Metals & Non-Metals
Non-Metals & their Properties

❖ NON-METALS:

Important properties of Non-metals

1. **Physical state:** Either gases or solids at room temperature.
   Exception: Bromine (liquid at room temperature).
2. **Surface:** Non-metals vary in colour with generally **dull surfaces**.
   Exception: Diamond, Crystals of iodine have bright lustre.
3. **Conduction:** Mostly Poor conductors of heat and electricity.
   Exception: Graphite
4. **Hardness:** Quite Soft.
   Exception: Diamond
5. **Malleable:** Non-malleable and non-ductile.
6. **Not Sonorous**.
7. **Very low melting and boiling point** as compare to metals.
   Exception: Diamond.
8. **Reactivity:** They generally form acidic or neutral oxides with oxygen.

Non-Metals: Only 22 nonmetallic elements, of which 11 are gases, one is a liquid and the rest 10 are solids. Non-mentals are placed on the right-hand side of the periodic table. At room temperature, non-metals are either solids or gases, except bromine, which is a liquid. Hydrogen (H_2), nitrogen (N_2), oxygen (O_2), chlorine (Cl_2) etc., are example of some gaseous non-metals. Carbon, sulphur (S_8), phosphorus (P_4), etc., are solids. **They play an important role in our daily life.**

(A) PHYSICAL PROPERTIES

1. Non-metallic solids are **brittle**. If they are hammered or stretched, they break into pieces. Carbon in the form of graphite is very soft.

2. Non-metals **do not have any lustre**, i.e., they do not have a shining surface. But **iodine**, which has a lustrous appearance, is an exception.
3. Non-metals are generally soft elements, except diamond (an allotropic form of carbon), which is the hardest known substance.
4. Non-metals do not conduct heat and electricity because unlike metals, they have no free electrons. But there is an exception. Graphite, an allotropic form of carbon, is a good conductor of electricity.

(B) CHEMICAL PROPERTIES

Due to energy considerations, non-metals cannot form positively charged ions by the loss of electrons. In fact, they form negatively charged ions (anions) by the gain of electrons. Hence, they are known as electronegative elements.

$Cl + e^- \longrightarrow Cl^-$; $O + 2e^- \longrightarrow O^{2-}$; $S + 2e^- \longrightarrow S^{2-}$.

(I) Reaction with Oxygen

Non-metals combine with oxygen to form oxides. These oxides are either acidic or neutral. They never form basic oxides. The non-metallic oxides are formed by sharing of electron pairs between the atoms of non-metal and oxygen. Hence, these are convalent compounds.

$C(s) + O_2(g) \quad CO_2(g)$

$S(s) + O_2(g) \quad SO_2(g)$

Both carbon dioxide (CO_2) and sulphur dioxide are acidic oxides. They dissolve in water to form acids.

$P_2O_5(s) + 3H_2O(l) \quad 2H_3PO_4(aq)$

(Phosphoric acid)

$CO_2(g) + H_2O(l) \quad H_2CO_3(aq)$

(Carbonic acid)

$SO_2(g) + H_2O(l) \quad H_2SO_3(aq)$

(Sulphurous acid)

Note : Certain oxides of non-metals are neutral. These oxides are neither acidic nor basic. These oxides donot have any effect on litmus paper.

Examples of neutral oxides are carbon monoxide (CO), nitrous oxide (N_2O), etc.

(II) Reaction with Acids

Non-metals do not displace hydrogen from dilute acids. For example, carbon or sulphur does not react with dilute acids. Hydrogen can only be displaced from dilute acids if electrons are supplied to the H^+ ions of the acid.

$$H_2SO_4\ (aq)\ \ 2H^+\ (aq) + SO_4^{2-}\ (aq)$$

$$2H^+\ (aq) + 2e^-\ \ H_2(g)$$

A non-metal is an electron acceptor. It cannot supply electrons to H^+ ions. Therefore, it does not displace hydrogen from dilute acids.

(III) Reaction with Chlorine

With chlorine, non-metals form covalent chlorides. The covalent chloride is generally a volatile liquid or a gas.

$$H_2(g) + Cl_2(g)\ \ 2HCl\ (g)$$

(Hydrogen chloride)

$$P_4(s) + 6Cl_2(g)\ \ 4PCl_3\ (g)$$

(Phosphorus trichloride)

$$P_4(s) + 10Cl_2(g)\ \ 4PCl_5\ (l)$$

(Phosphorus pentachloride)

(IV) Reaction with Hydrogen

Non-metals combine with hydrogen to form hydrides. For example, ammonia (NH_3), methane (CH_4), hydrogen sulphide (H_2S), water (H_2O), etc. These hydrides are stable compounds and are formed by sharing of electron pairs between the non-metal and hydrogen.

$$N_2(g) + 3H_2(g)\ \ 2NH_3(g)$$

$$H_2(g) + S(l)\ \ H_2S(g)$$

$$2H_2(g) + O_2(s)\ \ 2H_2O(l)$$

(water)

SULPHUR

Atomic number	:	16
Atomic mass	:	32
Electronic configuration	:	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$
Symbol	:	S
Valencies	:	+ 2, + 4 and + 6 , while in some compounds –2.

Sulphur is known to man since ancient time. In Sanskrit, sulphur is known as 'sulvari' which means 'destroyer of copper'. This is because it destroys the metallic properties of copper. Lavoisier studied its properties and identified it as an clement Sulphur is found in nature in free state and combine state.

❖ Combine State

(a) **Sulphates :** Gypsum ($CaSO_4.2H_2O$), Epsom salt ($MgSO_4.7H_2O$), Glauber's salt ($Na_2SO_4.10H_2O$)

(b) **Sulphides :** Cinnabar (HgS), Galena (PbS), Iron pyrites (FeS_2), Copper pyrites ($CuFeS_2$), Zinc blend (ZnS).

(c) **Organic matter :** In insulin, glucosionates of plants and animals, nature, gas petroleum, crude oil, coal gas, water springs.

❖ Allotropes of sulphur

Allotropes and allotropy : Two or more forms of an element which have different structure and other physical properties but have same chemical properties are known as allotropes of the element This property of elements is known as allotropy .

Sulphur has two allotropes the crystalline and non crystalline.

(A) Crystalline allotropes: Crystalline sulphur is found in two allotropic forms.

(i) **Rhombic sulphur** : This allotrope of sulphur is also known as α (alfa) sulphur At normal temperature this allotrope of sulphur is highly stable. It is insoluble in water but soluble in carbon disulphide When it is heated at 368.6 K (95.6° C), it is converted into other allotrope, monoclinic sulphur

(ii) **Monoclinic sulphur** : It is also known as β (beta) sulphur. It is found in the form of needle shaped crystals. Thus it is also known as prismatic sulphur. It is insoluble

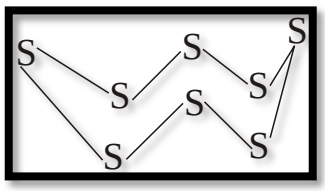
in water and soluble in carbon disulphide. This allotrope of sulphur is stable above 368.6 K temperature Below this temperature it is converted to α sulphur Both allotropcs of sulphur coexist at 368.6 K This temperature is known as transition temperature.

$$\text{Rhombic sulphur} \underset{}{\overset{368.6K}{\rightleftharpoons}} \text{monoclinic sulphur}$$

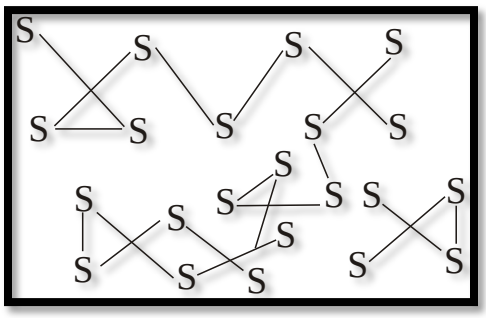
Both these allotropes of sulphur have 58 structure that forms a distorted ring.

(B) Non crystalline sulphur : This sulphur is found in three allotropic forms

(i) **Plastic sulphur** : When boiling sulphur is poured in cold water a soft rubber like substance is obtained which is known as plastic sulphur. This is an unstable allotrope of sulphur which gets converted slowly, into rhombic sulphur, It is also known as γ (gamma) sulphur. Plastic sulphur is unsynchronized chain structure.



Distorted ring of S_8 molecle in rhombic and monoclinic sulphur



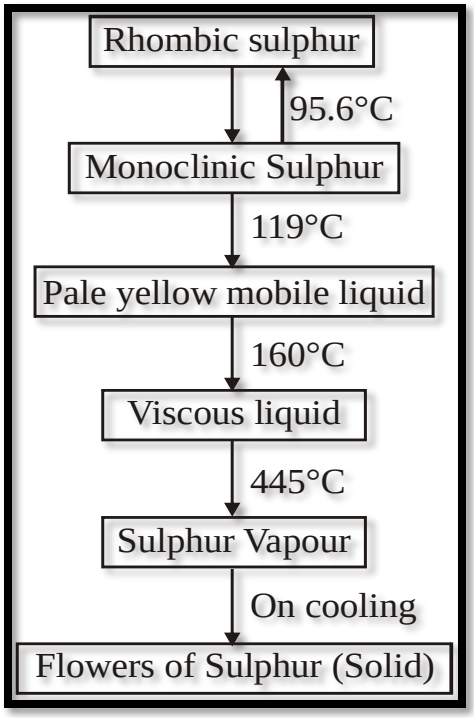
Chain of S. molecules in plastic sulphur.

(ii) **(delta) sulphur or milk of sulphur**: It is white coloured non crystalline sulphur It is used for preparing medicines.

(iii) **Colloidal sulphur** : This allotrope of sulphur is obtained by passing H_2S gas in dilute nitric acid solution.

$$H_2S + 2HNO_3\,(\text{dilute}) \rightarrow 2NO_2 + 2H_2O + S$$

This sulphur is soluble in Carbon disulphide but insoluble in water. On heating or after some times, this sulphur gets transformed into rhombic sulphur. It is also used in preparation of medicines.



Use of sulphur:

(i) sulphur is extensively used for industrial production of sulphuric acid.

(ii) It is used in gun powder and in manufacturing of match sticks.

(iii) It is used as powerful insecticide.

(iv) Sulphur is used in preparation of medicines, sulphur containing medicines are useful for skin diseases and blood purification,

(v) It is used in vulcanization of rubber.

PHOSPHORUS

Atomic number	:	15
Atomic mass	:	31
Electronic configuration	:	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$
Symbol	:	P
Valencies	:	+ 3,+ 5

Phosphrous is a Greek work meaning phos = light and phero = carry. This implies that phosphorus is an element that glows in darkness. Phosphrous was discovered by Brand a German scientist in 1669. He obtained this element for first time by distillation of a mixture of urine, sand and coal.

It is not found in free state in nature because it is highly reactive. In combined state, it is found in the form of phosphate compounds.

The principal minerals of phosphrous are

(i) Phosphorite $Ca_3(PO_4)_2$

(ii) Flourapatite $3Ca_3(PO_4)_2.CaF_2$

(iii) Chlorapatite $3Ca_3(PO_4)_2.CaCl_2$

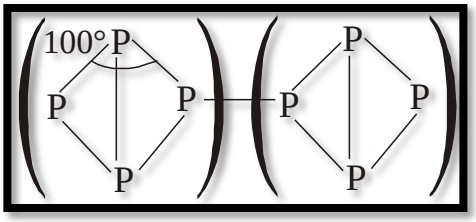
- **Allotropes of phosphorus** : There are many allotropes of phosphorus, they are as follows.
  - (i) White or yellow phosphorus,
  - (ii) Red phosphorus,
  - (iii) Black phosphorus,
  - (iv) Violet / purple phosphorus,
  - (v) Dark red phosphorus.

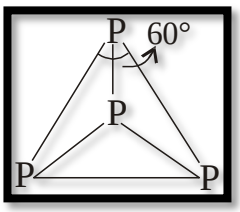
  Out of these white, red and black phosphorus are more common.

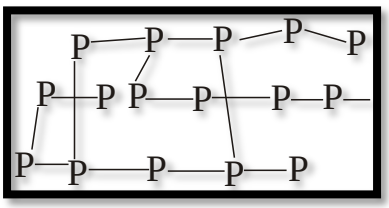
- **White phosphorus** is of white colour when it is pure but gradually it turns yellow. It has garlic like smell and is poisonous. It is a molecular solid having tetrahedral P_4 units. In this arrangement P-P-P bond angle is 60° and the structure is more strained. Due to this white phosphorus is more reactive. It catches fires in presence of air thus it is kept in cold water. It is soft and can be easily cut with knife.

- **Red phosphorus**: It has a complex chain structure. It is odourless and its ignition point is high. In red phosphorus, P-P-P bond angle is 100°.

- **Black phosphorus**: Due to its layered structure it is more stable. In this allotrope many layer of phosphorus atoms are interconnected. Similar to red phosphorus, it is also odourless.







Red phosphorus White phosphorus Black Phosphorus

❖ **Uses of phosphorus:**

(i) White phosphorus is used to prepare smoke clouds, fire balls, presentation of fire game and to manufacture coloured match sticks.

(ii) Red phosphorus is used to prepare match sticks,

(iii) Red Phosphorus is used to prepare phosphorus bronze alloy. This alloy contains copper, tin and phosphorus.

(iv) Compounds of phosphorus like zinc phosphide and calcium phosphide are used to kill rats.

SOME IMPORTANT COMPOUNDS OF NON-METALS

1. Ozone(O_3): Ozone is an allotrope of oxygen. Nascent oxygen is obtained from this compound, so it is a strong oxidizing agent. A layer of ozone is also found in the atmosphere. This layer prevents the harmful U.V. radiations coming from sun. Thus act as a protective layer. Following are important industrial uses of ozone gas.

(i) In production of artificial silk,

(ii) As bleaching agent.

(iii) As disinfectant.

(iv) For purifying drinking water.

(v) Ozone used as disinfectant and also for purifying air.

(vi) Used for preparation of potassium permanganate.

2. Hydrogen peroxide (H_2O_2)

It's chemical structure

H–O–O–H.

It exhibit both oxidizing and reducing properties. Usually its oxidizing properties are more Its important uses are as follows:

(i) The oxidizing property is employed in rejuveniling (re-brightening) of old paintings whose original lead coating has turned dirty due to its reaction with H_2S present in atmosphere, resulting in formation of PbS Hydrogen peroxide oxidises this yellow lead sulphide to white lead sulphate

$$PbS + 4H_2O_2 \quad PbSO_4 + 4H_2O$$

yellow white

(ii) Dilute solution of hydrogen peroxide is used as a disinfectant for wounds.

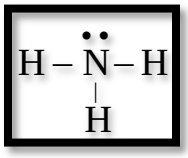
(iii) Concentrated H_2O_2 is used as rocket fuel oxidant.

(iv) The main industrial application of it is the bleaching of silk, hair, ivory, wool, wood etc

(v) It is used in medicine, cosmetics etc.

3. Ammonia (NH_3) :

Structure of ammonia



(i) Ammonia is used for manufacturing of nitrogen containing fertilizers (like ammonium nitrate, urea, ammonium phosphate and ammonium sulphate)

(ii) Ammonia is used for manufacturing of nitric acid.

(iii) It is used as freezing agent thus it is also used in ice factories

(iv) Used in synthesis of artificial silk.

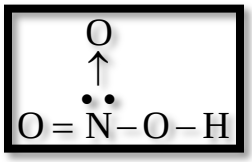
(v) Used for producing explosives.

(vi) It is useful in removing stains of fats, oils, grease etc. from clothes.

(vii) Dilute ammonia is used in medicines and cosmetics.

4. **Nitric acid (HNO_3) :**

Structure of nitric acid



Nitric acid is a strong oxidizing agent Its main industrial applications are as follows.

(i) Nitric acid is used for preparation of ammonium nitrate which is used as fertilizer,

(ii) It is also useful for preparation of other nitrates which are used in explosives and fire crackers. For example - potassium nitrate (KNO_3), nitroglycerine, trinitrotoluene etc are explosive.

(iii) Used for oxidation of rocket fuels.

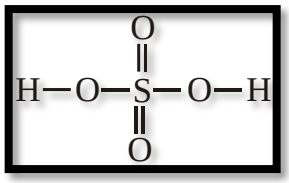
(iv) Used for manufacturing of dyes, medicines, artificial silk etc.

(v) In purification of gold and silver.

(vi) Used for manufacturing of sulphuric acid.

5. **Sulphuric acid (H_2SO_4) :**

Structure of sulphuric acid



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❖ **Main industrial uses are -**

(i) manufacturing of hydrochloric acid, nitric acid and fertilizers,

(ii) purification of petrol,

(iii) In dye industry

(iv) In metallurgy for the extraction of metals,

(v) In batteries.

(vi) In electroplating

(vii) In detergent industry

Infact sulphuric acid is used in the synthesis of hundreads of industrial products, thus it is also known as king of acids.

6. **Hydrochloric acid (HCl):**

Also known as acid of common salt. Its important uses are as follows-

(i) As an important reagent in laboratory

(ii) A Mixture of three part of HCI and one part of HNO_3 is called aquaregia in which metals are soluble,

(iii) In iron and steel industry.

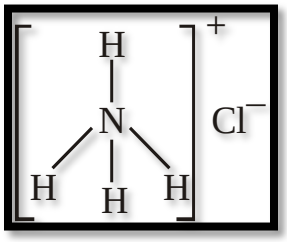
(iv) In textile industry,

(v) In manufacture of gum and dyes,

(vi) Manufacturing of chlorine gas which in turn used to prepare bleaching powder. It is used for the purification of drinking water.

(vii) For synthesis of metal and non-metal chlorides.

7. **Ammonium chloride (NH_4Cl) :**



It is commonly known as 'Nausadar' Its main uses are as follows-

(i) Soldering material is prepared by ammonium chloride, it is used for polishing utensils,

(ii) It is used in electric battery,

(iii) Used in colouring clothes,

(iv) Also used as medicine

(v) As reagent in laboratory.

8. **Silica (SiO_2) :** [O = Si = O]

In nature, silica is found in different forms Sand is present in nature in abundance which is a form of silica. It is more useful because of its hardness. Its main uses are as follows-

(i) Silica is used in the manufacturing of glass,

(ii) Jasper a semi precious stone, a form of silica

(iii) Silica form other silicates which arc used in electrical appliances, chemical laboratory equipment, optical lenses, prism etc.

(iv) Silicon is prepared from silica, which is used in semi conductor, transistor and alloys,

(v) Kieselguir is an allotrope of silica, is used for manufacturing dynamite.