcohol (e.g. ethanol) or a hydrocarbon, so-called non-aqueous solvents. For accurate work the distance moved by the solvent is marked on carefully with a pencil and the distances moved by each 'centre' of the coloured spots is also measured. These can be compared with known substances BUT if so, the identical paper and solvent must be used (See R_f values below).

Due to different solubilities and different molecular 'adhesion' some colours move more than others up the paper, so effecting the separation of the different coloured molecules.

Any colour which **horizontally matches** another is likely to be the same molecule i.e. red (1 and 6), brown (3 and 6) and blue (4 and 6) match, showing these three are all in the food dye (6).

Note that at the start of the experiment, the start line:

(i) **Should not be in the solvent**; because if the start line is in the solvent, the **mixture substances and the colours** on it **would dissolve in the solvent** and **will not move up** in the separating medium (filter paper). To prevent this, the start line should not be in the solvent at the star of the experiment.

(ii) Should be **draw in pencil** and **not in ink**, because if the start line is drawn in ink, **colours in ink** (ink has many colours) **would also separate** on the separating medium thereby **interfering** with the results. Hence drawn in pencil so as to prevent this from happening.

The distance a component (colour or dye) moves, compared to the distance the solvent front moves (top of grey area on 2nd diagram) is called the **reference value orR_f value** and has a value of 0.0 (not moved - no good), to 1.0 (too soluble - no good either), but **R_f** ratio values between 0.1 and 0.9 can be useful for analysis and identification.

The formula is:

Some technical terms: The substances (**solutes**) to be analysed must dissolve in the **solvent**, which is called the **mobile phase** because it moves. The paper or thin layer of material on which the separation takes place is called the **stationary or immobile phase** because it doesn't move.

Factors that Affect Chromatography

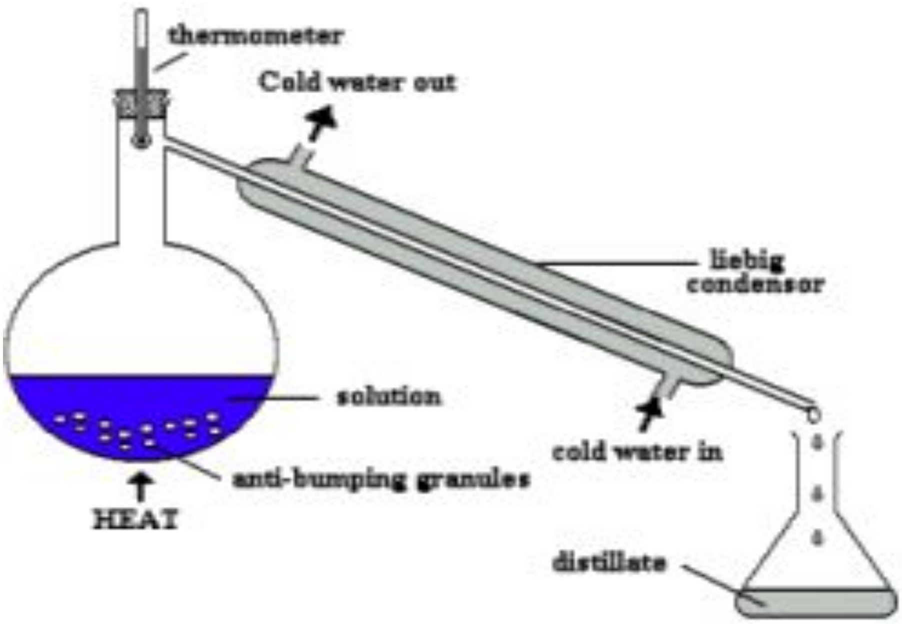
- the separating medium (stationary phase). How thick and porous the stationary phase is.
- the surface tension of the solvent, ie how fast or slow the solvent spreads on the medium
- the viscosity of the solvent, ie how thick or thin the solvent is.

Applications of Chromatography

- Separating proteins from amino acids
- Separating pigments from chlorophyll
- Obtaining anti-biotics from their growing media
- Identifying flavouring components in food stuffs

8. Simple distillation

Simple distillation is used to obtain pure liquid from a solution. e.g. obtaining pure water from salt or sea water.



Distillation involves 2 stages and both are physical state changes.

(i) The liquid or solution mixture is **boiled to vaporise** the volatile component in the mixture (**liquid** ==> **gas**). The ant-bumping granules give a smoother boiling action.

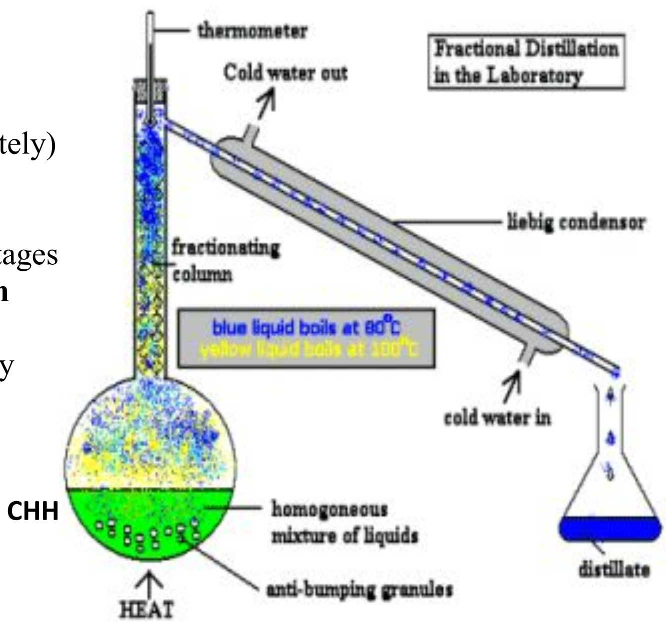
(ii) The vapour is cooled by cold water in the condenser to **condense** (**gas** ==> **liquid**) it back to a liquid (the distillate) which is collected.

This can be used to purify water because the dissolved solids have a much higher boiling point and will not evaporate with the steam.

9. Fractional distillation

Fractional distillation is used to separate **miscible liquids** (liquids that mix completely) and have **different boiling points.**

Fractional distillation involves 2 main stages and both are physical state changes. **It can only work with liquids with different boiling points**. However, this method only works if all the liquids in the mixture are



miscible [e.g. alcohol(ethanol) and water, crude oil etc].

(i) The liquid or solution mixture is **boiled to vaporise** the most volatile component in the mixture (**liquid** ==> **gas**). The ant-bumping granules give a smoother boiling action.

(ii) The vapour passes up through a **fractionating column**, where the separation takes place (theory at the end). This column is not used in the simple distillation described above.

(iii) The vapour is cooled by cold water in the condenser to **condense** (**gas** ==> **liquid**) it back to a liquid (the distillate) which is collected.

This can be used **to separate alcohol from a fermented sugar solution**.

It is used on a large scale **to separate the components of crude oil**, because the different hydrocarbons have different boiling and condensation points.

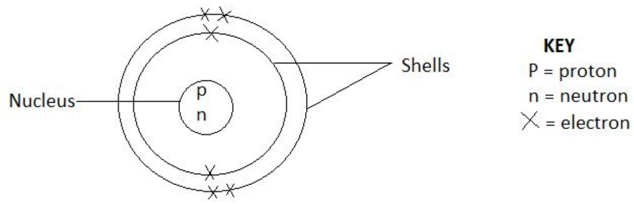
Fractional Distillation Theory:

Imagine green liquid is a mixture of a blue liquid (boiling point 80^{o}C) and a yellow liquid (boiling point 100^{o}C), so we have a coloured diagram simulation of a colourless alcohol and water mixture! As the vapour from the boiling mixture enters the fractionating column it begins to cool and condense. The highest boiling or least volatile liquid tends to condense more i.e. the yellow liquid (water). The lower boiling more volatile blue liquid gets further up the column. Gradually up the column the blue and yellow separate from each other so that yellow condenses back into the flask and pure blue distils over to be collected. The 1st liquid, the lowest boiling point, is called the 1st fraction and each liquid distils over when the top of the column reaches its particular boiling point to give the 2nd, 3rd fraction etc.

ATOMIC STRUCTURE/STRUCTURE OF AN ATOM

Atom is the smallest particle of an element that can take part in a chemical reaction. It is the smallest unit of a chemical matter and it is composed of three fundamental sub- particles: **electrons, neutrons and protons**.

The protons and neutrons form the core of an atom called the **nucleus**, while the electrons exist outside of the nucleus and in the orbitals (shells). The structure of an atom is shown below.



Here is a basic summary of the subatomic particles (neutrons, protons and electrons):

Sub-atomic	Relative mass	Electric charge	Location

particle			
Proton	**1**	**+1 (+ positive)**	**In the nucleus**
Neutron	**1**	**0 (zero)**	**In the nucleus**
Electron	**$^{1}/_{1840}$ or 0.00054**	**-1 (- negative)**	**In energy levels or shells around the nucleus**

Atomic Number and Mass Number

Atomic Number or proton number (Z) is the number of protons in the nucleus of an atom of an element.It can be calculated by using the formula:

proton number = mass number – neutron number; which is **Z = A - N**

Mass number or atomic mass (A), also known as **nucleon number,** is the total number of protons and neutrons in the nucleus of an atom of an element**.** Therefore the **mass or nucleon number = protons plus neutrons in the nucleus;** which is**A = Z + N**

The neutron number (N)is the number of neutrons in the nucleus of an atom ofan element. **Neutron number (N)= mass number - proton/atomic number;**which is **N = A - Z**

In a neutral atom the number of protons (+) equals the number of electrons (-), that is the number of positive charges is equal to the number of negative charges.

Examples

Q1. An atom of an element has the atomic number of 4 and 5 neutrons. Calculate its

(a) mass number.

Ans: A = Z + N, A = 4 + 5 = **9**

(b) number of electrons.

Ans: **4.** Since in a neutron atom the number of protons = number of electrons.

Q2. An atom has the nucleon number of 19 and 9 protons. Find the number of neutrons.

Ans: N = A – Z, N = 19 – 9 = **10**

Q3. If the mass number of element is 39 and its number of neutrons is 20. Calculate its:

(a) proton number

Ans: Z = A – N; Z = 39 – 20 =**19**

(b) electron number**Ans: 19**

Exercise

Q1. An atom of an element has the atomic number of 13 and 14 neutrons. Calculate its:

(a) nucleon number (b) number of electrons

Q2. the neutron number of element is 20 and its mass number is 40. Calculate its:

(a) atomic number (b) electron number

Atomic Numbers and Mass Numbers of the First 20 Elements

Name of element	**Atomic number**	**Mass number**
Hydrogen	1	1
Helium	2	4
Lithium	3	7
Beryllium	4	9
Boron	5	11
Carbon	6	12
Nitrogen	7	14
Oxygen	8	16
Fluorine	9	19
Neon	10	20
Sodium	11	23
Magnesium	12	24
Aluminium	13	27
Silicon	14	28
Phosphorus	15	31
Sulphur	16	32
Chlorine	17	35.5
Argon	18	40

Potassium	19	39
Calcium	20	40

Nuclide

A nuclide is the chemical symbol of an element with its atomic number and mass number.

Nuclide Notation

The general representation of a nuclide is shown below.

Where: **X =** the chemical symbol of an element

A = mass number

Z = atomic number

Examples of Actual Nuclides of Specific Elements

- $^{56}_{26}Fe$ **Iron nuclide** (iron-56)**, 26 protons, 30 neutrons** (56 - 26), 26 electrons
- $^{59}_{27}Co$ **Cobalt nuclide** (cobalt-59)**, 27 protons, 32 neutrons** (59 - 27), 27 electrons
- $^{246}_{98}Cf$ **Californium nuclide** (californium-98)**, 98 protons, 148 neutrons** (246 - 98), 98 electrons

Chemical Symbols of Elements

Chemical symbols of elements are abbreviations that are used to denote a **chemical element**. Typically, they are one or two letters.

- ✓ If a chemical symbol is one letter, it must **always** be a **capital letter**.
- ✓ If there are two letters, the **first letter** must **always** be a **capital letter** and the **second letter** must always be a **small letter.**
- ✓ Some elements have chemical symbols derived from Latin names.

The table below shows the chemical symbols of elements.

Name of element	Chemical symbol	Latin name
Hydrogen	H	
Helium	He	
Lithium	Li	
Beryllium	Be	
Boron	B	
Carbon	C	
Nitrogen	N	
Oxygen	O	
Fluorine	F	
Neon	Ne	
Sodium	Na	Natrium
Magnesium	Mg	
Aluminium	Al	
Silicon	Si	
Phosphorus	P	
Sulphur	S	
Chlorine	Cl	
Argon	Ar	
Potassium	K	Kalium
Calcium	Ca	
Iron	Fe	Ferrum
Copper	Cu	Cuprum

Silver	Ag	Argentums
Tin	Sn	Stannum
Gold	Au	Aurum
Mercury	Hg	Hydrargyrum
Lead	Pb	Plumbum

Isotopes

Isotopes are atoms of the same element with the same atomic number but different mass numbers due to different neutrons.

Isotopes of Hydrogen

Isotope	Nuclide	Protons	Electrons	Neutrons
Hydrogen 1	$^{1}_{1}H$	1	1	1 - 1 = 0
Hydrogen 2/ Deuterium	$^{2}_{1}H$	1	1	2 - 1 = 1
Hydrogen 3/ tritium	$^{3}_{1}H$	1	1	3 - 1 = 2

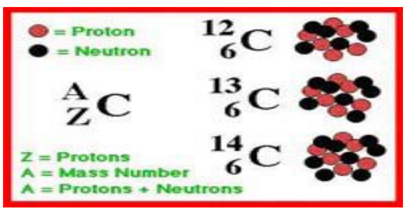
Isotopes of Chlorine

Chlorine atoms contain 17 protons and 17 electrons. About 75 per cent of chlorine atoms have 18 neutrons, while about 25 per cent have 20 neutrons.

Isotope	Nuclide	Protons	Electrons	Neutrons
Chlorine 35	$^{35}_{17}Cl$	17	17	35 - 17 = 18
Chlorine 37	$^{37}_{17}Cl$	17	17	37 - 17

Isotopes of Carbon

There are three isotopes of carbon: carbon 12, carbon 13 and carbon 14 as shown below.



The Most Stable Isotopes

Almost all but three of the carbon isotopes are unstable and exist for very short periods of time, before they decay. Out of the 15, 13 are radioactive isotopes. The three most stable are Carbon 12, Carbon13 and Carbon14. These are also the naturally occurring isotopes, while others are created through artificial transmutation of elements. Of these three, C14 is radioactive, while the other two aren't. C12 is the most abundant on Earth, constituting about 98.93% of the atoms in one mole of carbon, C13 is about 1.07% and C14 is the rarest (1 part in trillion).

Uses of Isotopes

Medical Usage - these are isotopes added into biological molecules (like sucrose, sugar) and injected into humans to look for accumulation which may indicate cancer and other diseases. Medical treatments. Radioactive iodine (I131) is used to treat hyperthyroidism or thyroid cancer by killing the thyroid tissue using radiation.

Chemical/Biological/Agricultural Usage - Isotopes are added to small biological molecules and then added into cells to see how bigger biological molecules are made from these cells. Isotopically label glucose to see if it is used in making penicillin by certain molds.:)

Archelogical dating - used to determine the age of older materials from carbon-14 dating and other dating. Warning it only works for materials that have carbon in them - like organic items (paper, cloth, wood etc) and not stone, brick.

Smoke alarms - Isotopes like Americium 241 is used in smoke alarms

Food irradiation using gamma rays. This kills surface bacteria which spoil foods faster and also may cause people to become ill.

Arrangement of Electrons in Shells of Atoms of Elements

Electrons are arranged in regular pattern in shells or energy levels. The energy levels can be represented as circles around the nucleus. The **nearer** the circle is to the nucleus, the **lower** the energy level and the **further** it is the **higher** the energy level.

Forces of attraction exist between the positively charged protons and the negatively charged electrons. These forces are called **electrostatic forces** of attraction. They prevent electrons from drifting away from the rest of an atom. The electrostatic forces of attraction in an atom **increase** as the **distance** between the nucleus and the electrons **decreases**and they (electrostatic forces of attraction) **decrease** as the **distance** between the nucleus and the electrons **increases**.

The energy levels can be denoted by letters:

- the first shell from the nucleus is represented by capital letter **K**
- the second shell from the nucleus is represented by capital letter **L**
- the third shell from the nucleus is represented by capital letter **M**
- the fourth shell from the nucleus is represented by capital letter **N**, etc.

Each one of these shells has the maximum number of electrons it can accommodate. The allocation of the maximum number of electrons that each shell can accommodate is done by using the formula:

$2n^2$:where: n = shell number/position from the nucleus

Examples:

- ✓ 1^{st} shell (K) can contain a maximum of 2 electrons (electrons 1-2),that is $2n^2 = 2\times1^2 = 2\times1\times1 = \underline{\mathbf{2}}$
- ✓ The 2^{nd} shell (L) can contain a maximum of 8 electrons (electrons 1-8),that is $2n^2 = 2\times2^2 = 2\times2\times2 = \underline{\mathbf{8}}$
- ✓ The 3^{rd} shell (M) can accommodate a maximum of 18 electrons (electrons 1-18), $2n^2 = 2\times3^2 = 2\times3\times3 = \underline{\mathbf{18}}$
- ✓ The 4^{th} shell (N) can contain a maximum of 32 electrons (electrons 1-32), $2n^2 = 2\times4^2 = 2\times4\times4 = \underline{\mathbf{32}}$.

Electronic Configuration

This is the arrangement of electrons in shells by using letters (as shells) and numbers (as electrons).

Examples

Show the electronic configuration of each one of the following.

(1) $\boxed{^{1}_{1}H}$ (2) $^{23}_{11}Na$ (3) $^{35}_{17}Cl$ (4) $^{56}_{26}Fe$

Ans:(1) K (2) K L M (3) K L M (4) K L M N
1 2 :8 : 1 2 : 8 : 7 2 : 8 : 8 : 8

Exercise

Write down the electronic configurations of the following.

1. $^{4}_{2}He$ 2. magnesium 3. $^{59}_{27}Co$ 4. neon 5. calcium

Electronic Structure

This is the arrangement of electrons in shells by using circles (as shells) and symbols (as electrons).

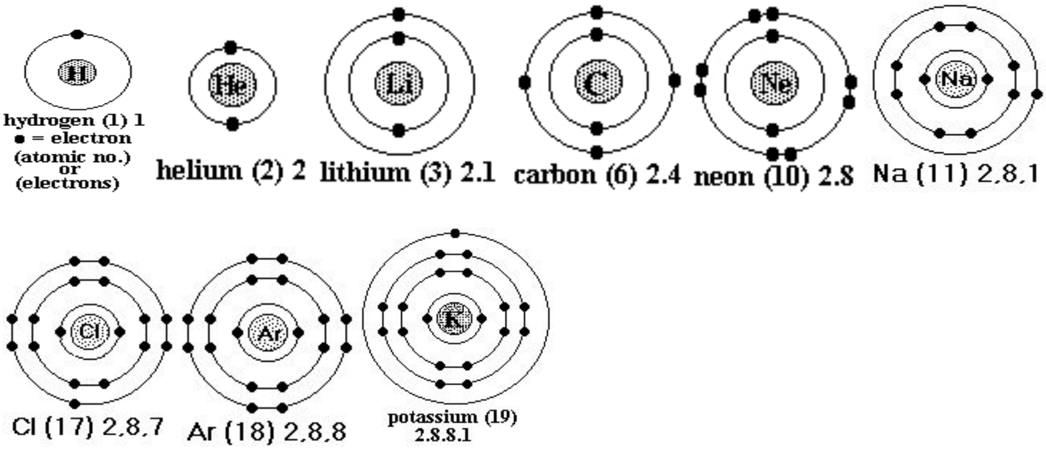
Examples

Write down the electronic structures of the following.

1. hydrogen 2. helium 3. lithium 4. carbon 5. neon 6. sodium 7. chlorine

8. argon 9. potassium

Answers



Exercise

Show the electronic structures (diagrams) of the following.

1. Beryllium 2. Nitrogen 3.Oxygen 4. Sulphur 5. Aluminium 6. Fluorine

Relationship between Electronic Configuration (or Structure) and the Periodic Table

If the electronic configuration or electronic structure of an atom of an element is known, it is very easy to determine the period number and the group number to which a particular element is found or belongs on the periodic table:

- the**numberof electrons in the outermost shell** of an element is **equal** to the **group** number to which it belongs on the periodic table.
- the**number of shells of** an element is **equal** to the **period** number to which it belongs on the periodic table.

Examples

Determine the group and the period to which each one of the following elements belong on the periodic table.

1. hydrogen 2. sodium 3. carbon 4. aluminium 5. argon 6. calcium 7. bromine

Answers

NOTE THAT electronic configurations should be known in order to determine the groups and the periods.

1. K	2. K L M	3. K L	4. K L M	5. K L M	6. K L M N	7. K L M N
1	2 : 8 : 1	2: 4	2 : 8 : 3	2: 8 : 8	2 : 8 : 8 : 2	2 : 8: 18 : 7
group 1	group 1	group 4	group 3	group 8	group 2	group 7
period 1	period 3	period 2	period 3	period 3	period 4	period 4

Exercise

Determine the group and the period of the following elements.

1. helium 2. nitrogen 3. fluorine 4. potassium 5. phosphorus 6. sulphur

Note: do not use the periodic table at this moment; use the table of atomic numbers of elements shown in this booklet/pamphlet. Only use the periodic table to confirm your answers.

VALENCY/VALENCE

Valence is the combining power of an atom. It is the number of electrons an atom can gain or lose.

How to Determine Valences of Elements

Electronic configuration/ structure of neutral atoms and the periodic table are crucial in determining valences of elements:

- If the number of electrons in the outermost shell ranges from 1 to 4, then that becomes the valence of that particular element.
- If the number of electrons in the outermost shell ranges from 5 to 8; the valence is found by subtracting that number from 8. The difference becomes the valence of that particular element.
- On the periodic table; the valences are determined by checking the group number of an element. Elements from group 1 to group 4, they have valences according to their groups. On the other hand, elements from group 5 to 8, their valences are found by subtracting their group numbers from 8.

Examples

Workout the valences of the following.

1. hydrogen 2. sodium 3. carbon 4. aluminium 5. argon 6. calcium 7. bromine

Answers

1. K	**2.** K L M	**3.** K L	**4.** K L M	**5.** K L M	**6.** K L M N	**7.** K L M N
1	2 : 8 : 1	2 : 4	2 : 8 : 3	2 : 8 : 8	2 : 8 : 8 : 2	2 : 8 : 18 : 7
valence=**1**	valence=**1**	valence=**4**	valence=**3**	valence:8-8=**0**	valence=**2**	valence:8-7=**1**

Group	1	2		3	4	5	6	7	8
Valency	1	2		3	4	3	2	1	0
Periodic table	H								
	Li	Be	Transition block	B	C	N	O	F	Ne
First 20 elements	Na	Mg	Variable	Al	Si	P	S	Cl	Ar
	K	Ca	Valences						

Some elements have variable valences; that is, they have more than one valence. For such elements, their valences are indicated in brackets after their names.e.g:

- copper (I) has the valence of 1
- copper (II) has the valence of 2
- iron (II) has the valence of 2
- iron (III) has the valence of 3

The number of electrons in the outermost shell can also help to identify metals and non-metals:

- Metals have 1to 3 electrons in their outermost shells; in exception of hydrogen and helium which have 1 and 2 electrons respectively in their outermost shells but are non-metals.
- Non-metals have 4 to 8 electrons in their outermost shells; including hydrogen and helium.

Differences between Physical Properties of Metals and Non-metals

Metals	**Non-metals**
Good conductors of heat and electricity	Bad conductors of heat and electricity
Solids at room temperature except mercury and have strong tensile strength (hard)	Can be solids, liquids or gases at room temperature and have low tensile strength

Are lustrous/have shinny appearance	Are non- lustrous/have dull appearance
They are malleable (can be drawn into sheets without breaking)	Are non-malleable
Have high melting and boiling points	Have low melting and boiling points
They are ductile/can be drawn into wires without breaking	They are non-ductile
They are sonorous /make ringing noise when stricken	They are non- sonorous

Radicals

Radicals are groups of atoms present in several compounds but incapable of independent existence.

The table below shows radicals and their valences.

Radical	**Formula**	**Valence**
Ammonium	NH4	1
Chlorate	ClO^3	1
Chloride	Cl	1
Hydrogen carbonate	HCO_3	1
Hydrogen sulphate	HSO_4	1
Hydroxide	OH	1
Nitrate	NO_3	1
Nitrite	NO_2	1
Carbonate	CO_2	2
Oxide	O	2
Sulphate	SO_4	2
Sulphide	S	2
Sulphite	SO_3	2
Phosphate	PO_4	3

Valences of Ions

Name	Ammonium	Copper	Iron (II)	Iron (III)	Lead (II)	Silver	Zinc
Symbol	NH_4^+	Cu^{2+}	Fe^{2+}	Fe^{3+}	Pb^{2+}	Ag^+	Zn^{2+}
Valence	1	2	2	3	2	1	2
Name	Carbonate	Hypochlorite	Hydrogen- Carbonate	Hydroxide	Nitrate	Sulphite	
Symbol	CO_3^{2-}	OCl^-	HCO^{3-}	OH^-	NO_3^-	SO_3^{2-}	

Valence	2	1	3	1	1	2	
Name	Hydrogen	Lithium	Sodium	Potassiu m	Chlorine	Bromine	
Symbol	H^+	Li^+	Na^+	K^+	Cl^-	Br^-	
Valence	1	1	1	1	1	1	

Chemical Formula

A **chemical formula** is a representation of a substance using symbols for its constituent elements.

Rules for Writing Chemical Formulae

Rule 1:Criss-Cross rule

(a). write the correct symbols of the elements and radicals
(b). Above each symbol, write the correct valence or oxidation numbers.
Ex.Mg^2, Al^3, O^2, Cl,
(c). To obtain the proper subscript, criss-cross the valence or oxidation number,and drop the algebraic sign.
Ex. Al^3O^2 becomes Al_2O_3

Rule 2: When the subscript is number 1, subscript is not written.
Ex. Sodium Chloride- Na^1 Cl^1 --- NaCl

Rule 3: When the valence # of both elements are numerically equal but grater than 1,the subscript are not also written.

Ex. Calcium Oxide~ Ca^2O^2 ----- Ca_2O_2 becomesCaO

Rule 4: All radicals take more than once (the subscript is 2 or more) must be enclosed in Parentheses( ).

Ex. Ammonium Sulphate $NH_4{}^1 SO_4{}^{2}$-----$(NH_4)_2$ SO_4

Examples

Write down the chemical formulae of the following.

Example 1 – Sodium chloride (common salt)

$$Na^{1+} \quad Cl^{1-} \Longrightarrow Na_1 \quad Cl_1 \Longrightarrow NaCl$$

Example 2 – Sodium oxide

$$Na^{1+} \quad O^{2-} \Longrightarrow Na_2 \quad O_1 \Longrightarrow Na_2O$$

Example 3 – Aluminium oxide

$$Al^{3+} \quad O^{2-} \Longrightarrow Al_2 \quad O_3 \Longrightarrow Al_2O_3$$

Example 4 – Lead oxide

$$Pb^{2+} \quad O^{2-} \Longrightarrow Pb_2 \quad O_2 \Longrightarrow PbO$$

Example 5 – Sodium hydroxide (caustic soda)

$$Na^{1+} \quad OH^{1-} \Longrightarrow Na_1 \quad OH_1 \Longrightarrow NaOH$$

Example 6 – Lead hydroxide

$$Pb^{2+} \quad OH^{1-} \Longrightarrow Pb_1 \quad (OH)_2 \Longrightarrow Pb(OH)_2$$

Exercise

Write the chemical formulae for the following compounds:

1) copper (II) chloride 2) lithium nitrate 3) ammonium sulphate 4) manganese (IV) nitrate 5) beryllium oxide 6) sodium carbonate
7) aluminium sulphate 8) calcium phosphate

CHEMICAL BONDING

Chemical bonding is the holding together of atoms of elements by forces called **bonds**. Atoms chemically bond with other atoms in order to **achieve a stable configuration** of their electrons; the structure of noble gases (2 or 8 electrons in the outermost shell). The group of elements called the noble gases are referred to as the inert gases because none of them are readily chemically reactive. The electronic structure of each member of the group is remarkably stable.

Types of Chemical Bonding

There are three ways by which atoms of elements are held together. These are electrovalent (ionic) bonding, covalent (molecular) bonding and metallic bonding.

Electrovalent (Ionic) Bonding

This type of chemical bonding involves the transfer of electrons from the outermost shell of an atom of a metal to the outermost shell of a non-metal.

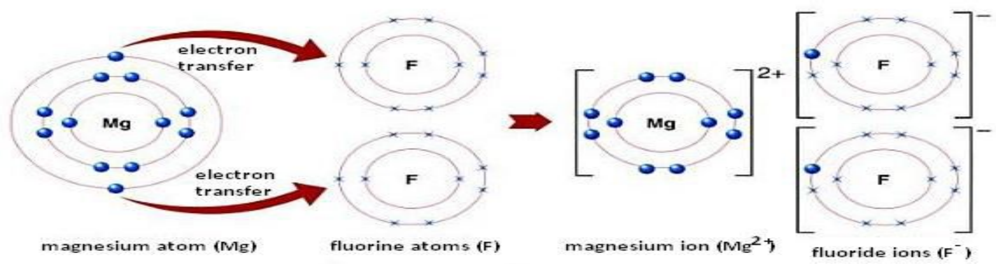
During electrovalent bonding, **ions** are formed. **Ions** are charged particles. There are two types of ions namely **cations** and **anions. Cations** are positively charged (+) ions. **Annions** are negatively charged (-) ions.

Examples

Show bonding in each one of the following.

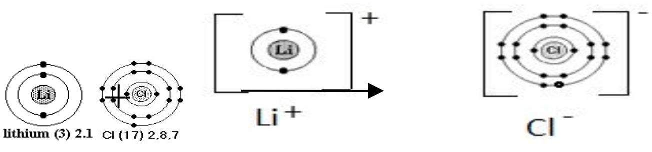
1. Magnesium fluoride ($MgFr_2$)

Answer



2. Lithium chloride (LiCl)

Answer:



3. Magnesium oxide (MgO)

Answer

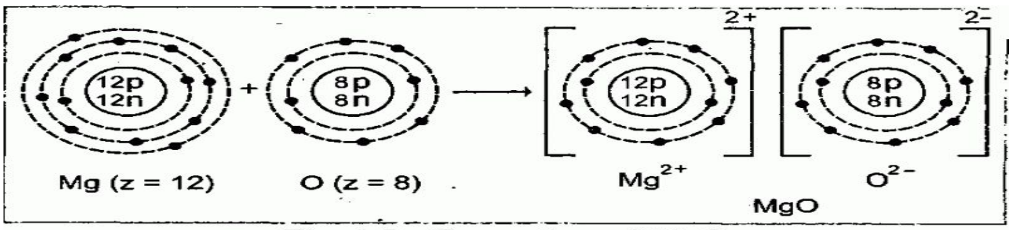
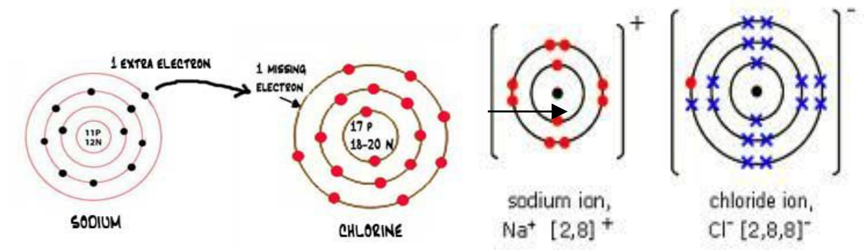


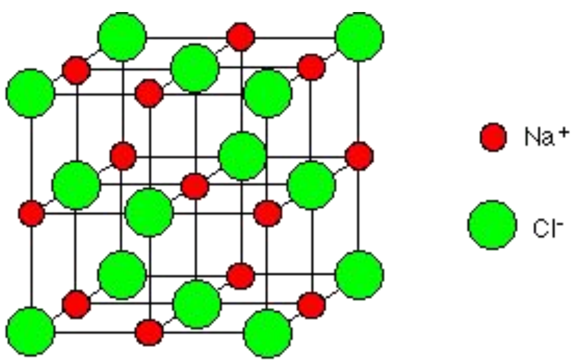
Fig. 1.5 : Formation of MgO

4.Sodium chloride (NaCl)

Answer:



Sodium chloride forms a crystal lattice. The crystal lattice of sodium chloride is shownbelow.



NOTE THAT: When ionic compounds are formed, the number of protons and neutrons remain the same but the number of electrons changes.

- Since an atom of a metal loses electrons, the electronic configuration changes; the number of electrons reduces; hence the number of electrons becomes less than that of protons.

- An atom of a non metal gains electrons; the electronic configuration changes; the number of electrons becomes more than the number of protons.
  e.g.

a. sodium chloride (NaCl): **Before reaction:** Na 2:8:1 Cl 2:8:7
After reaction: Na^+ 2:8 Cl^- 2:8:8

b. Magnesium oxide (MgO): **Before reaction**: Mg 2:8:2 O 2:6
After reaction: Mg^{2+} 2:8 O^{2-} 2:8

Compounds that are formed during electrovalent /ionic bonding are referred to as electrovalent /ionic compounds.

Characteristic Properties of Electrovalent Compounds

1. They are usually solids at room temperature.

2. They have high melting and boiling point and high density. The high melting and boiling points are due to **strong electrostatic forces of attraction** holding the atoms together.

3. They are soluble in inorganic solvents like water but insoluble in organic solvents like paraffin, oil, benzene, ethanol, etc.

4. They are non-volatile, i.e. they do not easily evaporate.

5. They conduct electricity only when in molten state or aqueous state or fused stste.

Covalent (Molecular) Bonding

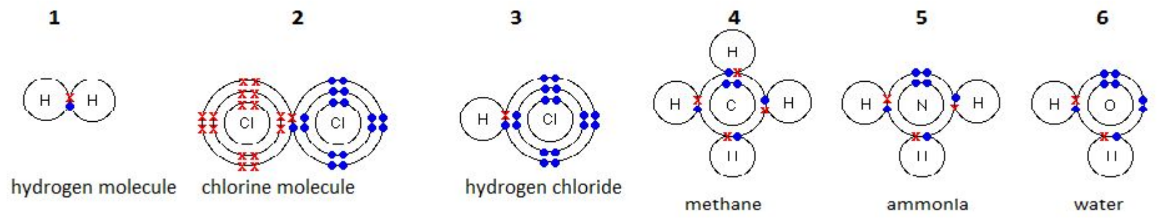
This type of bonding involves the sharing of electrons in the outermost shells of atoms of non-metals. During covalent bonding **molecules** are formed. Molecules are not charged particles.

Examples

Illustrate chemical bonding in each one of the following.

1. Hydrogen molecule (H_2) 2. Chlorine molecule (Cl_2) 3.Hydrogen chloride (HCl)
4.Methane (CH_4) 5.Ammonia (NH_3) 6. Water (H_2O)

Answers



Exercise

Show chemical bonding in the following

1. Oxygen molecule 2. Carbon dioxide 3.Nitrogen molecule 4. Boron fluoride

5. Phosphorus chloride

Compounds produced during covalent (molecular) bonding are known as covalent (molecular) compounds.

Characteristic Properties of Covalent Bonding

1. They are either liquids or gases at room temperature.

2. They have low melting and boiling points and low density.

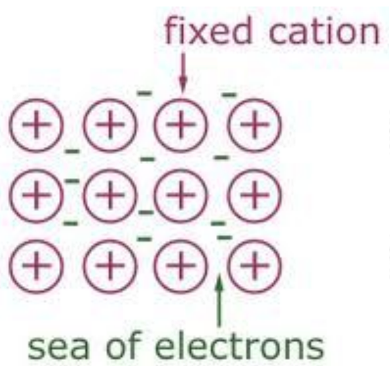
3. They are soluble in organic solvents such as paraffin, oil, diesel, ethanol, benzene, etc. but insoluble in inorganic solvents like water.

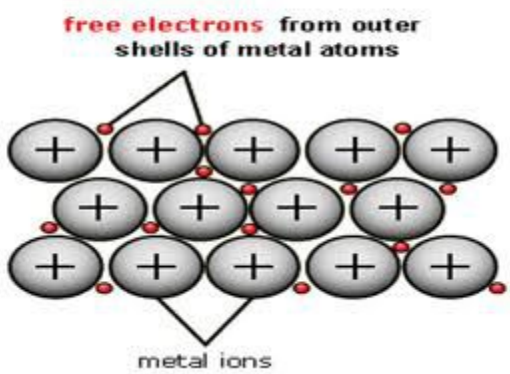
4. They are volatile, i.e. they easily evaporate.

5. They do not conduct electricity in any form.

Metallic Bonding

Metallic bonding the type of chemical bonding due to the **electrostatic attractive forces** between the **delocalized electrons** (free electrons), gathered in an electron cloud, and the positively **charged metal ions**. The electrons in metallic bonds float freely through the lattice of metal nuclei. This type of bonding gives metals many unique material properties, including excellent thermal and electrical conductivity, high melting points, and malleability. .Metallic bonding gives metals excellent conductivity because the delocalized electrons can move freely through the metal lattice, rapidly carrying energy in the form of heat or electricity.



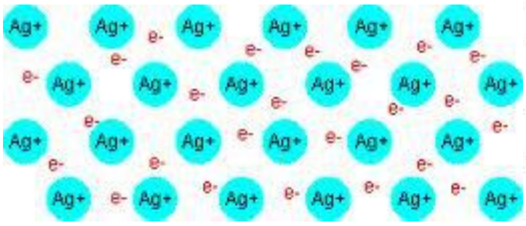


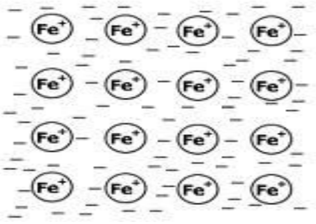
Examples

1. Show bonding in the following.

1. Silver 2. iron

Answers: 1.silver 2. iron





Exercise

Illustrate bonding in the following.

1. Copper 2. Magnesium 3. Sodium 4. potassium