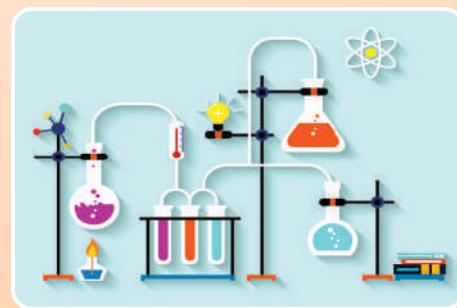


Chemistry



- ♦ *Concepts with Visual Understanding*
- ♦ *Daily life uses of Chemistry*
- ♦ *Core Chemistry (Detailed Theory)*



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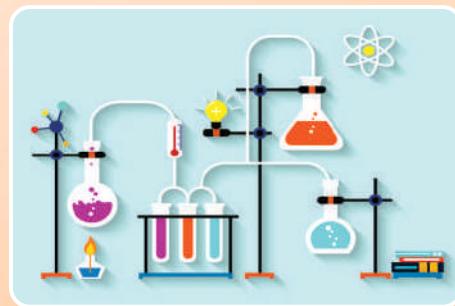
TOPICS

- Chapter - 01** *Applied Chemistry*
- Chapter - 02** *Atomic Structure*
- Chapter - 03** *Periodic Table*
- Chapter - 04** *Chemical Bonding*
- Chapter - 05** *Matter*
- Chapter - 06** *Acids bases and salts*
- Chapter - 07** *s block p block*
- Chapter - 08** *The d and f block elements*
- Chapter - 09** *redox reaction*
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- Chapter - 11** *General processes used in Chemistry*
- Chapter - 12** *Organic Chemistry*
- Chapter - 13** *Mole concept*
- Chapter - 14** *Solid State*
- Chapter - 15** *Solution*
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Chemistry

Chapter - 01

(Applied Chemistry)



- ♦ *Concepts with Visual Understanding*
- ♦ *Daily life uses of Chemistry*
- ♦ *Core Chemistry (Detailed Theory)*



APPLIED CHEMISTRY

Cement

It is silicates and aluminates of calcium.

Invented in 1824, by Joseph Aspdin.

It is also called Portland cement. Because first time it was made in Portland, England.

CaO – Quick lime (can't eat this)

Ca(OH)₂ – slaked lime (pH – 12.4) – we eat this.

It is also called milk of calcium (*Bhujachuna*) which is used in tobacco

CaO	+	SiO ₂	+	Al ₂ O ₃	+	MgO	+	Gypsum
Quick lime		Silicates		Aluminates				
60-65%		25-30%		5-10%		1-2%		2-3%
By total weight of cement								
Basic cement				commercial cement				

(i) Raw Materials: Limestone (CaCO₃), clay (Alumino Silicates – Al₂O₃.(SiO₂).2H₂O) and gypsum (CaSO₄.2H₂O).

(ii) Production: Limestone and clay are heated strongly in a furnace at 1770 K to 1870 K to form cement clinker. This clinker is mixed with 2-3% by weight of gypsum (CaSO₄.2H₂O) so as to regulate setting time and then ground to fine powder. Portland cement contains dicalcium silicate (26%) and tricalcium silicate (51%), tricalcium aluminate (11%).

(iii) Composition of cement: CaO(70%), MgO(2-3%), SiO₂(20%), Fe₂O₃(1-2%), Al₂O₃(5%), SO₃(1-2%). For good quality cement, the ratio of SiO₂ to Al₂O₃ should be between 2.5 to 4.00 and the ratio of lime to the total mixture of SiO₂, Al₂O₃ and Fe₂O₃ should be 2: 2.

Processes to Manufacture Cement

Cement is manufactured by any one of the following two processes.

(i) Dry process (2) Wet process

(i) Dry process: In this process, the dried raw materials are mixed in suitable proportion and the mixture is pulverized and then homogenized in mixing mills. This homogenized mass is known as raw meal. It is fed into the rotary kiln and burnt. Rest of the process is same as in wet process.

(ii) Wet process: Various processes involved are:

(a) Grinding of raw materials: The raw materials are crushed separately and then powdered. The clay is washed with water and is then mixed with requisite amount of powdered limestone. The mixture is pulverized into homogenized mass, known as Slurry.

(b) Heating: The pulverized dry mass, in dry process or Slurry, in wet process, is fed into rotary kiln with the help of screw conveyor and this slurry slowly moves forward due to rotary motion given to the kiln (1/2 to 1 revolution per minute). The charge is heated by burning dust which is blown from the other end with the help of a blower. The charge moves from the upper part to the lower part in two to three hours and finally cement is ready for use.

Why Gypsum is added into the cement?

Because Gypsum, slow down the settling process of cement.

CaCO₃ → Calcium Carbonate → Lime stone or marble, Acid Rain affects it → as it affects Taj Mahal.

Occupational lungs diseases:

These are the diseases that occurs due to the occupations of people.

Worker	Diseases
1. Cement	Silicosis → It affects lungs (silica)
2. Glass	Silicosis → It affects lungs (silica)
3. Stone Cutter	Silicosis → It affects lungs (silica)
4. Asbestos	Asbestosis (Silica)
5. Coal mine or cigarette, smoke	Black lungs disease or Anthracosisis

■1■



6. Cotton mill White lungs disease or Fibrinosis

So, we wear masks to save ourselves

Workers in glass/cement industry are advised to eat **jaggery** in order to remove any toxic material if entered in their body.

Fertilizers

Fertilizers are the substances which are added to the soil from time to time in order to avoid plant starvation and to promote their proper and healthy growth.

Plants need a number of elements like N, P, Mg, S, K, Ca, etc. for their proper healthy growth, in addition to water and sunlight.

Type of fertilizers

(i) Natural fertilizers: Decayed plants, tobacco stem ashes, cottonseed meal, wood, etc. These are of plant origin.

Bones, fish scraps, horns, guano, animal excreta, sewage, sludge, leather waste, etc. These are of animal origin.

(iii) **Artificial or Synthetic fertilizers:** These are further classified as follows:

(a) Nitrogenous fertilizers: They supply nitrogen to plant e.g. urea, CAN (calcium ammonium nitrate), nitrolim ($\text{CaCN}_2 + \text{C}$) ammonium sulphate, etc.

(b) Phosphatic fertilizers: They supply Phosphorus to plants e.g. super phosphate of lime, phosphatic slag, from steel furnaces, etc.

(c) Potash fertilizers: They supply Potassium to plants, e.g. potassium nitrate (nitre), potassium sulphate, potassium chloride, etc.

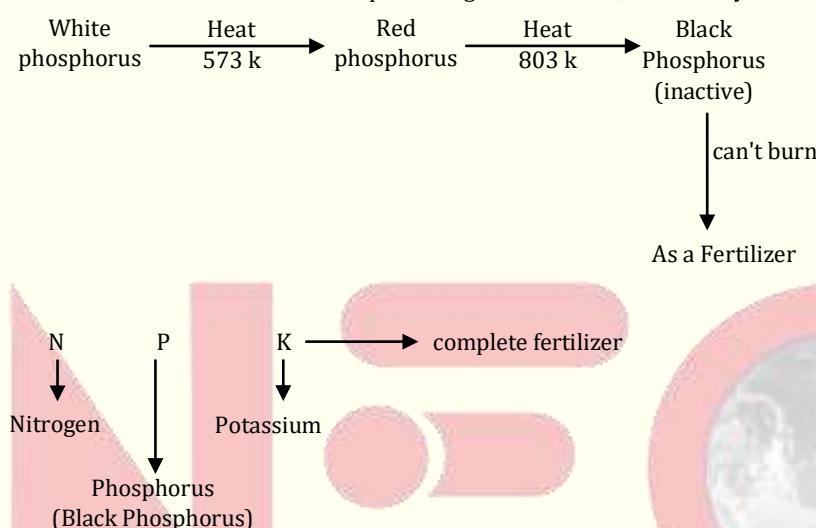
(d) Mixed fertilizers: They can supply all the three main nutrients i.e. N, P and K. They are thus also known as **NPK** fertilizers. They are obtained by mixing nitrogenous, phosphatic and potash fertilizers in suitable proportions.

Functions of Essential Nutrients

Nitrogen: It helps rapid growth, increases yield and protein contents, renders green colour of the leaves, etc.

Phosphorus: It gives formation, hastens maturity, helps in production of healthy plants tissues and increases resistance to frost and insect

It is insoluble in water but when kept for long time in water it turns to yellow in colour.



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(Director)



Potassium: It counteracts the effects of excess doses of nitrogenous and phosphatic fertilizers. It helps in the formation of healthy stalks and increases their resistance to disease.

Essentials of a Good Fertilizer

- (i) It should be soluble in water.
- (ii) The nutrient elements are readily available to the plants.
- (iii) The nutrient elements are available to the plants for a longer period.
- (iv) The fertilizer should be cheap and there should be no problem in its storage

SOME IMPORTANT GASES

Green House Gases: These are non-pollutants rather they increase temperature of earth (i.e. enhances Global Warming)

1. Water Vapour → Maximum in atmosphere

2. Carbon Dioxide (CO₂)

Some facts

- The Industry which produces CO₂ in maximum amount is Cement Industry
- The country which produces maximum CO₂ is CHINA > USA > INDIA
- India ranks 3rd among highest CO₂ producing countries.
- The abundant greenhouse gas in atmosphere due to human activities is CO₂ (by burning of fire)
- Carbon Credit: 1 CC ⇒ 1000 kg of CO₂ emission (1 tonne)

If 1000 kg of CO₂ emission is done by a company means 1cc is done.

3. CH₄ → methane

Most abundant gas in Paddy fields.

4. N₂O → Nitrous Oxide

5. CFC – Chlorofluorocarbon {earlier used in Refrigerator}

Brand Name: Freon Gas

CFC has been replaced by Ammonia (NH₃) and HFC (Hydro Fluro Carbon)

6. R – 22 → Brand name of HFC or AC Gas

CFC contains chlorine so it depletes Ozone layer.

7. Ozone – O₃ → secondary pollutant

8. SF₆ → Sulphur Hexa Fluoride

It is used as an Insulator (to absorb heat)

Nurseries create a poly house around to save plants.

→ To maintain required temperature during winter, necessary for growth of plants and this poly house is also known as green house.

Greenhouse effect: It increases the Earth's Temperature as these gases absorb the reflected sun rays from earth surface and trap these heat radiations inside the earth atmosphere. This increases the overall temperature of earth. This effect is known as greenhouse effect.

This leads to global Warming.

Note:

The gas which has maximum potential to absorb heat radiations.

→ SF₆ (Sulphur Hexa Fluoride)

Green house gas emitted in maximum quantity from plants.

→ Water Vapour

LPG (Liquified petroleum gas)

■ 3 ■



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The book cover features a yellow background with faint handwritten text in the background. A circular seal on the left says "FULLY REVISED UPDATED". The title "NEON COMPREHENSION" is at the top right, with "NEON" in large red letters and "COMPREHENSION" in white. Below it is a large black "CLOZE TEST". Underneath is the subtitle "(PREVIOUS YEAR EXAMS - SSC CGL / CPO & BANK)". To the right is a portrait of the author, Manisha Bansal Ma'am, in a red sari. On the left, there's a red triangle containing the text "SSC CPO BANK". At the bottom right, it says "Available on: Amazon Flipkart".

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Main composition

- * Ethane + Propane + Butane
 C_2H_6 C_3H_8 C_4H_{10}
(10%) (20 - 30)% (60 - 70)%
Or
- * Propane + Butane
(40 - 50)% (50 - 60)%
Or
- * Isopropane + Butane
 C_3H_8 C_4H_{10}
Or
- * Isopropyl Butane (C_4H_{10})
Methane (CH_4) is not present in this.

Modern LPG

Isobutane + Butane

C_4H_{10} + C_4H_{10}

Isobutane is an isomer of Butane.

The maximum pressure an LPG cylinder can hold is 100 - 120 bar.

For smell in LPG, Ethyl mercaptan or Ethanethiol is added to detect its leakage

$CH_2 CH_3 SH$ (S → sulphur → has smell)

Note:

- Cigarette lighter fuel → butane (gas)
- Olympic torch fuel Isopropylene butane
- Waste Dump areas have covers embedded with holes in order to provide leakage to methane gas so that methane may not compile at such places because due to accumulation of methane, blasts may occur.
- Methane is also known as 'bed gas'
- Ethane is a petroleum gas

CNG (Compressed natural gas)

Ethane + Methane → Bio gas
(15%) (85%)
 C_2H_6 CH_4

Butane is not present here

Pressure → 200 - 250 bar

Methane gas

Methane gas is also known as Bio gas (gobar gas)

(90 - 95% - CH_4 - Methane)

- Methanogens bacteria is responsible for the formation (production) of methane. It is the most primitive bacteria on earth. Even when there was no oxygen on earth this creature was present.
- Methane + air → Explosive
Eg: mine blast, waste dump areas blast is due to methane explosion
- People die in waste dumped areas due to excessive methane.
- Since methane is obtained from marshy areas it is also known as **marsh gas**.



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Sources of methane:

- (a) Paddy fields
- (b) Ruminants / cowdung
- (c) Land fills
- (d) Marshy areas

Gases used for artificial respiration

Atmospheric pressure decreases as we go up in the air and increases as we go down the surface of earth

Oxygen Cylinder: To save life of a person who cannot inhale atmospheric oxygen.

It contains Helium (15%) + oxygen (85%). This mixture is known as Heliox. Helium, an inert gas is added to dilute the oxygen.

Sea divers in deep sea water use trimix cylinder

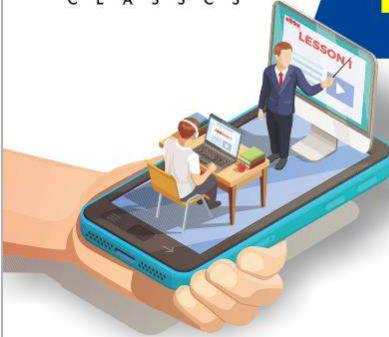
Nitrogen (70%) + Oxygen (20%) + Helium (10%)

Since our body rejects pure oxygen at high pressure deep under sea so we mix nitrogen with it to create natural atmosphere. Nitrogen is mixed with oxygen only where there is no normal atmosphere so we don't mix N₂ for using O₂ cylinders in Hospitals.

Helium increases the solubility of oxygen



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Welding gas

Oxygen + acetylene → oxy Acetylene gas
(cylinder) (cylinder) (pipes of both cylinder joined together)
Oxyacetylene can create a temperature of 3200° - 3400°C

■6■



Common Gas cutter

→ Oxygen + Hydrogen → Oxy hydrogen gas

Temperature → 3700°C

During welding UV rays are produced so, we use goggles to protect our eyes

Note: The highest melting point is of Tungsten metal (W) (3200°C - 3400°C)

Smoke bomb: Smoke Bomb is made up of

1. Potassium Chlorate ($KClO_3$) It is used as an oxidizer.
2. Sugar (sucrose or dextrin fuel)
3. Sodium Bicarbonate – To moderate the rate of reaction & keep it from getting too hot.
4. Powered organic Dye - To Impart Colour

Nitrous oxide (N_2O): It is also known as Laughing gas

Used for anesthesia

Advance anesthesia → Halothane + N_2O

Earlier used anesthesia → Chloroform ($CHCl_3$)

(IUPAC name of chloroform is tri - Chloromethane)

Tear Gas (Chloropicrin ($CCl_3 NO_2$))

This gas is used to disperse the crowd.

This gas is present inside small rubber balls. When the rubber ball strikes a surface it collapses and the gas is released out. The gas creates a burning sensation in our eyes. Hence Lachrymal glands of our eyes produce tears.

Ammonia gas (NH_3) is also used to disperse the crowd

Bhopal gas Tragedy:-

Reason - Leakage of gas - Methyl Isocyanide (H_3CNCO)

Company - Union Carbide (USA)

Product - Pesticide

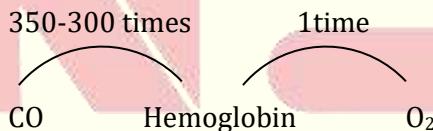
Date - 3rd Dec. 1984

Accused - Warren Anderson

The cylinder containing the gas had a blast resulting in the release of the gases carbon monoxide and cyanide. These poisonous gases killed many people.

CO (carbon monoxide)

It is the most harmful gas for humans. It combines with hemoglobin of blood and forms a stable compound carboxyhemoglobin due to which the oxygen carrying capacity of hemoglobin is reduced and person dies due to unavailability of oxygen. The affinity of hemoglobin for carbon monoxide is 300 times the affinity of hemoglobin for oxygen.



Artificial Ripening of Food

In this the fruits are ripened artificially by using certain chemical compounds so that they may be sold in the market.



Methods of Ripening of fruits

(फलों को पकाना)

Natural Artificial

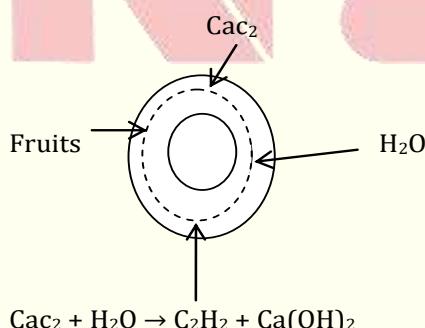
(naturally by trees using Ethylene or ethene (C_2H_4))

Artificial Ripening of fruits

Recommended
Ethylene
(Gas Hormone)
Ethane

Prohibited
Acetylene
 C_2H_2
carcinogenic due to carbide (C_2)

Government allowed the artificial ripening of fruits by ethylene and banned acetylene (C_2H_2) because it contains carbide (C_2) and this is carcinogenic (cancer causing). Acetylene on cooling sticks on fruits. Small vendors use calcium carbide (CaC_2) for artificial ripening and when they sprinkle water, acetylene gas is produced.



Water gas / Synthesis gas ($\text{CO} + \text{H}_2$)

It is used to keep the blast furnace warm

Producer gas (CO + N₂)

It is used as a fuel to run Automobiles in foreign





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Rocket fuel

In this, liquid Hydrogen is used because of its highest calorific value

Rocket engine is a cryogenic engine (cold engine)

1 gm. Petrol releases 50 kilo Joule of energy

1 gm. Diesel releases 45 kilo Joule of energy

1 gm. Hydrogen releases 145 kilo joule of energy

Note: $N_2 \rightarrow$ Third largest in universe

Argon \rightarrow Third largest gas in atmosphere

Study of fossils (Palaeontology)

The isotope of Carbon ^{14}C is a radioactive isotope and used for carbon dating i.e to estimate the age of fossils.

U-234 is used for Uranium lead dating i.e to estimate the age of earth.

Half life of carbon is 5400-5700 years and half life of uranium about 4.5 billion years

Use of some elements in diagnosing/ Treating diseases

- Cobalt - 60 \rightarrow cancer treatment
- Arsenic - 74 \rightarrow Brain tumor detection
- Iodine - 131 \rightarrow Thyroid cancer treatment
- Radium - 223 \rightarrow bone cancer treatment
- Sodium 24 \rightarrow to detect blood clots inside body. Its half life is very small (few hours) so mostly destroyed in our body only
- Phosphorus -32 \rightarrow Blood cancer treatment

Cobalt - 60, Sodium 24 and Phosphorus -32 are used in radiotherapy.

Catalytic Convertors: - It converts poisonous gases to non- poisonous gases. So, it is used in Engines of automobiles so that harmful gases may not emit out directly in Environment.

Catalytic convertors are made up of Transition Metals.

BS III, BS IV, BS VI

BS Stands for Bharat Stage

These are types of Engines named as per amount of Pollutants emitted by these engines.

BS III emits more pollutants

Where as

BS VI emits less pollutants so, less Harmful for environment.

Euro III or Euro V means which follow European standardizations.

CE \rightarrow means European certification and this is not Harmful.

FSSAI \rightarrow Food Security and standard authoring of India.

Some Diseases due to metals

1. Cadmium \rightarrow Itai - Itai Disease in Japan or Ouch - Ouch disease in Rest of the world

(Pain in kidney, first noticed in people of Japan)

2. Iron \rightarrow Siderosis Disease

(due to abnormal increase of iron in human body)

Do not confuse with \rightarrow Cirrhosis \rightarrow Disease of liver due to more alcohol consumption

3. Copper \rightarrow Wilson's disease (Body becomes yellow coloured)

As copper kills Bacteria so water kept in copper container is good for our health

But Excess of copper always affects our health

4. Nitrate: \rightarrow Blue baby syndrome or methemoglobinemia

(due to abnormal increase of nitrate in body)

■ 9 ■



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Note: Brown Ring test is used to check the presence of Nitrate in water

5. Mercury → Minemata Disease

This was the first disease due to Hg that happened to the people of minemata creek of Japan. It gives paralytic attack i.e. affects Brain.

6. Arsenic → Black foot Disease

White Lung Disease is due to fibres of cotton and Lungs cancer is due to Radon

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Energy (Electricity) Productions in India

Energy producing plants in India as per amount of energy produced by them

1st → Thermal power plants

2nd → Hydro power plants

3rd → solar power plants

4th → Nuclear power plants

This energy is used up to produce electricity

Nuclear power plants in India

1. 1st → Tarapur, Maharashtra.

It was established with the help of USA in 1969. This is the oldest power plant in the world. This is used for the production of Electricity.

2. Jaitapur, (Maharashtra) (Under Construction)
3. Gorakhpur (Haryana) (Under construction)
4. Narora Power plant (Buland Shehar, Uttar Pradesh) (working)
5. Rajuoli (Bihar)
6. Haripur (West Bengal)
7. Chhutka power plant (Madhya Pradesh)
8. Bhumpur Power plant (Madhya Pradesh)
9. Kovadda power plant (Andhra Pradesh)
10. Kalpakkam (Tamil Nadu)
11. Kudankulam (Tamil Nadu)
12. Kaiga (Karnataka)
13. Kakrapara (Gujrat)
14. Mithi Virdi (Gujrat)
15. Rawat bhata(Rajasthan)
16. Mahi banswara (Rajasthan)

■ 10 ■



America dropped 2 Atom bombs on Japan

Place	Date	Name of bomb	Radioactive elements used	Name of aircraft which dropped these bombs
Hiroshima	6-Aug-1945	LITTLE BOY	Uranium	Enola Gay
Nagasaki	9-Aug-1945	FAT MAN	Plutonium	B-29

Nuclear Bomb Testing in India (Atom Bomb)

Date	Operation name	Site
1974	Smiling Buddha	Pokhran
1998	Operation shakti	Pokhran

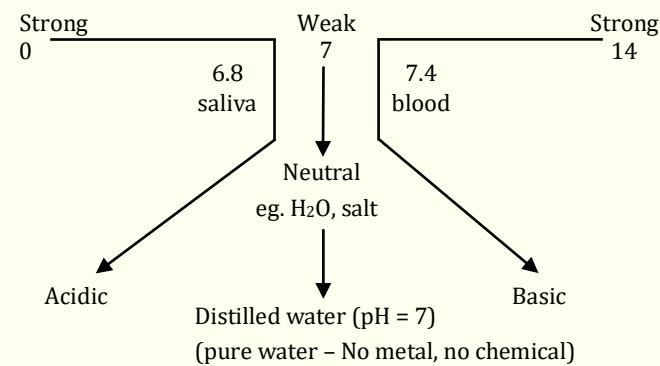
Now- a- days, we claim 90-110 atom bombs, we have with India

pH → Potential of Hydrogen / Power of Hydrogen

pH scale was given by S.P. Sorenson. pH is a measure of the hydrogen ion concentration of a solution. Solutions with a high concentration of hydrogen ions have a low pH and solutions with low concentrations of H⁺ ions have a high pH i.e it is used to specify how acidic or basic a water-based solution is. Acidic solutions have a lower pH, while basic solutions have a higher pH. At room temperature, pure water is neither acidic nor basic and has a pH of 7.

pH meter is used to detect pH of a liquid. It was given by Beckmen.

pH of blood - 7.4 pH of saliva - 6.8



Match sticks chemical → Potassium chlorate + Antimony sulphide

Match stick is made of which phosphorus → Red phosphorus

Holm's signal is an emergency signal in sea water.

= Calcium carbide + calcium phosphide

$\text{CaC}_2 + \text{Ca}_3\text{P}_2$ = Red coloured flame (gas) burns up frequently giving a signal in air.

The Quality of coal depends on the presence of amount of carbon.

Types of coal:

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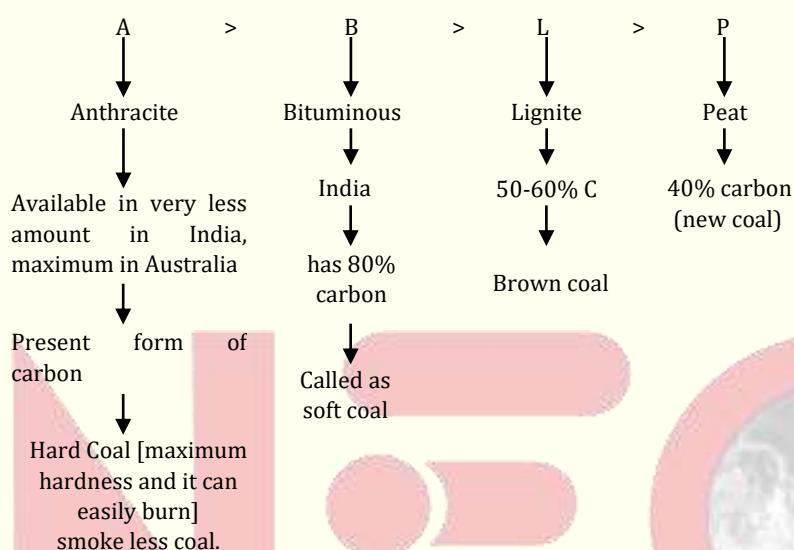


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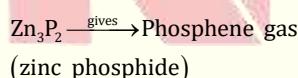
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Higher is the concentration of carbon, more black is the colour of coal. The coal formed in many thousand years is Anthracite.

Rat Poison



Due to eating of Zn_3P_2 , a gas called phosphene gas is formed inside body of rat so it moves out in open space.

Uses of Sulphur

Vulcanisation of Rubber is done by adding sulphur (Hardening) in 5-10% amount in Rubber.

Isoprene, chemical in form of milk that is obtained from plants and rubber is obtained from this.

Onion and garlic have a (bad odour) smell due to sulphur.

Hot Geysers or hot water from inside the earth surface is obtained when amount of sulphur is higher at that place.

Volcanic eruptions contain SO_2 mainly So, people are advised to stay away from such places as it may cause many respiratory diseases like Asthma.

Bullet proof jackets

Polyebonate is used to make Bullet proof glass and mixey Jar.

Hardest Material:

Natural – Diamond

Man made – Wurtzite (Boron nitride) – 400 GPa. (Made by china)

One of the hardest man made → Norbide

Hardness is measured in GPa = Giga Pascal [It is a unit of hardness]

Harshest metal → Platinum, Chromium, Titanium

Boron fibers + Carbon fibers → Stronger than steel fiber

Boron Carbide
Or

Norbide (40-50 GPa) → one of the man made hardest material.

Use

Bullet proof Jacket ← Polyamide (kevlar)

■ 12 ■



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Glass

(a) Silicates of Na and Ca (short trick SSC)

(b) Amorphous Solid (no shape)

(c) Super cooled liquid

(1400 – 1500° C → Heated + molten liquid – shaped to glass)

As after sometimes it is thicker at bottom (This process is called as Annealing)

SSC – silicates of Na & Ca)

Sodium silicate Silica (sand) 65-70% → silica Calcium silicate

Different colours of glass is due to different chemicals added into it

- Cobalt Oxide: blue-violet
- Cadmium Sulfide: yellow
- Gold Chloride: red
- Antimony Oxide: white
- Sulfur: yellow-amber
- Uranium Oxide: fluorescent yellow, green
- Chromic Oxide: emerald green

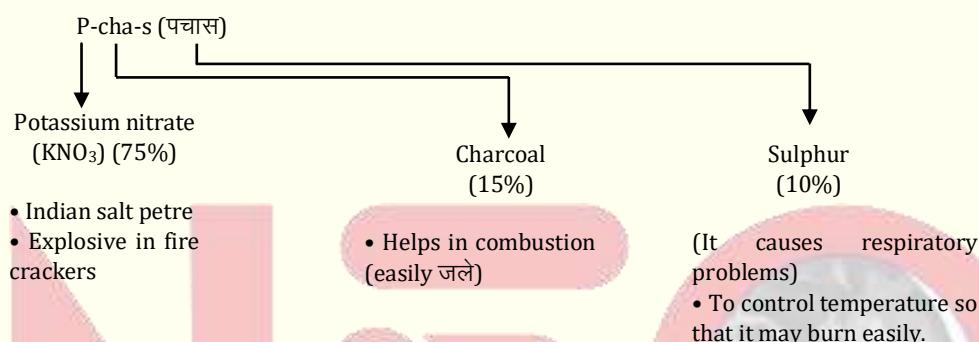
Asbestos

(Cemented roof) Building roof → CaSiO_3 , MgSiO_3

Use – fire proof jackets or fire proof material

Because it can't catch fire.

Gun Powder (Barood)



Fire crackers colours/ flame test

If any metal is kept on flame. It produces different type of colours.

Name	Colour	Trick
Barium	Green	Green Bar
Strontium or lithium	Red	SLR
Calcium	Brick Red	Cab Red
Copper	Blue	Blue copper
Magnesium	White	Magnesium white
White flash light of mobile is due to Mg.		
Sodium	Yellow	so ye
Yellow lamp in streets → Na vapour lamp (sodium – Na)		

■ 14 ■



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Fact

Most poisonous gas $\rightarrow CO$

Most harmful gas $\rightarrow SO_2$

Red medicine (Detol)

Potassium per magnet ($KMnO_4$)

Some daily life medicines

Antacids – Gas Reliever medicines.

(To reduce the acidity problems)

Anti helmenthic – Albendazol

Antipyretic – Reduce temperature of body. Ex: (PCM Paracetamol)

Analgesics – Pain relief medicines – Pain killers.

Tranquilizers – To reduce stress

Bleaching Power (common name)

$CaOCl_2$ (Calcium Hypochlorite \rightarrow now, earlier calcium oxychloride)

Use:

Where there is a lot of waste dumped on surface and it smells badly even after removing the waste. This is sprinkled at such place to remove bad odour.

It kills germs in water also (i.e. used as a germicide)

Hypothetical Chemical Element: eka-francium

Ununennium, also known as eka-francium or element 119, is the hypothetical chemical element with symbol Uue and atomic number 119. Ununennium and Uue are the temporary systematic IUPAC name and symbol respectively, until its discovery is confirmed and a permanent name is decided upon.

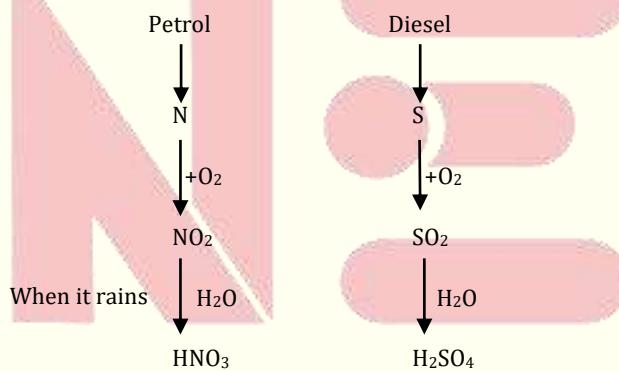
Taj Mahal

Reason for yellow colouration of Taj Mahal \Rightarrow Acid Rain.

Stone Cancer/ Marble Couch is the effect of acid rain on Taj Mahal.

The main reason is actually Acid Rain. Reasons for Acid Rain is presence of NO_2 and SO_2 in air.

When Petrol and Diesel are burnt, it releases gases which finally turns into acids and leads to Acid Rain.



Apple when cut turns into brown coloured apple

When an apple is cut (or bruised), oxygen is introduced into the injured plant tissue. This causes the PPO (Polyphenol Oxidase) enzyme in the apple's flesh to oxidize the polyphenols turning them into some other brown coloured products. Hence the colour changed.

Potatoes brown quickly when cut

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Potatoes brown quickly when exposed to fresh air because they are packed with starch. When these starches are exposed to oxygen, they undergo a process called oxidation, which leaves your **potato** with a grayish or brownish tint.

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Egg

Egg shell is made up of calcium carbonate

The **yolk** contains less water and more protein than the white, some fat, and most of the vitamins and minerals of the **egg**. These include iron, vitamin A, vitamin D, phosphorus, calcium, thiamine, and riboflavin. The **yolk** is also a source of lecithin, an effective emulsifier.

The **white** contains more than half the **egg's** total **protein**, a majority **of** the **egg's** niacin, riboflavin, magnesium, potassium and sodium, and none **of** the fat. The **white** **of** a large **egg** contains about 17 calories.

Cigarettes

The chemical constituents of cigarettes include:

Nicotine

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Nicotine is a colourless, poisonous alkaloid derived from the tobacco plant. It is a powerful drug, which affects the brain and a person quickly becomes addictive.

Tar

'Tar' is the term used to describe the toxic chemicals found in cigarettes. It's a sticky brown substance that forms when tobacco cools and condenses. It collects in the lungs and can cause cancer.

Carbon monoxide

An odorless, colourless gas that is released from burning tobacco. When it is inhaled it enters the blood stream and interferes with the working of the heart and the blood vessels. Up to 15% of a smoker's blood can be carrying carbon monoxide instead of oxygen.

Arsenic

Arsenic-containing pesticides used in tobacco farming occur in small quantities in cigarette smoke. Arsenic is commonly found in rat poison.

Ammonia

Ammonia is a toxic, colourless gas with a sharp odor. Ammonia compounds are commonly used in cleaning products and fertilisers. Also used to boost the impact of nicotine in manufactured cigarettes.

Acetone

Fragrant volatile liquid ketone, used as a solvent.

Toluene

Toluene is a highly toxic chemical. Industrial uses include rubbers, oils, resins, adhesives, inks, detergents, dyes and explosives.

Methylamine

Chemical found in tanning lotion.

Pesticides

A number of pesticides (toxic chemicals used to kill pests, usually insects) are present in cigarette smoke. These pesticides find their way into cigarettes because they're used on tobacco plants as they are growing.

Polonium - 210

Radioactive element – used in nuclear weapons as well as an atomic heat source.

Methanol

Fuel used in the aviation industry.

Silver chains turns black

Rust is called oxidation, because oxygen in the air starts to chemically react with the iron's outer layers. **Silver** doesn't oxidize, though; it tarnishes. Tarnish is formed when sulfur or sulfur compounds come into contact with **silver**.

Sorel cement

Sorel cement, also called **magnesium oxychloride cement (MOC)** or **magnesia cement**, it is a non hydraulic cement made from a mixture of magnesium oxide and magnesium brine. It was discovered by the French engineer Stanislas Sorel in 1867. He has found limited use due to its very poor water resistance and is commonly used artificial stone, wallboards, and as a binding agent in grindstones. On Mars it would be used to prepare concrete.

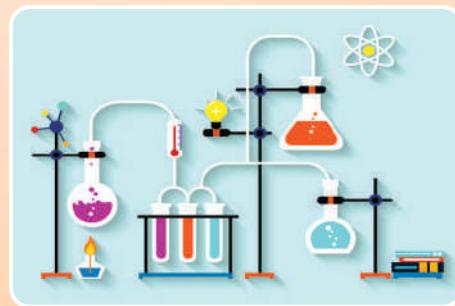
The **Sorel cement** is a mixture of magnesium oxide (burnt **magnesia**) with magnesium chloride with the approximate chemical formula $MgC_4Cl_2(OH)_6(H_2O)_8$, corresponding to a weight ratio of 2.5–3.5 parts MgO to one part MgCl₂.

The name "Sorel cement" is also used for zinc oxychloride cements, also discovered by Sorel, which is prepared from zinc oxide and zinc chloride instead of the magnesium compounds and **this is used as dental filling**.

Chemistry

Chapter - 02

(Atomic Structure)



- ♦ *Concepts with Visual Understanding*
- ♦ *Daily life uses of Chemistry*
- ♦ *Core Chemistry (Detailed Theory)*

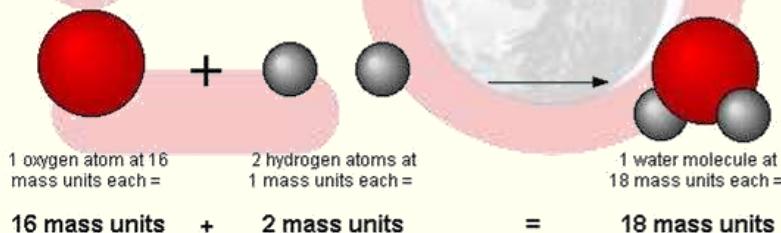


ATOMIC STRUCTURE

Dalton's Atomic Theory

By observing the laws of chemical combination John Dalton in 1808 proposed atomic theory of matter. The main points of Dalton's atomic theory are as follows:

1. Matter is made up of extremely small, indivisible particles called atoms.
2. Atoms of same substance are identical in all respects, i.e., they possess same size, shape, mass, chemical properties, etc.
3. Atoms of different substances are different in all respects, i.e., they possess different size, shape, mass, chemical properties, etc.
4. Atom is the smallest particle that takes part in chemical reaction.
5. Atoms of different elements may combine with one another in a fixed, simple, whole number to form compound-atoms (now called as molecules).
6. Atoms can neither be created nor destroyed, i.e., atoms are indestructible.



Limitations of Dalton's Atomic Theory

1. It failed to explain how atoms of different elements differ from one another, i.e., it did not tell anything about structure of the atom.
2. It could not explain how and why atoms of different elements combine with each other to form compound atoms or molecules.
3. It failed to explain the nature of forces that bind together different atoms in a molecule.
4. It failed to explain Gay-Lussac's law of combining volumes
5. It did not make distinction between ultimate particles of an element that take part in reaction (atoms) and ultimate particle that has independent existence (molecule).

Constituents of The Atom

John Dalton (1808) proposed matter to be composed of small indivisible particles called atoms.

Atom: It is the smallest particle of an element that can take part in a chemical reaction.

Atoms are made up of protons, neutrons and electrons.

The atomic radius is of the order of 10^{-10} metre.

Whole of the mass of an atom is concentrated in a small region called nucleus. The size of the nucleus is order of 10^{-15} m.

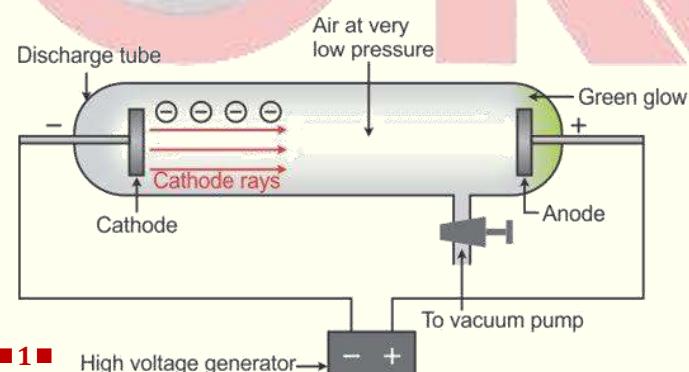
Discovery of Electron (Cathode Rays)

Cathode rays were discovered by **Julius Plucker** (1859).

In his experiment, he used a discharge tube

It is a long glass tube fitted with metal electrodes on either sides and across which high voltage can be applied. The tube is also connected to a vacuum pump for controlling the pressure of the gas inside the discharge tube.

This experiment shows that the fluorescence is due to bombardment on the glass walls of the tube by the rays





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emitted from the cathode. These rays are called **cathode rays**.

Properties of cathode rays

- They travel in straight lines.
- They consist of material particles.
- They get deflected towards positive plate, when an electric field is applied to them.
- When magnetic field is applied, they get deflected and the direction of deflection indicates the presence of negative charge on them.

Origin of cathode rays: Cathode rays initially originate from the metal which constitutes the cathode. These are also formed due to the bombardment of the molecules of the gas inside the discharge tube by the high-speed particles (electrons) which are emitted from the cathode.

The properties of cathode rays given above show that cathode rays are made up of material particles which are negatively charged. These particles which constitute cathode rays are called **electrons**.

Determination of [Charge (e)/Mass(m)] Ratio for Electrons

The electrons obtained from different sources were found to be exactly identical. This indicated that the **electrons are universal constituents of matter**.

An electron can be defined as a sub-atomic particle which is negatively charged with mass 9.10939×10^{-31} kg and charge equal to 1.6022×10^{-19} coulombs.

Electrons are present in the extra-nuclear part of the atom.

The relative charge of electron is -1 and its mass is approximately 0.00054 u or amu (taken as zero).

Electrons are **fundamental particle of matter**. Electron is represented as ${}_{-1}^0 e$.

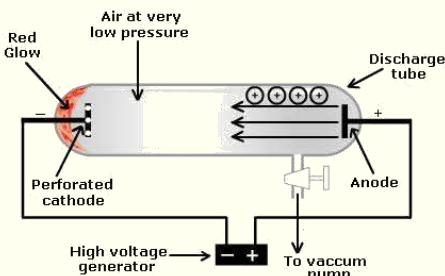


Fig.: Formation of positive rays or anode rays.

These rays consist of positively charged particles moving away from anode.

Origin: It is believed that the positively charged particles that constitute the anode rays are formed when electrons are knocked out from the atoms or molecules of the gas inside the discharge tube by the particles of fast moving cathode rays. Thus, these are the residual positively charged particles left when electrons have been knocked out.

Note: Anode rays are not emitted from anode but in the space between anode and cathode.

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Properties of Anode Rays

■ 2 ■



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- (i) They travel in straight lines.
- (ii) They consist of material particles.
- (iii) They are deflected by electric and magnetic fields.
- (iv) The value of positive charge on these rays depend up to the nature of the gas in the discharge tube.
The magnitude of positive charge is same as an electron (1.6×10^{-19} coulombs).

The mass of the positively charged particle called proton is calculated as follows:

$$m = \frac{e}{e/m} = \frac{1.6 \times 10^{-19} C}{9.58 \times 10^4 C/g} = 1.67 \times 10^{-24} g$$

Protons are positively charged particles with mass 1.67262×10^{-27} kg and charge equal to 1.6022×10^{-19} coulombs.

Protons are present in highly dense central part of the atom called **nucleus**.

The mass of proton is 1.00727 u or amu (approx. taken as 1 u or amu).

Protons are denoted as p or ${}_1^1 p$ or ${}_1^1 H$.

Protons are fundamental particles of all atoms.

Discovery of Neutrons

Neutrons were discovered by James Chadwick. These neutral particles were found to have a mass 1.675×10^{-27} kg which is almost equal to that of a hydrogen atom. These particles carried no charge (i.e., they are neutral). Neutrons are present in the nucleus of the atom.

Except for hydrogen (which contains only one proton and one electron), the atoms of all other elements including isotopes of hydrogen (i.e. deuterium and tritium) contain all the three fundamental particles (i.e. electron, proton and neutron).

Quarks: Fundamental particles such as protons and neutrons are believed to be made up of various combinations of elementary particles called quarks. These were first proposed by **Murray Gell-Mann**.

Quarks are believed to have fractional charges and other properties such as flavour and colour.

Atomic number (Z): The number of unit positive charges present in an atom is known as **atomic number**.

Atomic number (Z) = Number of protons (p)

In an atom, the number of protons is the same as the number of electrons, therefore, atomic number must be also equal to the number of electrons.

Mass number (A): It is defined as, the total number of protons and neutrons in the nucleus. It is denoted by A.

Thus, Mass number = Number of protons + Number of neutrons

It is always a whole number.

If we know the mass number and atomic number of an element, we can calculate the number of protons, electron and neutrons and thus can predict the structure of the atom.

Atomic Number (Z) = Number of protons (j) = Number of electrons (e)

(Protons + neutrons) are collectively called **nucleons**.

Atomic Numbers (Z) and mass number (A) of an element X are generally indicated as:

${}^A_Z X$ Or ${}_Z^A X^A$

Isotones: Atoms having same number of neutrons are called isotones.

e.g., ${}^14_6 C$ and ${}^{16}_8 O$ (both have 8 neutrons).

Isotopes: They are atoms of same element having different mass number but same atomic number.

e.g., ${}^{35}_{17} Cl$ and ${}^{37}_{17} Cl$.

Isobars: They are atoms which have same mass number

but different atomic number. e.g., ${}^{40}_{18} Ar$, ${}^{40}_{19} K$ and ${}^{40}_{20} Ca$.



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■ 4 ■



Isodiapheres: Atoms of different elements having same difference in number of neutrons and number of protons are called isodiapheres. e.g., $^{235}_{92}\text{U}$ and $^{231}_{90}\text{Th}$.

In U, $n-p = [(235-92)-92] = (143 - 92) = 51$

and Th, $n - p = [(231-90)-90] = (141-90)=51$

Isosters: Those molecules which have same number of electrons and the same atomicity, e.g., N_2O and CO_2 (both have 22 electrons and atomicity of both is 3)

Isoelectronic: Those atoms which have same number of electrons, e.g., Na^+ , Mg^{2+} , F^- , Ne , etc. (each has 10 electrons).

Thomson Model of Atom

- J.J. Thomson proposed a model in which atom was assumed to be a uniform sphere with radius 10~8 cm of positive electricity (positive charge) with electrons embedded into it in such a way as to give the most stable electro static arrangement.
- In this model the atom is visualized as a pudding or cake of positive charge with raisins (electrons) embedded into it. This model is also called the 'raisin pudding' model.
- The mass of atom is considered to be evenly spread over the atom according to this model.

Drawbacks of Thomson Model of Atom

This model of atom could account for the electrical neutrality of atom, but it could not explain the results of gold foil experiment carried out by Rutherford.

Rutherford's Model (Nuclear Model of Atom)

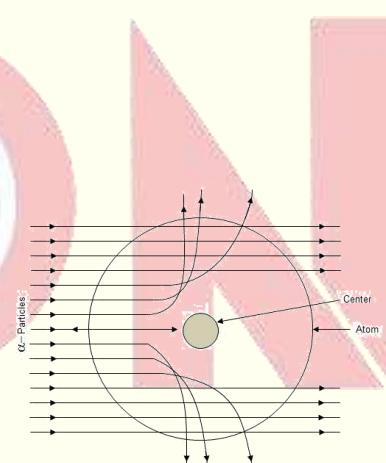
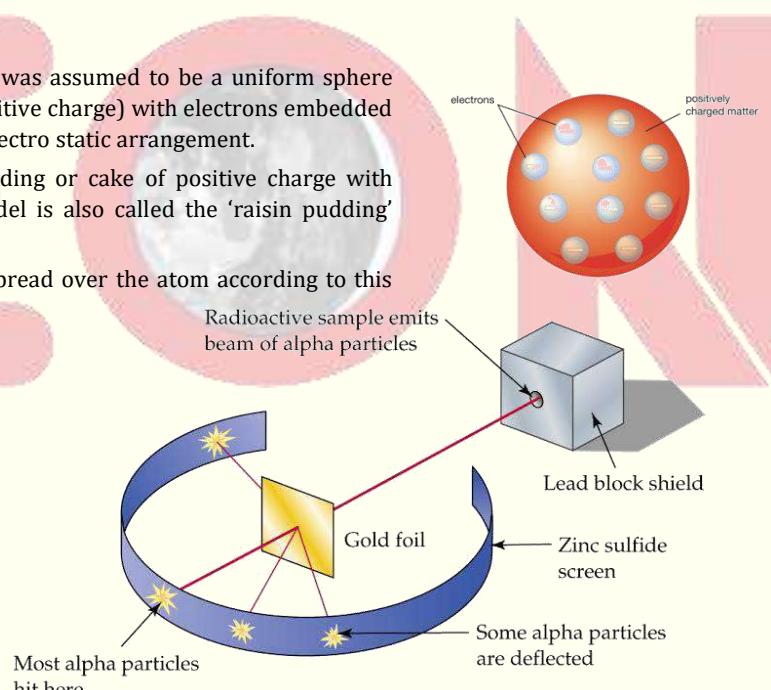
Rutherford bombarded high energy α -particle from radioactive source on thin foil (thickness 10^{-7} m) of gold metal, α -particles are positively charged helium nuclear having high energy, emitted during radioactive decay of unstable elements like Uranium.

It has + 2 charge and mass 4 u. The thin gold foil had a circular fluorescent ZnS screen around it. Whenever an α -particle struck the screen, He observed a tiny flash of light was produced at that point that :

- Most of the α -particles passed through the gold foil undetected.
- A small fraction of α -particles angles,
- A very few α -particles (about 1 in 20,000) bounced back, i.e.

Rutherford explained his observations as follows:

- Since most of the α -particles pass through the foil undetected, it indicates that the most of the space in an atom is empty.
- α -particles being positively charged and having considerable mass could be detected only by some heavy, positively charged centre. The small angle of detection of α -particles indicated the presence of a heavy positive centre in the atom. Rutherford named this positive centre as nucleus.
- α -particles which make head-on collision with the positive centre are deflected through large angles. Since the number of such α -particles is very small, the space occupied by the heavy positive centre must be very small.



The radius of the nucleus is about (10^{-13} cm) which is about $\frac{1}{100,000}$ of that of the radius of atom (10^{-8} cm).

If we consider cricket ball as nucleus then the radius of atom will be about 5 km.

Based on his scattering experiment Rutherford put forward nuclear model of the atom. The main points of this model are:



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(i) Most of the mass and all the positive charge on an atom is concentrated in a very small region called nucleus. Size of the nucleus is extremely small as compared to the size of the atom.

(ii) The nucleus is surrounded by electrons which are revolving around it at very high speeds. The centrifugal force due to this motion balances the electro static force of attraction.

(iii) Total negative charge on electrons is equal to the total positive charge on the nucleus so that atom on the whole is electrically neutral.

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Drawbacks of Rutherford's Model of Atom

(i) When a body is moving in a orbit, it undergoes acceleration even if the body is moving with constant speed in an orbit (due to change in direction), so an electron moving around the nucleus in an orbit is under acceleration.

According to Maxwell's electromagnetic theory, charged particles when accelerated must emit electro magnetic radiations. Therefore, an electron in an orbit will emit radiation. The energy carried by radiations comes from electronic motion. The electron should lose energy and move closer and closer to the nucleus following a spiral path and ultimately, will fall into the nucleus within 10^{-8} sec. But actually this does not happen.

Thus, Rutherford's model cannot explain the stability of atom if the motion of electron is described on the basis classical mechanics and electromagnetic theory.

(ii) It does not give any idea about distribution of electrons around the nucleus and about their energies.

Electromagnetic Radiations

According to Newton, light was regarded as stream of particles also known as corpuscles of light. This is particle nature of light. This failed to explain the phenomenon of interference and diffraction and so it was replaced by wave theory given by C. Huygens.

Thus, light radiations are regarded as having dual nature i.e., wave nature as well as particle nature.

In 1856, James Clark Maxwell stated that X-rays, Y-rays and heat etc. emit energy continuously in the form of radiations or waves and the energy is called radiant energy. These waves are associated with electrical and magnetic fields and are, therefore known as electromagnetic waves (or radiations).

Radiations: It is defined as, the emission and transmission of energy through space in the form of waves.

Electromagnetic radiations: Those radiations which are associated with electric and magnetic field are called electromagnetic radiations. All of them move with same speed regardless of their wavelength.

They travel at 3×10^8 m / s which is called speed of light. It is denoted by 'c'.

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Frequency: It is defined as, the number of waves passing through a point in one second. It is denoted by 'v' (nu). The unit of frequency is s^{-1} or hertz (cycles/second). It is related to velocity and wavelength by formula.

$$v = \frac{c}{\lambda}$$

Where C is velocity of light ($2.9979 \times 10^8 \text{ m s}^{-1}$) taken as $3 \times 10^8 \text{ m s}^{-1}$, ' λ ' is wavelength.

Wavelength: It is the distance between centre of two adjacent crests or troughs. It is denoted by (λ) and the unit is metre or nm (nanometre). ($1 \text{ nm} = 10^{-9} \text{ m}$, $1 \text{ pm} = 10^{-12} \text{ m}$).

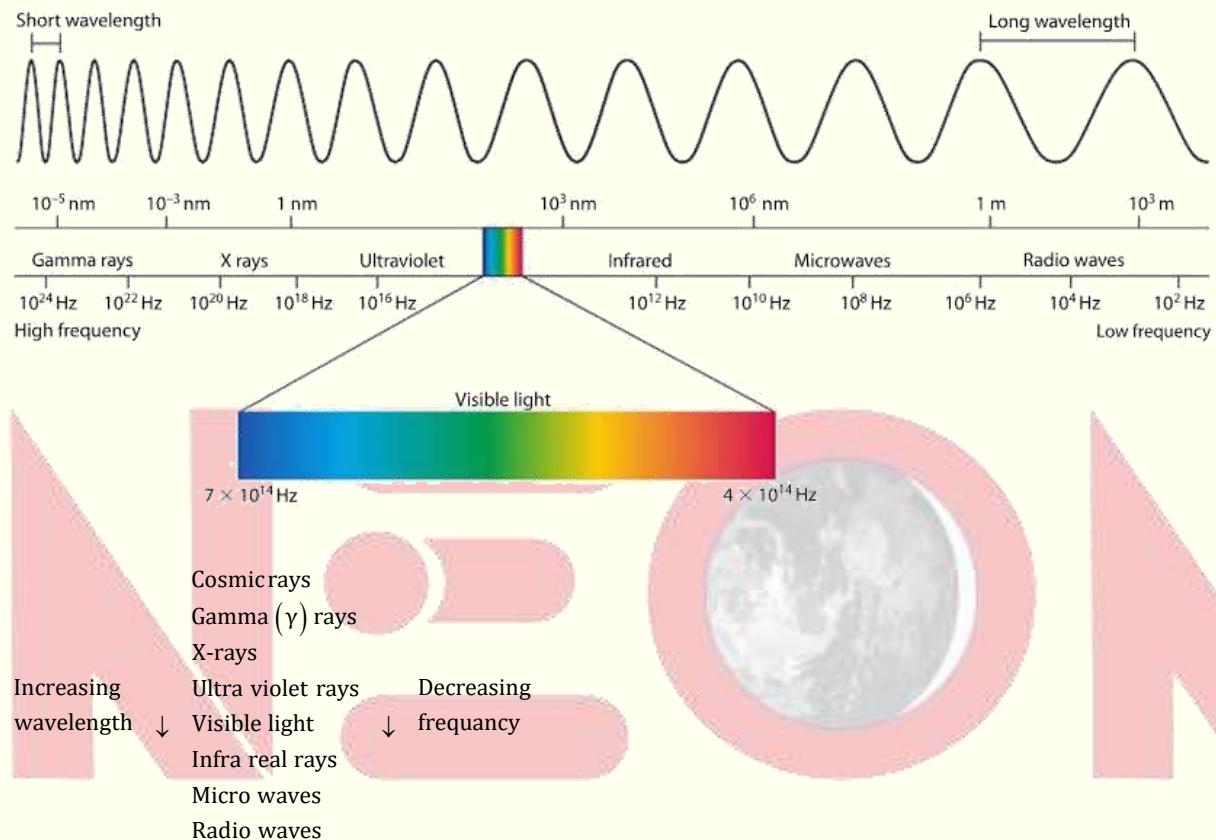
Wave number: It is the reciprocal of wavelength. It is defined as, the number of waves in 1 cm or 1 m length i.e., per unit length. It is denoted by u .

$$u = \frac{1}{\lambda} \text{ m}^{-1} \text{ or } \text{cm}^{-1}$$

Amplitude: The height of crest or depth of trough is called amplitude of wave.

Electromagnetic Spectrum

The visible light in the presence of which our eye can see contains radiations having wavelengths between $3800 - 7600 \text{ \AA}$. In addition to visible light there are so many other electromagnetic radiations, such as cosmic rays, gamma rays, X-rays, ultraviolet rays, infrared rays, micro waves and radio waves. Arrangement of all the electromagnetic radiations in the increasing order of their wavelength or decreasing order of their frequency is called electromagnetic spectrum.



Spectrum It is the combination of lights of different wave lengths.

When light passes through a prism, a series of colour bands is obtained. It is called visible spectrum. Visible spectrum ranges from $8 \times 10^{14} \text{ Hz}$ (violet light) to $4 \times 10^{14} \text{ Hz}$ (red light).



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Continuous spectrum: The combination of lights of different frequency in continuous manner is called continuous spectrum e.g., visible spectrum. A similar spectrum is produced when a rainbow appears in the sky.

Cause of spectrum: When electromagnetic radiations interact with matter, energy is exchanged and atoms and molecules may absorb this energy and electrons get excited to higher energy levels. When such electrons (i.e., excited electrons) come back to lower energy level, they emit radiations belonging to different parts of electromagnetic spectrum.

Absorption spectrum: It is like photographic negative of emission spectrum. A continuous beam of radiations is passed through a sample which absorbs radiations of certain wavelengths. The missing wavelengths which correspond to the radiations absorbed by the matter levels dark spaces in bright continuous spectrum. It is called absorption spectrum.

Atomic Spectrum

When an element is excited by some methods such as by heating, by passing electric current or bypassing electric discharge, the atoms of the element emit electromagnetic radiations of definite frequencies. The arrangement of these radiations in the order of increasing wavelength or decreasing frequencies is called atomic spectrum.

The instrument used for obtaining a spectrum is called spectroscope. In the spectroscope light is passed through a prism and the emergent light is observed. When we pass a beam of radiations having different frequencies through a prism, these radiations undergo unequal deviation and get arranged in order of decreasing frequencies. This phenomenon of splitting of a beam of light into radiations of different frequencies after passing through the prism is called dispersion.

In case of dispersion of sunlight, the seven colours obtained change from violet to red without any discontinuity. Such a spectrum is called continuous spectrum.

On the other hand, atomic spectra of most of the elements consists of a number of bright lines separated by dark bands. That is why atomic spectrum is also known as line spectrum. The lines in the line spectrum of an element are characteristic of the atoms of the element. Therefore, atomic spectrum of an element can be used to identify the element and is sometimes called fingerprint of its atoms.

The atomic spectrum of hydrogen can be obtained by passing the light being emitted from the discharge tube containing hydrogen at low pressure, through the spectrograph.

The spectrum obtained consists of a large number of sharp lines. Lines in the emission spectrum of hydrogen are present in ultraviolet, visible and infrared regions. Actually it has only four lines that can be seen by eyes, however many more can be observed photographically in U.V. region.

Balmer formula: In 1885, Balmer showed that the wave number \bar{u} of any line in the visible spectrum of atomic hydrogen could be given by simple empirical formula:

$$\bar{u} = R \left(\frac{1}{2^2} - \frac{1}{n^2} \right), R = 1.09677 \times 10^7 \text{ m}^{-1}$$

Where R is Rydberg constant and n has values 3, 4, 5, ...

Lyman series: When excited electrons in hydrogen atoms fall from higher energy levels to first energy level, the series of lines observed are called Lyman series. They are observed in ultraviolet region.

$$\text{Lyman } \bar{u} = R \left(\frac{1}{1^2} - \frac{1}{n^2} \right), n = 2, 3, 4, 5, \dots$$

Balmer series: When excited electrons in hydrogen atoms fall from higher energy levels to second energy level, the series of lines observed are called Balmer series. These lines are observed in visible region.

$$\text{Balmer } \bar{u} = R \left(\frac{1}{2^2} - \frac{1}{n^2} \right), n = 3, 4, 5, 6, \dots$$

Paschen series: When excited electrons in hydrogen atoms fall from higher energy levels to third energy level, we observe Paschen series. They are observed in infrared region.

$$\text{Paschen } \bar{u} = R \left(\frac{1}{3^2} - \frac{1}{n^2} \right), n = 4, 5, 6, 7, \dots$$

Brackett series: When excited electrons in hydrogen atoms fall from higher energy levels to fourth energy level, we observe Brackett series. They are also observed in infrared region.

$$\text{Brackett } \bar{u} = R \left(\frac{1}{4^2} - \frac{1}{n^2} \right), n = 5, 6, 7, 8, \dots$$

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Pfund series: When excited electrons in hydrogen atoms fall from higher energy levels to fifth energy level, Pfund series are observed. They are also found in infrared region of spectrum.

$$\text{Pfund } \bar{u} = R \left(\frac{1}{5^2} - \frac{1}{n^2} \right), n = 5, 6, 7, 8 \dots$$

Rydberg formula:

$$\bar{u} = R_H \left[\frac{1}{n_1^2} - \frac{1}{n_2^2} \right], n = 6, 7, 8, 9, \dots$$

where \bar{u} is wave number, ' λ ' is wavelength, R_H is Rydberg constant, n_1 is lower energy level, n_2 is higher energy level.

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Planck's Quantum Theory

The amount of energy associated with a quantum of radiation is proportional to the frequency of radiation is expressed as

$$E \propto v \text{ or } E = hv = \frac{hc}{\lambda} = h\nu$$

where h is a constant known as Planck's constant and is equal to 6.625×10^{-34} joule-sec.

A body can emit or absorb energy only in terms of the integral multiples of quantum.

Thus, a body can emit or absorb energy as hv , $2hv$, $3hv$, $4hv \dots nhv$ but it cannot emit or absorb energy such as $1.6 hv$ or $3.2 hv$.

Bohr's Theory

(i) An electron did not radiate energy if it stayed in one orbit and therefore did not slow down.

(ii) When an electron moved from one orbit to another, it either radiated or absorbed energy. If it is moved towards nucleus, energy is radiated.

Bohr's Model of Atom

In order to overcome the short comings of the Rutherford's model. Neils Bohr (1913) proposed a new model of the atoms based upon quantum theory of radiations. Main points of this model are:

1. The electrons in an atom revolve around the nucleolus only in certain selected circular orbits. These orbits are associated with definite energies and are called energy shells or energy levels. These are numbered 1, 2, 3, 4 ... etc., or designated as K, L, M, N, etc. shells.

■ 10 ■



2. Only those orbits are permitted in which the angular momentum of the electron is a whole number multiple of $\frac{h}{2\pi}$, where h is Planck's constant.

$$mv r = n \frac{h}{2\pi}, \text{ where } n = 1, 2, 3 \dots \text{ no. of orbit.}$$

i.e., angular momentum is quantized.

Success of Bohr's Model (Postulates of Bohr)

- (i) It could explain the stability of the atom.
- (ii) Bohr's theory helped in calculating energy of an electron in a particular orbit of hydrogen atom or hydrogen-like atoms.

Energy of an electron in n^{th} orbit of hydrogen and hydrogen-like atoms.

$$E_n = -\frac{1312z^2}{n^2} \text{ kJ/mol}$$

Radius of n^{th} orbit for hydrogen and hydrogen-like atoms.

$$\frac{n^2}{Z} \times 0.529 \times 10^{-10} \text{ m}$$

Radius of first orbit in hydrogen atom can be calculated as:

$$r_n = \frac{n^2}{Z} \times 0.529 \times 10^{-10} \text{ m}$$

$$r_{1(H)} = 0.529 \times 10^{-10} \text{ m} \quad [\because n = 1, Z = 1]$$

$$= 0.529 \text{ \AA}$$

- (iii) Bohr's Model could explain the atomic spectrum of hydrogen.



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Dual Nature of Matter: de Broglie Equation

Louis de Broglie (1924) proposed that just as radiations have particle nature, the material particles are also associated with wave nature. He also gave a relation for calculating the wavelength of the wave associated with a particle of mass m moving with velocity v as given under

$$\lambda = \frac{h}{mv} = \frac{h}{p}$$

Where h is Planck's constant and p is the momentum of the particle. 'λ' is wavelength. This relationship has been verified by an experiment.

Heisenberg's Uncertainty Principle

It is not possible to determine the exact position of the simultaneously for a sub-atomic particle like electron at any given instant to an arbitrary degree of precision. Consequently, it is not possible to determine the path of the electron in which it moves. If 'Δx' is uncertainty in position and 'Δv' is uncertainty in velocity, then

$$\Delta x \cdot \Delta v \geq \frac{h}{4\pi m}$$

Where, 'h' is Planck's constant, 'm' is mass and $\pi = 3.142$ or $\frac{22}{7}$.

Wave function (Ψ): The amplitude of the wave associated with a particle as obtained from the Schrodinger wave equation. The wave function is a mathematical expression, a function of the position of the particle. Its physical significance is that the square of the value of Ψ at any point, $|\Psi|^2$ is proportional to the probability of finding the particle at that point.

Orbital: It is the region or space where there is maximum probability of finding the electron.

Quantum Numbers

In order to characterise an electron in an atom, a set of four numbers known as quantum numbers, is required. These four quantum numbers are principal quantum number, azimuthal quantum number, magnetic quantum number and spin quantum number.

1. The Principal Quantum Number (n)

This quantum number determines to a large extent the energy of an electron and the average distance of an electron from the nucleus. It is denoted by the letter n. Size of the orbital is determined by this quantum number. It can have any whole number values such as 1, 2, 3, 4 ..., etc. The energy levels or energy shells corresponding to these numbers are designated as K, L, M, N, etc. As the value of n increases, the electron gets farther away from the nucleus and its energy increases.

2. The Azimuthal Quantum Number or Angular Quantum Number (l)

This quantum number determines angular momentum of the electron. This is denoted by l. This quantum number determines the shape of the orbital in which the electron is located. l may have all possible whole number values from 0 to n - 1 for each principal energy level. The various sub-level are designated as s, p, d, f depending upon the value of l as shown below :

Value of l →	0	1	2	3
Subshell →	s	p	d	f

For n = 1, l can have only one value i.e., 0. It means that first energy level has only one sub shell, i.e. 1s

For n = 2, l can have values 0 and 1. It means that second energy level has only two sub shells, i.e., 2s and 2p.

For n = 3, possible values of l are 0, 1 and 2. This implies that third energy level has three sub shells, i.e., 3s, 3p and 3d. Similarly, fourth energy level (n = 4) can have four sub shells i.e., 4s, 4p, 4d and 4f.

3. The Magnetic Quantum Number (m)

This quantum number which is denoted by m refers to the different orientations of electron cloud in a particular subshell. These different orientations are called orbitals. The possible values of m range from -l through 0 to +l, thus making a total of $(2l + 1)$ values.

For l = 0 (i.e., s-sub shell), m can have only one value, m = 0. It means that s-sub shell has only one orbital.

For l = 1 (i.e., p-sub shell), m can have three values, -1, 0 and +1. This implies that p-sub shell has three orbitals.

For l = 2 (i.e., d-sub shell), m can have five values, -2, -1, 0, +1, +2. It means that d-sub shell has five orbitals.



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For $l = 3$ (i.e., f-sub shell), m can have seven values, -3, -2, -1, 0, +1, +2, +3. It means that f-subshell has seven orbitals.

4. The Spin Quantum Number

The quantum number which is denoted by s

This quantum number tells us about the spin of the electron. This spin can be either clockwise or anticlockwise. The spin quantum number can have only two values which are $+\frac{1}{2}$ and $-\frac{1}{2}$.

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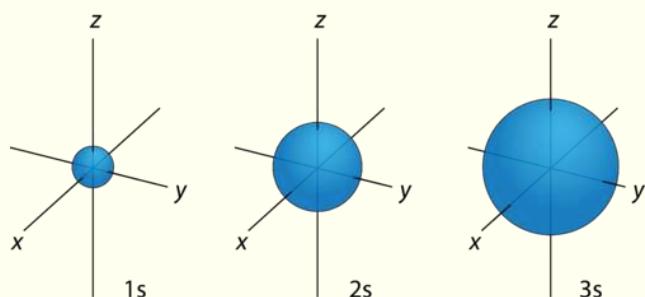
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Shape of orbitals

For s-orbitals: The probability of finding the electron is same in all directions at a particular distance. s-orbitals are spherically symmetrical.

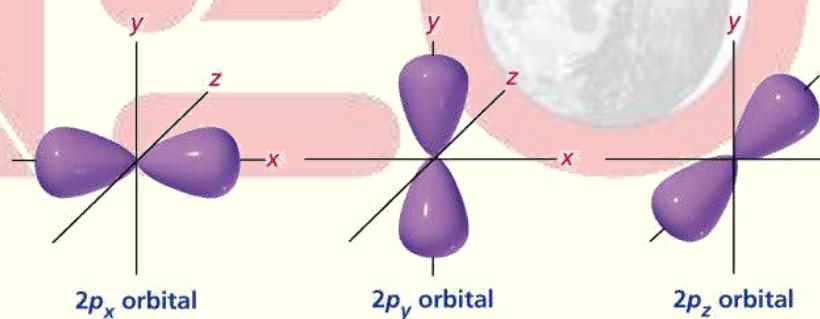


Node is the point of zero probability

Node → Zero probability points

- (i) In the ns-orbital, the total number of nodes is $(n - 1)$.

For p-orbitals: There are three possible orientations of electron cloud. These three orientations or orbitals of a p-subshell are designated as p_x , p_y and p_z . p_x , p_y and p_z orbitals are oriented along x-axis, y-axis and z-axis respectively. Each p-orbital has two lobes which are separated by a point of zero probability called node. Each p-orbital is thus, dumb-bell shaped.



For d-orbital: d-orbitals are present in the d-shell for which $l = 2$ and $m = -2, -1, 0, +1, +2$. This means that there are five orientations leading to five different orbitals. The shape of d-orbital is double dumb-bell.

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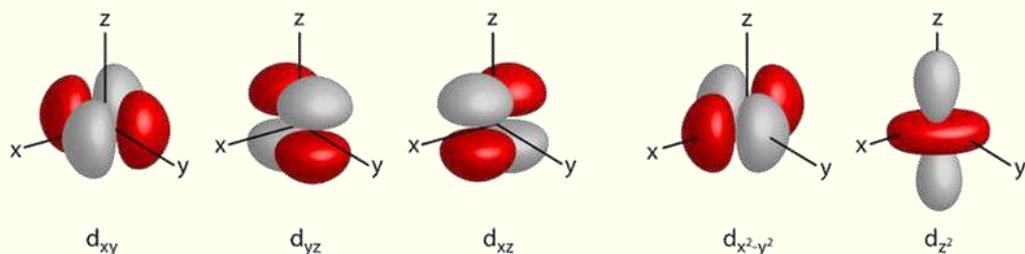


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Filling of Electrons in Orbitals

Ground state or Normal state: The state of an atom when all the electrons occupy their lowest energy levels as required by their n and l values is called ground state or normal state.

Excited state: If the electrons occupy a higher position than the permitted values, the state of the atom is considered as excited state.

Rules for Filling up of Electrons

- **Pauli's Exclusion Principle**

No two electrons in an atom can have all the four quantum numbers same.

Any orbital can have a maximum of two electrons and these two must have opposite spins.

Some important points about distribution of electron on the basis of quantum number:

The maximum number of electrons in each principal energy shell is $2n^2$.

The maximum number of orbitals in each principal energy shell is n^2 .

s-subshell has only one orbital with maximum of two electrons

p-subshell has three orbitals with maximum of six-electrons

d-subshell has five orbitals with maximum of ten electrons

f-subshell has seven orbitals with maximum of fourteen electrons.

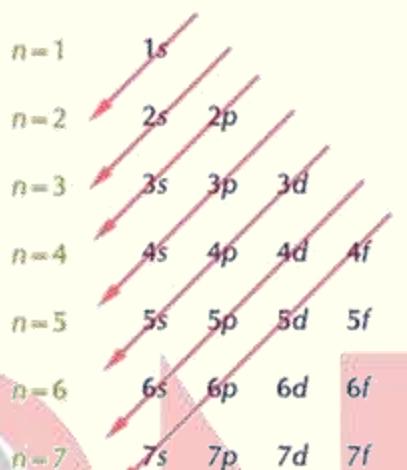
- **Aufbau Principle**

According to it, "the electrons are added progressively to the various orbitals in increasing order of energies starting from the orbital of lowest energy."

The increasing order of energies of various orbitals is 1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s, 4d, 5p, 6s, 4f, 5d, 6p, 7s ...

The energy level diagram for multi electron atom is according to Aufbau principle.

1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p < 5s < 4d < 5p < 6s < 4f < 5d < 6p < 7s > 5f < 6d < 7p is sequence of orbitals in which electrons are filled.



- **Hund's rule of Maximum Multiplicity**

No electron pairing takes place in s, p, d and f-orbitals until each orbital in the given subshell contains one electron having parallel spin, e.g., N(7) has electronic configuration $1s^2, 2s^2 2p_x^1 2p_y^1 2p_z^1$ according to Hund's rule and not $1s^2 2s^2 2p_x^2 2p_y^1$

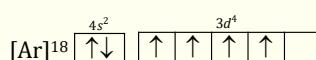
Rules for getting sequence of filling the orbitals with electrons

- **Bohr Bury's Rules**

- Orbitals fill in order of increasing value of $(n + l)$
- If two orbitals have the same value of $(n + l)$, the one with lower 'n' will be filled first.

Chromium ($Z = 24$)

Expected configuration:



Actual configuration :

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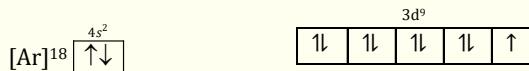
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Copper (Z = 29)

Expected configuration:



Actual configuration



The reason for exceptional configuration is based on the concept of system. The stability of the atom is linked with symmetry of the electronic configuration. The half-filled and fully filled configuration are more symmetrical and the symmetry leads to greater stability.

1 to 30 'Electronic Configuration'

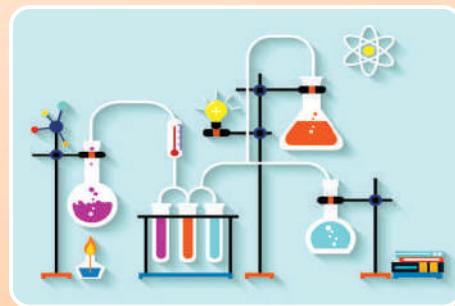
Atomic Number	Name of the Element	Electronic Configuration
1	Hydrogen (H)	1s ¹
2	Helium (He)	1s ²
3	Lithium (Li)	[He] 2s ¹
4	Beryllium (Be)	[He] 2s ²
5	Boron (B)	[He] 2s ² 2p ¹
6	Carbon (C)	[He] 2s ² 2p ²
7	Nitrogen (N)	[He] 2s ² 2p ³
8	Oxygen (O)	[He] 2s ² 2p ⁴
9	Fluorine (F)	[He] 2s ² 2p ⁵
10	Neon (Ne)	[He] 2s ² 2p ⁶
11	Sodium (Na)	[Ne] 3s ¹
12	Magnesium (Mg)	[Ne] 3s ²
13	Aluminum (Al)	[Ne] 3s ² 3p ¹
14	Silicon (Si)	[Ne] 3s ² 3p ²
15	Phosphorus (P)	[Ne] 3s ² 3p ³
16	Sulfur (S)	[Ne] 3s ² 3p ⁴
17	Chlorine (Cl)	[Ne] 3s ² 3p ⁵
18	Argon (Ar)	[Ne] 3s ² 3p ⁶
19	Potassium (K)	[Ar] 4s ¹
20	Calcium (Ca)	[Ar] 4s ²
21	Scandium (Sc)	[Ar] 3d ¹ 4s ²
22	Titanium (Ti)	[Ar] 3d ² 4s ²
23	Vanadium (V)	[Ar] 3d ³ 4s ²
24	Chromium (Cr)	[Ar] 3d ⁵ 4s ¹
25	Manganese (Mn)	[Ar] 3d ⁵ 4s ²
26	Iron (Fe)	[Ar] 3d ⁶ 4s ²
27	Cobalt (Co)	[Ar] 3d ⁷ 4s ²
28	Nickel (Ni)	[Ar] 3d ⁸ 4s ²
29	Copper (Cu)	[Ar] 3d ¹⁰ 4s ¹
30	Zinc (Zn)	[Ar] 3d ¹⁰ 4s ²

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Chemistry

Chapter - 03

(*Periodic Table*)



- ♦ *Concepts with Visual Understanding*
- ♦ *Daily life uses of Chemistry*
- ♦ *Core Chemistry (Detailed Theory)*



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Periodic Table

Modern Periodic table has completed 150th anniversary in 2019 as it was made in 1869.

Total = 118 elements (Atomic No. 118 – Oganesson (Og)

119 is a hypothetical element

First periodic table was given by – Mendeleev (on basis of atomic weight)

Modern periodic table was given by – Henry Moseley (on basis of atomic number)

Modern periodic table was proposed by – Neil's Bohr



1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
H Hydrogen 1.00724	Be Beryllium 9.012182	Ds Darmstadtium (271) 2-8-18-32-32-17-1	Li Lithium 6.941	Na Sodium 22.9897692	Mg Magnesium 24.309	Other nonmetals	Alkali metals	Alkaline earth metals	Halogens	Transition metals	Post-transition metals	Noble gases	B Boron 10.811	C Carbon 12.0107	N Nitrogen 14.0067	O Oxygen 15.9994	F Fluorine 18.998422	He Helium 4.0026018
K Potassium 39.0961	Ca Calcium 40.078	Sc Scandium 44.95961	Ti Titanium 47.887	V Vanadium 50.9415	Cr Chromium 51.981	Mn Manganese 54.93891	Fe Iron 55.845	Co Cobalt 58.931195	Ni Nickel 58.684	Cu Copper 63.546	Zn Zinc 65.38	Ga Gallium 69.723	Ge Germanium 72.64	As Arsenic 74.9166	Se Selenium 78.94	Br Bromine 79.904	Ne Neon 20.1797	
Rb Rubidium 85.4678	Sr Strontium 87.62	Y Yttrium 88.90085	Zr Zirconium 91.224	Nb Niobium 92.9068	Mo Molybdenum 95.96	Tc Technetium 97.9772	Ru Ruthenium 101.07	Rh Rhodium 102.9036	Pd Palladium 104.42	Ag Silver 107.8652	Cd Cadmium 112.411	In Indium 114.818	Sn Antimony 119.718	Sb Antimony 121.76	Te Tellurium 137.46	I Iodine 126.90447	Xe Xenon 131.313	
Cs Cesium 132.90541919	Ba Barium 137.327	La-Lu Lanthanides (151)	Hf Hafnium 178.49	Ta Tantalum 180.5478	Re Rhenium 186.207	Os Osmium 190.23	Ir Iridium 192.221	Pt Platinum 191.034	Au Gold 196.99639	Hg Mercury 200.59	Tl Thallium 204.3033	Pb Lead 207.2	Bi Bismuth 208.9846	Po Polonium 208.9846	At Astatine 210.9870	Rn Radon 222.9871		
Fr Francium (220)	Ra Radium (226)	Ac-Lr Actinides (88)	Rf Rutherfordium (261)	Db Dubnium (262)	Sg Seaborgium (263)	Bh Berkelium (264)	Hs Hassium (265)	Mt Meitnerium (268)	Ds Darmstadtium (271)	Rg Roentgenium (272)	Cn Copernicium (285)	Uut Ununtrium (289)	Fl Flameium (289)	Uup Ununpentium (288)	Lv Livermorium (293)	Uus Ununseptium (294)	Uuo Ununoctium (295)	

For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

La Lanthanum 138.90547	Ce Cerium 140.115	Pr Praseodymium 140.90765	Nd Neodymium 144.242	Pm Promethium (145)	Sm Samarium 151.94	Eu Europium 151.94	Gd Gadolinium 157.25	Tb Terbium 158.9233	Dy Dysprosium 160.5	Ho Holmium 164.9232	Er Erbium 167.23	Tm Thulium 166.93421	Yb Ytterbium 173.054	Lu Lutetium 174.9858
Ac Actinium (227)	Th Thorium 232.03806	Pa Protactinium 231.03898	U Uranium 238.02891	Np Neptunium (237)	Pu Plutonium (244)	Am Americium (243)	Cm Curium (247)	Bk Berkelium (247)	Cf Californium (247)	Es Einsteinium (247)	Fm Fermium (247)	Md Mendelevium (246)	No Nobelium (249)	Lr Lawrencium (262)

Non-Metals = 17

There are a total of definitely at least 17 non-metals in the periodic table, which are as follows:

1. Hydrogen (Z=1)
2. Helium (Z=2)
3. Carbon (Z=6)
4. Nitrogen (Z=7)
5. Oxygen (Z=8)
6. Fluorine (Z=9)
7. Neon (Z=10)
8. Phosphorous (Z=15)
9. Sulphur (Z=16)
10. Chlorine (Z=17)
11. Argon (Z=18)
12. Selenium (Z=34)(Disputed)
13. Bromine (Z=35) (Only liquid non metal)
14. Krypton (Z=36)
15. Iodine (Z=53)
16. Xenon (Z=54)
17. Radon (Z=86)

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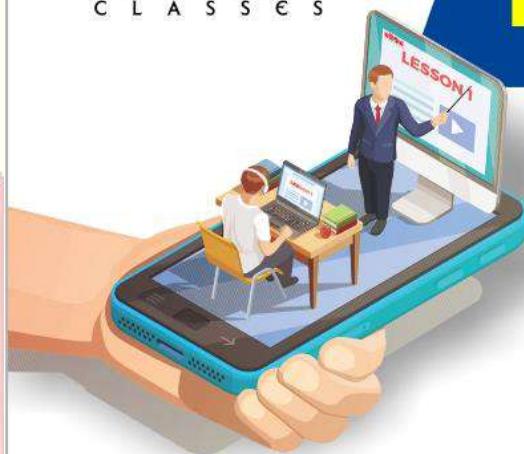
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Periodic table

It is the arrangement of the known elements in certain groups in such a way that elements with similar properties are grouped together in a tabular form.

Historical Developments

At present 118 elements are known (however the identity of elements with atomic numbers 113, 115 and 117 is not yet fully established).

Lavoisier classified elements into metals and non-metals.

Dobereiner's Law of Triads :

In 1817, Dobereiner, a German Chemist, arranged elements with similar properties in group of three in such a way that the atomic mass of the middle element was nearly the same as the average atomic masses of the first and third elements. A few triads proposed by him are listed below.

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Element	Atomic mass	Element	Atomic mass	Element	Atomic mass
Li	7	Ca	40	Cl	35.5
Na	23	Sr	88	Br	80
K	39	Ba	137	I	127

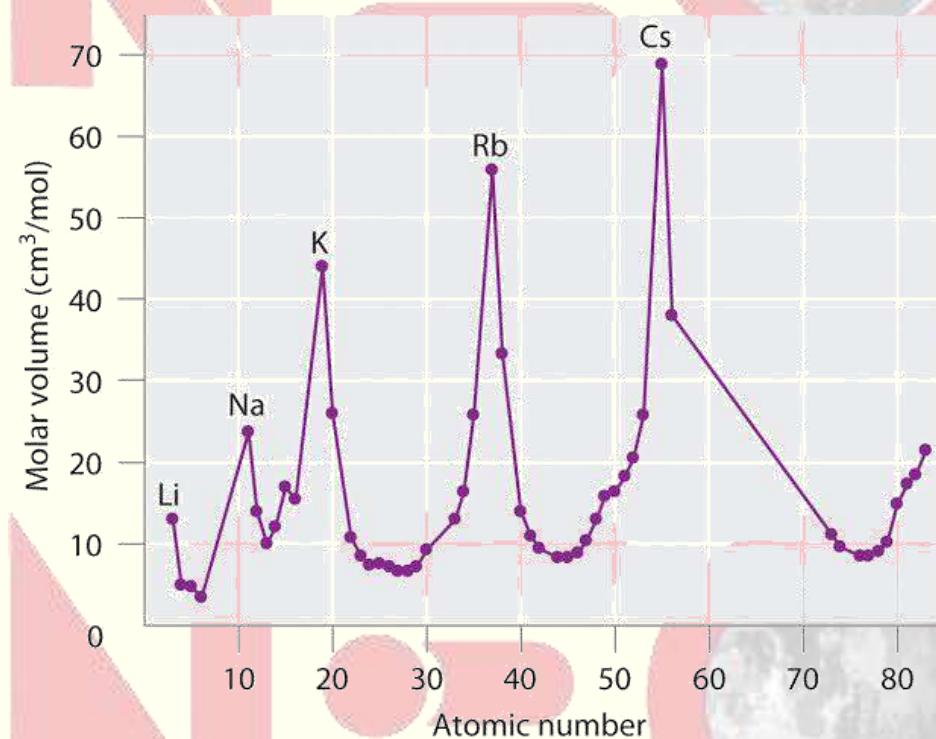
Limitation: He could not classify all the elements, known at that time, into trials.

Newland's Law of Octaves: In 1865, John Newlands, arranged the elements, in increasing order of their atomic weights and found that any given element has similar properties to the eighth element that followed it. The relationship was same as that existing between musical notes and its octaves.

Li	Ba	B	C	N	O	P
Na	Mg	Al	Si	P	S	Cl
K	Ca					

Limitations: He could not classify all elements known at that time.

Loether Meyer's Atomic Volume Curve: Loether Meyer, in 1869 plotted a graph between atomic volumes (atomic mass/density) of the elements and their atomic masses



He pointed that the elements with similar properties occupy similar positions in the curve. For example,

- The most electropositive elements called as alkali metals (Li, Na, K, Rb, Cs) occupy the peaks on the curve.
- Comparatively less electropositive elements known as alkaline earth metals (Be, Mg, Ca, Sr, Ba) occupy the descending positions on the curve.

(iii) Similarly, the most electronegative elements called as halogens (F, Cl, Br, I) occupy the ascending positions on the curve.

On the basis of his observations, Lothar Meyer pointed out that there is a definite relationship between the physical properties of the elements and their atomic masses. These are, rather, a periodic function of their atomic masses, which means that these properties get repeated after a definite interval (or period) of atomic masses.

Note: A plot of atomic volume and atomic number also follows the same pattern.

Mendeleev's Periodic Law: The law was given by Mendeleev. According to him, "The physical and chemical properties of the elements are a periodic function of their atomic masses".

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Periodic Table of Elements Based on Mendeleev's Periodic Law

I	II	III	IV	V	VI	VII	VIII
0 H 1.01							
He 4.00	Li 6.94	Be 9.01	B 10.8	C 12.0	N 14.0	O 16.0	F 19.0
Ne 20.2	Na 23.0	Mg 24.3	Al 27.0	Si 28.1	P 31.0	S 32.1	Cl 35.5
Ar 40.0	K 39.1	Ca 40.1	Sc 45.0	Ti 47.9	V 50.9	Cr 52.0	Mn 54.9
	●Cu 63.5	Zn 65.4	Ga 69.7	Ge 72.6	As 74.9	Se 79.0	Fe 55.9
Kr 83.8	Rb 85.5	Sr 87.6	Y 88.9	Zr 91.2	Nb 92.9	Mo 95.9	Co 58.9
	●Ag 108	Cd 112	In 115	●Sn 119	Sb 122	Te 128	Ni 58.7
Xe 131	Ce 133	Ba 137	●La 139	Hf 179	Ta 181	W 184	Ru 101
	●Au 197	●Hg 201	Tl 204	●Pb 207	Bi 209	Po (210)	Rh 103
Rn (222)	Fr (223)	Ra (226)	●Ac (227)	●Th 232	●Pa (231)	●U 238	Pd 106
							Pt 195

● Lanthanide series

● Actinide series

● Known to Ancients

Dobereiner's triads

Known to Mendeleev

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Mendeleev is called the "Father of periodic table" because of his contribution in arrangement of elements in the form of periodic table.

The main characteristics of Mendeleev's periodic table are

- The elements are arranged in vertical columns called groups and horizontal rows called periods.
- There are nine groups indicated by Roman numerals as I, II, III, IV, V, VI, VII, VIII and zero.
- The elements of first seven groups have been divided into sub-groups designated as 'A' and 'B' on the basis of similarity in properties. Group VIII consists of triads of elements (contains total 9 elements).The zero group contains inert gases or noble gases and their valency is zero. Zero group was added to the periodic table at a very late stage.
- There are seven periods (numbered 1, 2, 3, 4, 5, 6, 7) to accommodate more elements. Periods 4, 5, 6 and 7 are divided into two halves. The first half of the elements are placed in the upper left corner and second half occupy lower right corner in each of these periods.

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Periods 1, 2, 3 are short periods
There are only two elements in first period.

These are long Periods
(Period 4, 5, 6) There are eighteen elements in fourth and fifth period.

There are thirty two elements in sixth period.

The longest period is sixth because seventh is still incomplete.

Importance of Mendeleev's Periodic Table

- (i) It made the study of elements systematic.
- (ii) It helped in prediction of new elements and their properties.
- (iii) It helped in correction of doubtful atomic masses.

Defects in Mendeleev's Periodic Table

- (i) Position of hydrogen is controversial.
- (ii) Anomalous position of some elements. In some cases the elements with higher atomic masses precessed the elements with lower atomic masses e.g. Ar (39.9) precessed K (39.1); Co (58.9) precessed Ni (58.7).
- (iii) Isotopes (atoms of same elements with different atomic masses) have been placed together.
- (iv) There is no correlation of elements in sub-groups. The properties of elements in sub-group 'A' differ from those in sub-group 'B' of the same group.
- (v) In some cases elements with similar properties have been placed in different groups e.g., copper and mercury.
- (vi) Lanthanides and actinides have not been provided a proper place.
- (vii) No proper explanation was afforded for cause of periodicity.

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Modern Periodic Law

In 1913, Moseley gave the modern periodic law. It states, "The physical and chemical properties of the elements are the periodic function of their atomic numbers."

Cause of Periodicity

Periodicity refers to the repetition of similar properties of the elements placed in a group and separated by certain definite gaps of atomic numbers.

The periodicity in properties of elements placed in any group is due to repetition of the same valence shell electronic configuration after a certain definite gap of atomic numbers (magic numbers) such as 2, 8, 8, 18, 18, 32.

Long form of Periodic Table

It is the latest form of periodic table. It contains 7 periods and 18 groups numbered 1, 2, 3, 18 (IUPAC).

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Group →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Period ↓	1	H																He	
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne	
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar	
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr	
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe	
6	55 Cs	56 Ba	57 La	*	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	89 Ac	*	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og
			*	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu		
			*	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr		

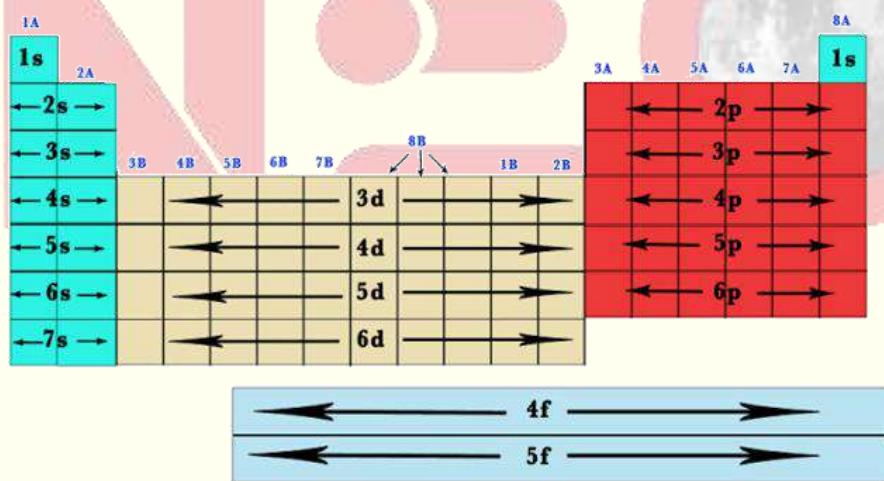
Characteristics of Groups

- (i) All the elements in a group have same general electronic configuration, e.g., alkali metals (ns^1), alkaline earth metals (ns^2).
- (ii) The elements in a group are separated by definite gap of atomic numbers (2, 8, 8, 18, 18, 32) called Magic numbers.
- (iii) The atomic size of the elements increases down the group.
- (iv) The physical properties such as melting and boiling points density, solubility, etc. follow a systematic pattern.
- (v) The elements in each group have generally similar chemical properties because these are related to the valence shell electronic configuration.

Characteristics of Periods

- (i) In all elements present in a period, the electrons are filled in the same valence shell.
- (ii) The size of atoms of elements generally decreases as we move from left to right in a period.
- (iii) The metallic character of the elements decreases as we move from left to right in a period.
- (iv) As the electronic configuration changes along the period, the chemical properties of the elements also changes.

Division of Periodic Table into different blocks.



■ 6 ■



s block elements

Those elements in which the last electron is filled in the valence S-subshell of outer most energy level. This block consists of two groups i.e., group 1 (alkali metals) and group 2 (alkaline earth metals).

General electronic configuration: ns^{1-2}
(where, n = 1 to 7)

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Characteristics of s-block elements: The general characteristics of the s-block elements are:

- (i) All the elements are soft metals.
- (ii) They have low melting and boiling points.
- (iii) They are highly reactive in nature.
- (iv) Most of them impart characteristic colours to the flame.
- (v) They form ionic compounds by losing their valence electrons and thus, show oxidation states of + 1 and + 2 in their compounds.
- (vi) They are good reducing agents.
- (vii) All of them are good conductors of heat and electricity.

p-block elements

In these elements the last electron is filled in the valence p-subshell. There are six groups in this block (group 13 to 18).

General electronic configuration: $ns^2 np^{1-6}$
(where n = 2 to 7)

Characteristics of p-block elements: The general characteristics of p-block elements are:

- (i) p-block elements include both metals and non-metals. In each group, the metallic character increases from top to bottom while in each period, the non-metallic character increases from left to right.

■7■



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- (ii) The compounds of these elements are mostly covalent in nature.
- (iii) Some of the elements show variable oxidation states.
- (iv) In every period, the reducing character of the elements decreases from left to right while the oxides of most of the elements are acidic in nature.

d-block elements

This block includes those elements in which the last electron enters the d-subshell of the last but one (penultimate) energy level. There are ten vertical columns or groups in the d-block from group 3 to 12.

General electronic configuration: $(n-1)d^{1-10} ns^{0-2} np^{1-6}$

(where n = 2 to 7)

The d-block elements are called the transition elements because the properties of these elements are midway between those of s and p-block elements. There are four transition series (or periods) in this block. The first three transition series have ten elements each while the fourth is incomplete.

Characteristics of d-block elements: The important characteristics of the d-block elements are listed below:-

- (i) They are all metals with high melting and boiling points.
- (ii) Most of the d-block elements form coloured compounds which are normally of complex nature.
- (iii) They show variable oxidation states.
- (iv) The compounds of the elements are generally paramagnetic in nature.
- (v) A large number of d-block elements such as Fe, Co, Ni, Mn, Cr, Pt, V, etc. act as catalysts.
- (vi) They also have tendency to form alloys with other metals.

f-block elements

In the elements of this block, the filling of the last electron takes place in the (n- 2) f-subshell. At the same time, (n - 1)d subshell may contain zero or one electron while ns-subshell is having two electrons.

General electronic configuration:

$(n-2)f^{1-14} (n-1)d^1 ns^2$

(where n = 6 to 7)

The f-block elements are also called inner-transition elements. There are two series of such elements each having fourteen elements. In the first series, the filling of electrons takes place in the 4f-subshell. It is known as lanthanide or lanthanoid series (atomic no. 57-71) since it follows lanthanum (La) of (d-block and a member of group 3). Similarly, in the second series, the filling takes place in the 5f-subshell. It is called actinide or actinoid series (atomic no. 89-103) as it follows actinium (Ac) of d-block, also belonging to group 3.

Characteristics of f-block elements: A few important characteristics associated with the f-block elements are:

- (i) The f-block elements are heavy metals.
- (ii) They have generally high melting and boiling points.
- (iii) Just like d-block elements, these elements also form complex salts and show variable oxidation states (+ 3 is the common oxidation state) in their compounds.
- (iv) The compounds of these elements are generally coloured.
- (v) Most of the elements of the actinide series are coloured.



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Classification of Elements

The elements present in the four different blocks of the periodic table can also be classified into the following:

- (a) **Noble gases:** These are the elements present in group 18. Actually each period ends with a noble gas element. The general electronic configuration of the elements is ns^2np^6 which means that they have completely filled valence 5 and p-orbitals (helium with ls^2 configuration is an exception). All the members are of gaseous nature and because of the completely filled orbitals, they have very little tendency to take part in chemical combination. These are also called inert gases.
- (b) **Representative elements:** These include both the s and p-block elements with the exception of noble gases. The general characteristics of these elements have been discussed already.
- (c) **Transition elements:** The transition elements include all the d-block elements and they are present in the centre of the periodic table between s and p-block elements. These have been divided into ten groups (3 to 12).

Locating the Position of an Element in the Periodic Table

The period, block and group to which a particular element belongs can be located with the help of the following guidelines.

The principal quantum number, of the valence shell represents the period of the element.

The subshell in which the last electron is filled corresponds to the block of the element.

Group of the element is predicted from the electrons present in the outermost (n) shell as follows :

For s-block elements: Group no. is equal to no. of ns electrons.

For p-block elements: Group no. is equal to $10 + \text{no. of } ns \text{ and } np \text{ electrons}$.

For d-block elements: Group no. is equal to sum of the no. of $(n - 1)$ d and ns electrons.

For f-block elements: Group no. is 3.

- (d) **Inner-transition elements:** The elements that belong to the f-block of the periodic table are known as inner transition elements because they form transition elements because they form transition series within the transition elements of d-block.

Advantages of Long Form of Periodic Table

- (i) The position of the elements in the periodic table is linked with their electronic configuration.
- (ii) Each group is an independent group and the idea of subgroups has been discarded.
- (iii) One position for all the isotopes of an element is justified, since the isotopes have the same atomic number.
- (iv) The division of the elements into s, p, d and f-block has been quite helpful in understanding their properties.



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- (v) Lanthanides and actinides are placed at the bottom of the periodic table because their properties are different from other groups.
- (vi) It is quite easy to remember and reproduce.

Defects in Long Form of Periodic Table

- (i) Hydrogen has been placed at the top of alkali metal because of its electronic configuration ($1s^1$). On similar basis, Helium($1s^2$) should have been included in group 2 of alkaline earth metals. But it is placed in group 18 of noble gases. Apart from this, hydrogen resembles halogens of group 17 in many characteristics.
- (ii) Lanthanides and actinides should have been accommodated in the main body of the periodic table. But these have been placed separately at the bottom of the periodic table.

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Periodic Trends in Properties of Elements

The properties of elements which are directly or indirectly related to the electronic configuration of their atoms and show gradation in moving down a group or along a period, are called **periodic properties**.

Such properties are valency, atomic radius, ionic radius, ionization energy (I.E.), electron affinity (E.A.), atomic volume, etc.

Some physical properties though not directly connected to electronic configuration but are linked with group of atoms and not with single atom, may also be considered as periodic properties, e.g., m.p., b.p., density, etc.

Atomic Radius

It is the most probable distance from the centre of the nucleus to the outermost shell of electrons.

- (a) **Covalent radius:** It is equal to half of the distance between the centres of the nuclei of two atoms held together by a purely covalent bond.
- (b) **van der Waals radius:** Noble gases do not have molecules, so it is not possible to measure covalent or ionic radius. Their atoms are held together by weak van der Waals forces of attraction. The van der Waals radius is half of the distance between the nuclei of two non-bonded neighbouring atoms of two adjacent molecules in the solid state.
- (c) **Metallic radius:** It is half the distance between centre of the nuclei of two adjacent atoms in the metallic crystal.

Note: The three radii are in the following order:

van der Waals radius > Metallic radius > Covalent radius.

Ionic Radius

It is the effective distance from the centre of nucleus of an ion up to which it exerts influence on the electron cloud.

■ 10 ■



Note:

- (i) The radius of cation is always smaller than that of the atom.
- (ii) The radius of anion is always larger than that of the parent atom.

Anionic radius > Atomic radius > Cationic radius.

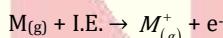
Isoelectronic species: Such species belong to different atoms or ions of elements which have same number of electrons but different magnitude of nuclear charge.

e.g. S²⁻, Cl⁻, K⁺.

Within the series of isoelectronic ions, the size of the ions decreases with increase in the magnitude of nuclear charge, e.g. Al³⁺< Mg²⁺< Na⁺< F⁻< O²⁻< N³⁻

Ionization Enthalpy

It is the energy required to remove an electron from an isolated gaseous atom in its ground state.



If gaseous atom is to lose more than one electrons, they can be removed only one after another i.e., in succession and not simultaneously. This is known as successive ionisation energy or potential:

I. E₃> I.E₂> I. E₁.

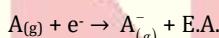
Factors on which I.E. depends

- (i) **Atomic size:** The ionization energy decreases with increase in atomic size.
- (ii) **Nuclear charge:** The ionization energy increases with increase in magnitude of nuclear charge.
- (iii) **Screening effect:** The reduction in force of attraction by the electrons of shells present in between the nucleus and valence electrons is called screening effect or shielding effect. Greater the number of intervening electrons between valence electron and nucleus, the greater will be shielding or screening effect and hence lower is the I.E.
- (iv) **Penetration effect:** Penetration power of various subshells of a particular energy levels is in the orders s > p > d > f. Therefore for the same shell it is easier to remove an electron from p-subshell than from s -subshell. Thus greater the penetration power higher is the I.E.
- (v) **Electronic configuration:** The elements having relatively stable electronic configuration have relatively higher values of ionization energy, e.g.

- (a) The noble gases having stable configuration (ns²np⁶) have highest ionisation energies within their respective periods.
- (b) The elements like N (1s²2s² 2p_x¹ 2p_y¹ 2p_z¹) and P (1s²2s²2p⁶3s² 3p_x¹3p_y¹3p_z¹) having configurations in which orbitals belonging to the same subshell are exactly half-filled are quite stable and so they have relatively high ionisation energies.
- (c) The elements like Be (1s²2s²) and Mg (1s²2s²2p⁶3s²) have all electrons paired. Such configurations being stable also result in higher value of I.E.

Electron Affinity

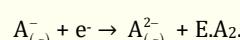
It may be defined as, the amount of energy released when an electron is added to an isolated gaseous atom of the element.



The energy released when an atom gains an electron is called electron gain enthalpy.

The larger value of electron affinity reflects greater tendency of an atom to accept the electron. The units of electron affinity are electron volt per atom or kilojoules per mole of atoms.

First electron affinity (energy release when first electron is added to gaseous atom) is positive for almost all elements. The energy change taking place when an electron is added to isolated monovalent anion (in ground state) is called second electron affinity (E.A.₂).



Similarly, A_(g)²⁻ + e⁻ → A_(g)³⁻ + E.A.₃

The second, third etc., electron affinities are called successive electron affinities.

Note: The successive electron affinities one always negative.

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Factors Affecting Electron Affinity

- (i) Nuclear charge: Greater the nuclear charge more will be the value of electron affinity.
- (ii) Atomic size: Larger the size of the atom, smaller will be the value of electron affinity.
- (iii) Electronic configuration: Stable the electronic configuration of an atom, lower will be its electron affinity.

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Electronegativity

It is the tendency of an atom of an element to attract the shared pair of electrons towards itself in a covalent bond. Greater the electronegativity of an atom, greater will be its tendency to attract the shared pair of electrons towards itself.

Factors Affecting Electronegativity

- (i) **Effective nuclear charge:** Greater the effective nuclear charge greater is electronegativity.
- (ii) **Atomic radius:** Smaller the atomic radius greater is the electronegativity.

Electropositivity

Tendency of atoms of an element to lose electrons and form positive ions is known as electropositivity.

Note: A more electropositive element has more metallic character.

Variation in Properties

Variation from Left to Right across a Period

1. **Atomic number:** Increases.
Reason: This is because of increase in the number of protons in the nucleus of atoms of the element as we move from left to right across a period.
2. **Atomic weight:** Generally increases.
Reason: This is because of increase in the number of protons and neutrons in the nucleus of atoms of the elements across a period.
Exception: (i) $^{39.95}\text{Ar}$ and $^{39.10}\text{K}$, (ii) $^{58.93}\text{Co}$ and $^{58.71}\text{Ni}$, (iii) $^{127.60}\text{Te}$ and $^{126.90}\text{I}$.
3. **Nuclear charge:** Increases.
Reason: This is because of continuous increase in the number of protons, i.e., positive charge in the nucleus of atoms of the elements on moving across a period.
4. **Effective nuclear charge:** Generally increases on moving from left to right across a period.
Exception: Effective nuclear charge decreases sharply from group 17 to 18 in a period.
5. **Number of valence electrons:** On moving from left to right across a period, the number of valence electrons increases from 1 to 8 except first period where the increase is from 1 to 2 only.
6. **Valeency:** On moving from left to right in each short period (2nd and 3rd), the valency with respect to oxygen increases from 1 to 7 (Na_2O to Cl_2O_7) while that with respect to hydrogen rises from 1 to 4 (NaH to SiH_4) and then falls to 1 (PH_3 to HC_1).
Exception: Group 18 elements (noble gases) on the extreme right of the table have got zero valency.
7. **Atomic Radius:** Generally, decreases because of increase in effective nuclear charge on moving from left to right across a period.



Raja Sir

Income Tax Inspector

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Explanation: From left to right across a period orbit number remain constant and effective nuclear charge increases progressively. Consequently relative pull (attractive force) of the nucleus on outermost electrons becomes more and more so atomic size decreases.

Exception:

- (i) Transition elements exhibit little variation in their atomic radii. This is due to poor shielding effect of d-electrons.
- (ii) Lanthanide series of elements also exhibit little variation in their atomic radii. This is due to lanthanide contraction.
- (iii) There is increase in atomic radius from group 17 to 18 because of sharp decrease in the value of effective nuclear charge from group 17 to 18.

8. **Ionic radius:** The variation of ionic radii follows the same trend as those of atomic radii for the same reason.

Note: Anionic radii > Atomic radii > Cationic radii.

9. **First ionisation energy (1st I.E.):** In general, 1st I.E. of elements increases across a period because of increase in effective nuclear charge and decrease in atomic radii from left to right in a period.

Explanation: As the effective nuclear charge increases and atomic size (radius) decreases across a period, attractive force of nucleus on outermost electrons becomes more, so energy required to remove the electron becomes greater and consequently ionisation energy increases from left to right across a period.

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Exceptions:

- (i) Transition metals series show a small variation in their I.E.

- (ii) I.E. (Be) > I.E. (B), I.E. (N) > I.E. (O), I.E. (Mg) > I.E. (Al), I.E. (P) > I.E. (S).

Note: I.E. 1st < I.E. 2nd < I.E. 3rd

10. **Electron affinity (E.A.):** Generally, increases owing to increase in effective nuclear charge and decrease in atomic size across a period.

Explanation: As the effective nuclear charge increases and atomic size decreases from left to right along a period, the attraction of added electron with the nucleus increases and consequently great amount of energy is released and E_A increases from left to right along a period.

Note: Electron affinity of noble gases is zero.

11. **Electronegativity (E.N.):** Generally increases from left to right along a period. Since both I.E. and E.A. increases along a period, electronegativity also increases.

$$\text{Reason: E.N.} = \frac{\text{I.E.} + \text{E.A.}}{5.6}$$

Exception: Noble gases do not exhibit electronegativity because of their stable outermost electronic arrangements.

12. **Atomic volume:** Generally, decreases from left to right in a period, provided physical state of elements remains same.

$$\text{Atomic volume} = \frac{4}{3} \pi r^3$$

Reason: Since atomic radius decreases from left to right in a period, atomic volume also decreases in the same direction.

■ 13 ■



13. **Electropositivity of elements:** Generally, decreases across periods.
Reason: It is because of increase in the I.E. of elements from left to right in a period.
14. **Metallic Character:** Decreases across a period.
Reason: It is because of decrease in atomic size and hence increase in the I.E. of elements along a period from left to right.
15. **Non-metallic character:** Increases along a period.
Reason: As electronegativity of elements increases from left to right in a period, non-metallic character also increases in the same direction.
16. **Basic nature of oxides:** Decreases from left to right in a period.
Reason: Since electropositivity and hence metallic character of elements decrease along a period, basic nature of their oxides naturally decreases.
17. **Acidic nature of oxides:** Increases from left to right in period.
Reason: Since electro negativity and hence non-metallic character increases along a period, therefore, acidic nature of their oxides naturally increases.
18. **Basic nature of hydroxides:** In general, it follows the same trend as that of basic nature of oxides for the same reason.
19. **Acidic nature of hydroxides:** In general, it follows the same trend as that of acidic nature of oxides for the same reason.
20. **Acidic nature of hydrides:** Generally, increases from left to right in a period.
21. **Basic nature of hydrides:** Generally, decreases.
Reason: Since acidic nature of hydrides increase from left to right in a period, basic nature of hydrides naturally decreases.
22. **Reducing power of hydrides:** Generally, decreases along a period.
Reason: This is owing to increase in the electro negativity of elements from left to right in a period.
Example: In the second period, LiH is the strongest reducing agent and HF is the weakest reducing agent.
23. **Reactivity of metals:** Generally, decreases from left to right in a period.
Reason: I.E. and E.A. increases in a period from left to right.

Variation from Top to Bottom in a Group.

1. **Atomic number:** Increases.
Reason: Increase in number of protons as, we move from one period to the next period.
2. **Atomic weight:** Increases.
Reason: This is because of increase in number of proton and neutrons with increase in atomic number.
3. **Nuclear charge:** Increases.
Reason: This is because of continuous increase in number of protons in the nucleus of atoms as we move from top to bottom.
4. **Effective nuclear charge:** Generally, increases on moving from top to bottom in a group.
5. **Number of valence electrons:** Remains same reason. The outermost configuration of all the elements in a group remains same.
6. **Valeency:** Remains same.
Atomic Radius: Increases.
Reason: The increase in size is due to extra energy shells added to the atoms in each period.
7. **Ionic Radius:** Increases.
Reason: In a particular group, the ions (cations or anions) increase in size from top to bottom due to increase in number of shells.
9. **First ionisation energy:** Decreases.
Reason: On moving in a group, the atomic size increases gradually due to addition of a new energy shell. The force of attraction of the nucleus towards. The valence electrons decreases which results in decrease in I.E.
10. **Electron affinity:** Decrease.
Reason: The electron gain enthalpy becomes less negative from top to bottom in a group.



Reason: Due to increase in size of the atom the force of attraction between nucleus and the outermost energy level decreases.

11. **Electronegativity:** Decreases.

Reason: As we move down in the group both I.E. and E.A. decreases hence the value of electron negativity decreases.

12. **Atomic volume:** Increases from top to bottom in a group.

Reason: Due to increase in atomic radius in a group.

13. **Electropositivity of elements:** Generally, increases

Reason: It is because of increase in atomic size and decrease in I.E. of elements in a group.

14. **Metallic character:** Increases.

Reason: Increase in electropositive nature of elements top to bottom in a group.

15. **Non-metallic character:** Decreases in a group.

16. **Basic nature of oxides:** Increases in a group.

Reason: Oxides of metals are generally basic in nature.

17. **Acidic nature of oxides:** Decreases from top to bottom.

Reason: Metallic character increases in a group.

18. **Basic nature of hydroxides:** Increases in a group.

19. **Acidic nature of hydroxides:** Decreases in a group.

20. **Acidic nature of hydrides:** Decreases from top to bottom a group.

21. **Basic nature of hydrides:** Generally, increases in a group.

22. **Reducing power of hydrides:** Generally, increases in a group due to increase in electro-positivity in a group.

23. **Reactivity of metals:** Increases in a group.

Reason: Reactivity increases in a group due to decrease in I.E. and E.A.

एक नये अंदाज, नए Concept के साथ

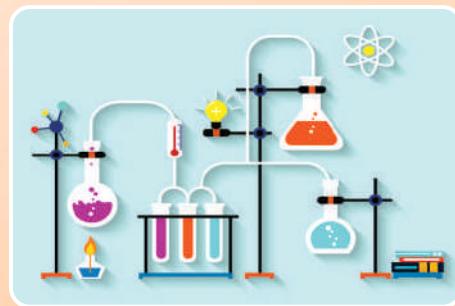
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Chemical Bonding

Chemical bond: It refers to the attractive force which binds various constituents (atoms, ions, molecules, etc.) in different chemical species.

Octet rule: An atom tends to gain, lose or share electrons during molecule formation so that there are eight electrons surrounding it.

or

The atoms of different elements take part in a chemical combination in order to complete their octet (i.e. to have eight electrons in the outermost or valence shell) or duplet (i.e. to have two valence electrons) in some cases such as H, Li, Be, etc.



Lewis symbols: Lewis introduced symbols to represent the valence electrons in an atom. These symbols are called Lewis symbols.

In Lewis symbols, the valence electrons are represented as dots surrounding the symbol of an atom or ion. e.g. Lewis symbol for sodium is Na similarly for some other atoms these are Li, Be, B, C, N, O, F, Ne, etc.

These symbols are also called electron dot symbols.

Importance of Lewis Symbols

(i) They represent the number of valence electrons.

(ii) They also give information of the valency of element. Valency is equal to either the number of valence electrons or (8 - number of valence electrons) e.g., the valency of Li, Be, B and C is 1, 2, 3, 4, respectively and that of N, O, F and Ne is 3 (8-5 = 3), 2, 1, 0, respectively.

Electronic Theory of Valency

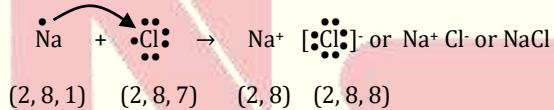
This theory explains the combination of atoms in terms of their electronic structure. It was given by Lewis and Kossel (1916) and was extended by Langmuir (1919). It assumes that the combination of atoms occurs due to rearrangement of electrons in their outermost shell. The rearrangement may involve either transference of electrons from one atom to another or mutual sharing of electrons.

Ionic or Electrovalent Bond

Ionic bond is formed by the transference of electrons from one atom to another. This type of bond is generally formed between a metal and a non-metal. The metallic ion atom loses its valence electrons and changes into positive ion (cation) while a non-metallic atom gains electron and changes into negative ion (anion). The oppositely charged ions are held together by electrostatic force of attraction. Thus ionic bond may be defined as the electrostatic force of attraction holding the oppositely charged ions. It is formed by complete transfer of electrons from one atom to the other.

The compounds which contain the ionic or electrovalent bonds are known as ionic or electrovalent compounds e.g., NaCl, BaCl₂, CaF₂, etc.

Formation of NaCl



The number of electrons which an atom losses or gains while forming the ionic bond is called its electrovalency.

The atom which loses electron is called electropositive atom.

The atom which gains electron is called electro negative atom.

Electron Dot Representation of Some Ionic Compounds

■1■



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The book cover features a yellow background with a faint watermark of various words like 'James', 'Rose', '007', 'Collection', 'Bond', 'Raja', 'Maaan', 'Rode', '007', 'Sam', 'Jang'. At the top left is a circular seal with a sunburst border containing the text 'FULLY REVISED UPDATED'. To the right, the word 'NEON' is written in large red letters with a globe icon in the letter 'O', and 'COMPREHENSION' is written in yellow below it. The main title 'CLOZE TEST' is in large black letters, with '(PREVIOUS YEAR EXAMS - SSC CGL / CPO & BANK)' in smaller black letters underneath. Below the title, there are three bullet points: '+ 55+ Cloze Tests With Detailed Analysis', '+ 50+ Cloze Tests Based On Grammar', and '+ 200+ Cloze Tests For Practice'. A portrait of Manisha Bansal Ma'am is on the right side. At the bottom left is a red box containing the text 'SSC CPO BANK'. At the bottom right, it says 'Available on: '. The book has a 3D effect with red and orange diagonal stripes on the sides.

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NEON
COMPREHENSION

CLOZE TEST

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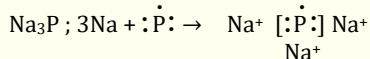
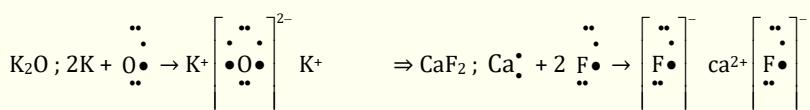


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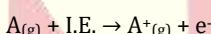


Since the ion has a uniform field of influence around it so the ionic bond is non-directional in nature.

Energy Changes during Formation of Ionic Bond

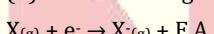
The formation of ionic bond may the following three stages:

(i) Formation of gaseous cation



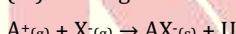
The energy required for this step is called ionisation energy (I.E.)

(ii) Formation of gaseous anion



The energy released in this step is called electron affinity (E.A.)

(iii) Packing of ions of opposite charges to form ionic solids



The energy released in this step is called lattice energy.

Note: For the formation of a stable ionic compound, the net energy released should be larger than the energy required.

Hence for the formation of stable ionic bond

(a) Ionisation energy of cation forming atom should be low.

(b) Electron affinity of anion forming atom should be high.

(c) Lattice energy should be high.

Lattice energy (U): It is the amount of energy released when one mole of ionic solid is formed by the close packing of gaseous ions of opposite charges.

Note: The magnitude of lattice energy gives us idea about the inter ionic forces.

Factors on which lattice energy depends: It depends upon the following factors:

(i) Size of the ions: Smaller the ions, lesser is inter nuclear distance and greater will be the inter ionic attraction hence larger will be the magnitude of lattice energy.

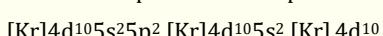
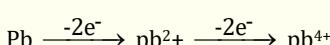
(ii) Charge on the ions: Larger the charge on ions, higher is the value of lattice energy.

Variable valency: There are many elements which exhibit variable valency, e.g. Fe shows valency of + 2 and + 3; Pb shows valency of + 2 and + 4.

- (a) In case of transition elements with electronic configuration $(n - l) d^{1-10} ns^{1-2}$, the attainment of noble gas configuration is not possible because it is not energetically favourable to lose so many electrons. Therefore, normally they lose valence electrons to form cations with lower valency, but the electronic configuration of such an ion is not stable (as it is not a noble gas configuration), so they may lose one or more d-electrons to exhibit the higher electro valency.
- (b) In case of heavier elements of p-block, the variable electrovalency is exhibited due to inert pair effect. In heavier elements of p-block, the effective nuclear charge experienced by valence electrons becomes larger due to poor shielding of inner d-and f-orbitals and due to this the s-electrons in valence shell start becoming inert towards bonding. This reluctance of s-electrons of valence shell to participate in bonding is called inert pair effect.

Due to inert pair effect, only p-electrons of valence shell participate in bonding and a cation of lower valency is formed.

Under drastic conditions when s-electrons also participate in bonding, the cation of higher valency is formed. e.g.



[Inert pair effect]

General Characteristics of Ionic Compounds

(i) They are crystalline solids and are generally brittle.

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- (ii) They have high m.p. and b.p.
- (iii) They are good conductors of electricity.
- (iv) They are soluble in polar solvents, e.g., water.
- (v) They give ionic reactions.

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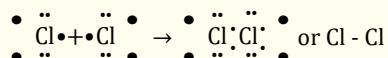
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Covalent Bond

It is formed by mutual sharing of electrons between the two atoms with each atom contributing equal number of electrons for sharing e.g.,



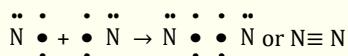
The bond can be shown by a line (—) between atoms instead of a bond pair.

The valence electrons not involved in sharing are called non-bonding electrons or lone pairs or unshared pairs.

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Multiple covalent bonds: If atoms share one electron pair it is called single covalent bond, if two electron pairs are shared it is called double covalent bond, if three electron pairs are shared it is called triple covalent bond. The double and triple covalent bonds are collectively called multiple covalent bonds e.g.



The covalency of an element is the number of electrons which it contributes for sharing while forming a covalent bond.

General Characteristics of Covalent Bond (or Covalent Compounds)

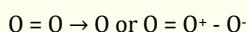
- (i) Covalent compounds exist as individual molecules and they generally have low m.p. and b.p.
- (ii) They are insoluble in water (polar solvent) but soluble in non-polar solvents (e.g. CCl_4 , CS_2 , etc)
- (iii) They give molecular reactions.

Coordinate-Covalent Bond or Dative Bond

This type of bond is formed by mutual sharing of electrons between two atoms but shared pair of electrons is contributed by only one of the two atoms, the other atom simply participates in bonding.

The atom which donates electron pair is called donor. The atom which accepts the electron pair in order to complete its octet is called acceptor.

The coordinate-covalent bond is represented by an arrow (\rightarrow) pointing towards acceptor or by putting formal positive charge on donor, formal negative charge on acceptor and covalent bond between them e.g., ozone molecule (O_3).



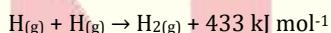
Limitations of Octet Rule

- (i) It is not able to explain the formation of covalent molecules such as BeH_2 , BeCl , BF_3 , etc. where central atom does not acquire octet even though the bonds are formed by mutual sharing of electrons.
- (ii) Violation of octet rule is observed in compounds such as PF_5 , SF_6 , IF_7 , etc. where the central atom has more than eight electrons in their valence shell.
- (iii) This rule is not able to explain the energy changes during the bond formation.
- (iv) This rule is based on the fact that noble gases are inert and do not take part in bond formation but recent researches have shown the participation of some noble gases like Kr and Xe in bonding. Some of their compounds are XeF_2 , XeF_4 , XeOF_2 , XeOF_4 , XeF_6 , KrF_2 , etc.

Quantum Theory of Covalent Bond

According to modern wave mechanical model of atom, a covalent bond is formed by overlapping of atomic orbitals.

It has been found that the energy of hydrogen molecule is less as compared to energy of two hydrogen atoms.



Thus we can say that there is always a decrease in energy whenever atoms combine to form a molecule.

Actually when atoms are far apart they do not have any force of interaction (attraction or repulsion), as they tend to come closer, two different forces operate.

- (i) The nucleus of one atom is attracted towards the electrons of the other and vice-versa. Energy is released in attraction.
- (ii) The nuclei of the atoms as well as their electrons repel each other. Energy is needed to overcome the force of attraction.

A stable molecule will be formed, if magnitude of attractive forces > magnitude of repulsive forces.

Note:

- (i) When two hydrogen atoms approach each other the overall potential energy of the system decreases. Hence a stable molecule of hydrogen is formed.
- (ii) In case of approach of helium atoms, the overall repulsive forces are more than the attractive forces and so a molecule of helium is not formed.

Orbital concept of covalent bond: According to it, a covalent bond is formed as a result of overlap of orbits belonging to the two having opposite spins of electrons.



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Conditions Favourable for Orbital Overlapping

- (i) Only the atomic orbitals with one electron (half-filled) can take part in overlap.
- (ii) At the time of overlap, the combining orbitals must have opposite spin of electrons.
- (iii) The overlap must be maximum.

Types of Orbital Overlap (Sigma and pi bonds)

Sigma bond: The bond which is formed by the head overlapping of half-filled atomic orbitals along the inter nuclear axis is called sigma bond.

Pi bond: The bond which is formed by the side wise lateral overlapping of half-filled atomic orbitals in a direction perpendicular to the inter nuclear axis is called pi bond.

Note:

- (i) s-half-filled atomic orbital is always involved in axial overlapping only since it is spherically symmetrical, it always takes part in sigma bond formation. The sigma-bond formation may involve s-s, s-p or p-p overlapping.
- (ii) π -(pi) bond is formed only in addition to a sigma-bond.

Bonding Parameters

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Bond energy: It is the amount of energy required to break one mole bonds of a particular type between the atoms in the gaseous state of a substance. It is measured in kilo joules (kJ).

It depends upon the following factors

- (i) Size of the atom: Larger the size of participating atoms, more will be the bond length and smaller will be the bond energy.
- (ii) Multiplicity of bond: Greater the bond multiplicity, more will be the bond energy.

Bond length: It is the average distance between the centres of the nuclei of the two bonded atoms in a molecule corresponding to minimum energy and maximum stability. It is measured in nm (nanometres) or pm (picometres).

The bond length is influenced by the following factors.

- (i) Size of the atoms: Larger the size of atoms forming the bond larger is the bond length.
- (ii) Multiplicity of bond: More is the multiplicity of bonds, smaller is the bond length.
- (iii) Types of hybridisation: Greater the s-character associated with a particular bond, smaller will be the bond length, e.g.
 sp^3C-H (111 pm) $> sp^2C-H$ (110 pm) $> sp C-H$ (108 pm)

Bond angle: It is the average angle between two (molecular orbitals) bonds meeting at the same nucleus in a polyatomic molecule. It is measured in degrees and minutes.

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Coordinate-Covalent Bond

It is a special type of covalent bond in which shared pair of electrons is supplied only by one of the atoms forming the bond. The atom which supplies the electrons is called donor while the other atom which only uses the shared pair of electrons is known as acceptor. It is shown by arrow-head (\rightarrow).

Orbital concept of coordinate bond: According to orbital concept, a coordinate bond is formed by the overlap of a filled orbital of one atom with empty orbital of the other.

Polar covalent bond: If covalent bond is formed between two dissimilar atoms having difference in electronegativity, then the shared pair of electron is more towards more electronegative atom which acquires δ^- charge and other atom acquires δ^+ charge. This type of bond is called polar covalent bond. The compounds having polar covalent bond form ions in an aqueous solution. It is also called ionic character of the covalent bond.

The extent of ionic character of a covalent bond depends upon the difference in electro negativity values of the two atoms forming the bond. Greater the difference in electro negativity values, greater is the percentage of ionic character. If x_A and x_B represent electro negativities of atoms A and B.

if $x_A - x_B = 1.7$, bond A - B is 50% ionic.

if $x_A - x_B > 1.7$, bond A - B is mainly ionic.

if $x_A - x_B < 1.7$, bond A - B is mainly covalent.

Dipole moment: Dipole moment of a molecule is the product of its net positive or negative charge and distance between the atoms. It is represented by arrow pointing from positive to negative end. It is usually designated by a Greek letter μ .

Mathematically, $\mu = e \times d$, where e = net + ve or -ve charge, 'd' is distance between the atoms. Its unit is Debye, where 1 Debye = 10^{-18} esu cm. Its S.I. unit is Cm (Coulomb-metre).

Dipole moment and molecular structure

(i) In diatomic molecules, the dipole moment of the bond also gives the dipole moment of the molecule.

(ii) In polyatomic molecules, the dipole moment is the resultant of the vectors which represent various bond dipoles. The resulting dipole in such cases depends upon the geometry of the molecule and the spatial orientation of various dipoles.

Tri atomic molecules

(a) In linear molecules (e.g. CO₂) the two dipoles cancel each other and the resultant dipole moment is zero.

(b) In case of bent molecules (e.g. H₂O) they do not cancel each other and the resultant dipole moment is there. μ for H₂O is 1.83 D.

Similarly, we can find the resultant dipole moment for other polyatomic molecules.

Covalent Character in Ionic Bonds— Fazzan's Rule

Polarising power: It refers to the power of the positive ion to cause distortion in the electron cloud of the negative ion.

Polarizability: The ability of negative ion to undergo polarisation is called polarizability.

The % of covalent character in an ionic bond depends upon the polarising power of the cation and the anion.

Factors on which Polarizing Power Depends

(i) Size of the cation: Smaller the size of cation, larger will be its polarizing power e.g. Li⁺ is smaller than K⁺ ion, so LiCl has more covalent character than KCl.

(ii) Electronic configuration of cation: For two cations of similar size and charge, the cation with noble gas configuration has smaller polarizing power, e.g. polarising power of Cu⁺ (96 pm) > Na⁺ (95 pm). Thus, CuCl is more covalent than NaCl.

Factors on which Polarizability of Anion depends

Size of the anion: Larger the size of the anion higher will be its polarizability, e.g. LiI is more covalent than LiCl.

Bonding in Solid State, Hydrogen Bond Andresonance

Ionic crystals: In ionic crystals, the units occupying crystal points are positive or negative ions e.g. NaCl.

Types of Ionic crystals



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(i) **AB type:** Such crystals contain equal number of cations and anions, e.g. NaCl, CsCl, ZnS, etc.

(ii) **AB₂ type:** In such crystals, the number of anions is twice the number of cations e.g. CaF₂, TiO₂, etc.

(iii) **AB₃ type:** In such crystals, the number of anions is three times the number of cations e.g. AlF₃,

(iv) Layer structure

Covalent solids: In such solids covalent bonds extend throughout the solid and so they may be considered as very large molecules e.g. diamond, graphite etc. They are also known as atomic solids.

Molecular solids: In such solids the individual covalent molecules are held together by van der Waals forces of attraction e.g. sugar, urea, ice, camphor, etc.

Metallic solids: In such solids the metal atoms are held together by metallic bonds. In metallic bonding, a regular lattice of positive kernels is held together by a cloud of loosely bound electrons. These electrons are free to move throughout the lattice e.g. Ag, Au, Na, Cu, Fe, K, Al, etc. All metals and alloys have metallic bonds.

Metals: Those elements which can lose electrons are called metals. They are mostly solids except mercury and gallium. They are good conductors of heat and electricity. Some of them are malleable and ductile.

Hydrogen Bond

It is electrostatic force of attraction between hydrogen atom of one molecule and a highly electronegative element (such as N, O or F) within the same molecule or another molecule of same or different compounds.

Conditions for Hydrogen Bonding

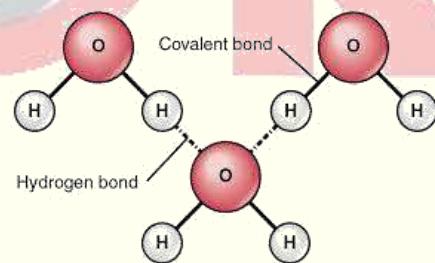
(i) The hydrogen atom must be linked to highly electro negative atom such as F, O, N.

(ii) The size of electronegative atom must be small. Smaller the size of the atom, greater will be polarization of covalent bond with hydrogen atom and so greater will be extent of dipolar attraction.

Types of Hydrogen Bond

(i) **Intermolecular hydrogen bond:** For the formation of this type of bond, both, hydrogen atom and the electro negative atom, (atoms forming hydrogen bond) must belong to different molecules e.g. H—F...H—F.

(ii) **Intra-molecular hydrogen bond:** It is formed when hydrogen atom and the electronegative atom taking part in hydrogen bond formation belong to the same molecule e.g. o-Nitro phenol, Salicyaldehyde, o-Nitrobenzaldehyde.



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