6. THE NON-METALS

All the elements can be divided broadly into metals and non-metals. There are only 22 non-metallic elements out of which 11 are gases, (e.g. oxygen, nitrogen and chlorine) one liquid (bromine) and remaining 10 are solids (e.g.) carbon, sulphur, phosphorous and iodine). The non-metallic elements are placed on the right-hand side of the periodic table.

PHYSICAL PROPERTIES

Non-metals have usually low densities, are brittle and do not give sheets (non-malleable) or wires (non-ductile). They don't posses Lustre and cannot be polished.

Non –metals are generally bad conductors of heat and electricity. Unlike metals, non-metals have no free electrons. Only graphite an allotropic form of carbon is an exception and is a good conductor of electricity.

CHEMICAL PROSPERITIES

Unlike metals, non-metals are electronegative that is, they have a tendency to accept electrons and form negative ions.

1. Non-metals give acidic or neutral oxides on combination with oxygen. These oxides are formed by sharing of electrons i.e. covalent oxides are formed. Acidic oxides on combining with water give acids. For example.

$$\text{Sulphur + Oxygen} \rightarrow \underset{\text{Sulphur trioxide}}{So_3(g)} + \underset{\text{water}}{H_2O(l)} \rightarrow \underset{\text{Sulphuric acid}}{H_2SO_4(aq)}$$

2. Non – metals do not displace hydrogen from acids, i.e. they don't react with dilute acids.
3. Non-metals combine with hydrogen to form hydrides. These hydrides are covalent compounds. Example are methane CH_4, ammonia NH_3, hydrogen sulphide (H_2S) etc.
4. Non-metals form covalent chlorides, i.e., non-metals combine with chlorine by sharing of electrons. Example is carbon tetrachloride CCI_4.

Though the non-metals are small in number, they are major constituents of air, ocean and earth. Let us now study the chemistry of certain non-metal elements in detail.

HYDROGEN

Hydrogen (atomic number 1, atomic weight 1.00797) is the first chemical element in the periodic system. Under ordinary conditions it is a colourless, odourless, tasteless gas composed of diatomic molecules, H_2. Its three isotopes are protium (H) deuterium or heavy hydrogen (H) and tritium (H). It is the lightest substance known. It is a major constituent of water and all the organic matter and is widely distributed throughout the universe. At ordinary temperatures, hydrogen is comparatively unreactive but at elevated temperature, it is highly reactive. It reacts with oxygen to form water. With nitrogen it undergoes an important reaction to give ammonia. It reduces some salts to the metallic state. Large quantities of hydrogen are consumed in the catalytic hydrogenation of unsaturated liquid vegetable oils to make solids fats. Hydrogeneration is used in the manufacture of organic chemicals. Hydrogen is also used as a rocket fuel in combination with oxygen or fluorine.

COMPOUNDS OF HYDROGEN – WATER

Water is probably the most abundant as well as the most important compound upon the earth. Water is essential to all forms of life. It is the most abundant compound in the biosphere. Of the total estimated global water supply of about 1.4×10^9 km^3. The oceans and inland saline water bodies hold 97.3% and fresh water amounts to only 2.7%. Unfortunately most of the fresh water is not readily accessible, being locked up in frozen lakes, glaciers or under the ground. The fraction of water available for human use in only 0.003% of the total global water supply. In nature water is found in all three phases solid, liquid, and gas.

Molecular Structure. Water has the chemical formula H_2O. The oxygen atom shares electrons with the two hydrogen atoms. The oxygen atom has slightly greater attraction for electrons than the hydrogen atoms do. Hence the shared electrons than the hydrogen atoms do. Hence the shared electron pairs will be a little closer to the oxygen atom than the hydrogen atoms. As are result the oxygen end of the water molecule will have a slight negative charge; the hydrogen end a slight positive charge. A molecule of this type, with one part negatively charged and another positively charged, is called a polar molecule. Since the bonds between the atoms of water molecule are both polar and covalent, they are often called polar covalent. This gives water unusual properties as we shall see.

Due to the polar character of the water molecule one of the two positively charged hydrogen atoms of such a molecule will link itself to the negatively charged oxygen end of another molecule. Perhaps the other hydrogen end of the first molecule will attach itself to the oxygen end of a third molecule. The hydrogen bridge formed in this way between the oxygen ends of two different water molecules is called a hydrogen bond.

Physical Properties. Water has some important physical properties

Water as a solvent. Water is an excellent solvent because of the polar character of the water molecule. It can attach itself readily to either positive or negative ions, surrounding them and promoting the solvent effect. At the same time, water has a high dielectric, or insulating power, for the electric forces existing between ions. Hence it tends to keep electrically charged ions apart, thus spreading the solvent effect over a wide area.

The dissolving power of water is one of its most important properties. Various substances in the earth's crust go into solution in rain or in standing or flowing water. Huge rocks can gradually be broken down in this way. Minerals dissolved in water are absorbed by plants and are used to make new tissue. The food manufactured by a plant in the process of photosynthesis is transported, dissolved in water, throughout the plant. In the human body, dissolved food is carried to the cells in the blood-stream, which is made up mostly of water.

The expansion of water upon freezing. Most substances contract when they solidify from the liquid state. Water however, expands considerably when it freezes. This remarkable quality is due to the linkage between molecules because of hydrogen bonding. As the temperature becomes lower, and the molecules become more sluggish, there will be more and more hydrogen bonding.

The expansion of water as it freezes has various important consequences. For one thing, the water that makes its way between cracks in rock expands upon freezing and exerts great pressure. This gradually causes fragment of rock to break off. Thus freezing water becomes an effective erosive agent.

Because the ice that forms on a body of water—a river, say, or a pond—is lighter than the water that has not yet been frozen, it stays on the surface instead of sinking to the bottom. The ice, therefore, will collect on the surface and the water will freeze from the surface downward. The surface ice tends to insulate the liquid water underneath it from the effects of freezing temperatures. The thicker the ice becomes, the greater its insulating force will be. Hence unless a body of water is very shallow, it may never be frozen over entirely. It is for this reason that aquatic plant and animal life can survive freezing temperatures. The fact that freezing takes place only on the surface of bodies of water has an important effect on the climate.

The high specific heat of water The specific heat of water is higher than that of any other substance and, therefore it is used as a measuring stick. It is given as 1. The specific heat of other substances is given as a fraction of 1. Because of its high specific heat, water can absorb large amounts of heat with relatively little change in temperature, compared to other substance. That is why it is used in the cooling system of automobiles.

Since, much heat is required to raise the temperature of water; it is often used in heating systems. The water in a hot water heating system, for example, absorbs a large amount of heat in the furnace and gives off this heat as it passes through the radiators in the different rooms of house.

The high boiling and freezing points of water. The linking of water molecules by hydrogen bonds has an effect upon its boiling and freezing points. It requires added energy to break down the linked molecules of water as the temperature is raised to the boiling point, when the liquid will pass to the gaseous state. Therefore the boiling point of water, 100° Celsius, is much higher than we would expect. When a liquid becomes a solid, its molecules are combined to form a crystal lattice. Because many water molecules are already joined together even in the liquid state, the water will become solid - that is, will freeze - at a higher temperature than we would expect.

The high heat of vaporization and fusion. The amount of heat required to change one gram of liquid into a gas without any change in temperature is called the heat of vaporization. For water the heat of vaporization is 539.6 calories per gram at its boiling point of 1000 Celsius. The amount of heat absorbed by one gram of a solid when it changes into a liquid with no change in temperature is known as the heat of fusion. For water it is 79.6 calories per gram.

Both the heat of vaporization and the heat of fusion are higher for water than for most other substances. This has a pronounced effect upon the climate of the land areas near large bodies of water, as well as upon wind direction and wind velocity near such bodies of water.

Chemicals Properties The water molecule exhibits a high thermal stability at room temperature. Water displays a versatile range of chemical behavior. When water combines with certain compounds, it forms acids. Thus it reacts with carbon dioxide to produce carbon acid. When water reacts with certain other compounds, it forms bases. For example, calcium oxide or quicklime, combines with water to form the base calcium hydroxide, or slaked lime. Water reacts with some salts such as ammonium chloride to form acid solutions with other salts, such as sodium carbonate it reacts to form basic solution. When sodium chloride NaCl, is added to water the sodium ions (Na) are separated from the chloride ions (CI) The resulting solution is a good conductor of electricity.

Water molecules attach themselves directly to certain substance to from compounds called hydrates. Certain substances that would otherwise not react at all will combine chemically when water is added. For example, chemical reactions in plant or animal tissue take place only in the presence of water. Iron combines with the oxygen of the air to form iron oxide, or rust, only because water is present in the air in the form of water vapour.

Substances Found in Water. Pure water is seldom found in nature. For one thing, water is such an excellent solvent that it generally contains dissolved materials in greater or lesser amounts. Salts dissolved in sea water make up some thing 35 parts per thousands on the average. There are far less dissolved salts in freshwater lakes and streams that are fed chiefly by precipitation (rain, snow, sleet, and so on) and small streams, but they are present nevertheless.

Gases are also dissolved in water. When air goes in solution in water, the oxygen it contains is used by fishes and other forms of acquatic life of respiration. Nitrogen, carbon dioxide, and the other gases found in the air are also dissolved in water.

When water sinks into the earth, it dissolves minerals contained in the soil and rocks.

Hard Water and Soft Water. If some of the salts present in water (calcium, magnesium and iron salts) are in high quantities water does not form lather with soaps easily. The effectiveness of water for washing purposes is then reduced. We call this type of water hand water. Soaps are sodium salts of fatty acids. Calcium or magnesium ions present in hard water form insoluble salts with soap and prevent the formation of lather. A large amount of soap will be used up in precipitating calcium or magnesium salts and only after they are completely removed, will lather be formed. Hard water poses problems when used in industrial boilers for producing steam, because it causes the formation of scales or deposits on the walls of the boilers. Removal of dissolved calcium and magnesium ions from hard water is called water softening.

There are two types of hardness temporary and permanent. Temporary hardness is caused by the presence of bicarbonates and this type of hardness can be removed by merely boiling the water. Boiling decomposes the bicarbonates to give carbon dioxide and insoluble carbonates which can be removed by filtration or decantation. Temporary hardness can also be removed by the addition of a calculated amount of lime whereupon magnesium and/or calcium carbonate is precipitated.

Permanent hardness is caused by the presence of soluble calcium or magnesium salts other bicarbonates. These cannot be removed by boiling. This type of hardness can be converted into soft water using (i) chemical additives in calculated amounts (such as washings soda $NaCo_3$) or sodium polymetaphosphate; (ii) ion-exchange method by adding zeolites or organic ion-exchange resins.

OXYGEN

Oxygen (O), atomic number 8, atomic weight 15.9994 and electronic configuration 2,6 under ordinary conditions is a colourless odourless gas. The most abundant of all the elements in the earth's crust, it forms about one-fifth (by volume) of the atmosphere. Chemically very active, among its most abundant binary compounds are water and silica. Oxygen condenses to a pale blue liquid.

A most useful element, both combustion and respiration involve oxygen. It has many uses. Oxyacetylene burners produce very high temperature flames for cutting and welding metal. When steel is being made, oxygen is used to remove the impurities from the molten iron. Pure oxygen stored in cylinders, is used to support breathing—to help patients in hospitals, and for high altitude or underwater work. Space rockets have to carry liquid oxygen in order to burn their fuels in space, in manufacturing liquid rocket fuels, liquid oxygen is used to burn either liquid hydrogen or kerosene.

The oxygen cycle is an important natural process. Respiration and commercial activities transform oxygen to carbon dioxide and other gases. Photosynthesis by green plants uses carbon dioxide to release oxygen.

Ozone. Ozone is a powerful oxidizing allotropic form of oxygen. The ozone molecule contains three atoms (O_3). The gas is blue; liquid and solid ozone are an opaque blue-black color. Having a characteristic, pungent odour, ozone is irritating to mucous membranes and toxic to human beings and lower animals. Ozone is formed when electrical apparatus produces sparks in air.

Ozone is a powerful oxidising agent. In the presence of water, it is a powerful bleaching agent. Ozone is used in the treatment of drinking water supplies.

Ozone occurs to a variable extent in the earth's atmosphere. Near the surface the concentration is usually 0.02-0.03 ppm. At vertical elevations above 20 km, ozone is formed by photochemical action on atmosphere oxygen. Atmospheric ozone acts a selective filter for ultraviolet rays, stopping the harmful ones and letting the beneficial ones by.

NITROGEN AND ITS COMPOUNDS

Nitrogen is a chemical element (N), atomic number 7, atomic weight 14.0067 . The electronic configuration is 2,5. Nitrogen is a gas under normal conditions. Its molecular formula is N2.

Molecular nitrogen is the principal constituent of the atmosphere (78% by volume of dry air), in which its concentration is a result of the balance between the fixation of atmospheric nitrogen by bacterial, electrical (lightning), and chemical (industrial) action, and its liberation through the decomposition of organic materials by bacteria or combustion. In the combined state, nitrogen occurs in a variety of forms. It is a constituent of all proteins (both plant and animal) as well as of many other organic materials. Its chief mineral source is sodium nitrate.

Because of the importance of nitrogen compounds in agriculture and the chemical industry, much of the industrial interest in elementary nitrogen has been in processes for converting elemental nitrogen into nitrogen compounds. Nitrogen is also used for filling bulbs of incandescent lamps and, in general, wherever a relatively inert atmosphere is required. In its liquid form nitrogen is used for preserving frozen food. Bull semen is frozen in liquid nitrogen at artificial insemination centers for cattle.

Ammonia (NH3) is a colourless, alkaline gas, soluble in water and posses a choking smell. Commercially ammonia is manufactured by Haber's process. In this process, nitrogen and hydrogen taken in the ratio 1:3 is passed over a catalyst (finely divided iron and alumina or molybdenum) at very high pressure (200-250 atm) and a temperature of 450ºC.

$N_2 (g) + 3H_2 (g)$ ® $2NH_3 (g)$

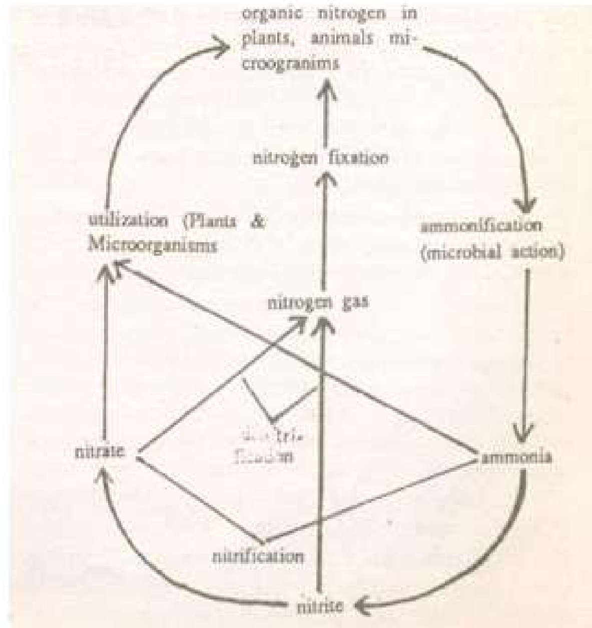
Ammonia

The case of liquefaction and heat absorption make ammonia an effective refrigerant. The largest use of ammonia is as a fertilizer. The ammonia provides nitrogen for the soil in a form in which it can be used by plants. Hydrazine, which is often prepared from ammonia, is used as jet and rocket fuel.

Nitric Acid (HNO3). It is used in the manufacture of explosives such as nitroglycerin, guncotton, trinitrotoluene (T.N.T.) and picric acid. It is also used in medicines, celluloid, collodion, photographic film, dyes and rayon and nitrogenous fertilizers.

Nitrogen Cycle is the collective term for natural biological and chemical processes through which inorganic or organic nitrogen are interconverted. In this cycle, nitrogen compounds pass continuously from the soil to living organism and back again from each of these to atmosphere. This process is crucial to the maintenance of life on earth.

Atmospheric nitrogen cannot be used as such by plants or animals; it is used by plants in the form of compounds such as ammonia or nitrates. Most soils contain some amounts of nitrates in the form of ammonia compounds or in the form of decaying plant and animal matter (humus). Plants use these nitrates as food and convert them into amino acids and proteins. Proteins in plants either return to the soil when the plant dies or passes on to animals that consume. The animals return the nitrogenous compounds to the soil through wastes or by decay on death.



Nitrogen is not only constantly circulating between the soil and living things, it also passes back and forth between each of these and the atmosphere. Some nitrogen is converted by lightning flashes into nitric oxide and nitrogen dioxide and carried as nitric acid to the soil by rain. The nitric acid forms nitrates in the soil. Certain types of bacteria in the soil, called denitrifying bacteria, convert some of the nitrogen compounds there directly into atmosphere (diatomic) nitrogen.

Certain other types of bacteria known as nitrifying bacteria, take nitrogen directly from the air and convert it into nitrogen compounds as waste products. Some of these bacteria live in the soil. Other bacteria, called rhizobia, live in colonies inside pinhead-sized nodules on the roots of certain plants called legumes, such as beans, peanuts, alfafa, etc. In this symbiotic relationship, the rhizobia take carbohydrates from the plants and use them to synthesise nitrogen compounds, while the plants use the nitrates produced by the bacteria for proteins, creating more carbohydrates as a by-product.

Another of the numerous nitrogen cycles takes place in water. Fish pass nitrogen compounds into the water from their wastes. Bacteria convert these into nitrates, which nourish aquatic plants such as algae. Algae are in turn eaten by fish for nourishment, and the cycle begins anew.

The conversion of nitrogen from the atmosphere into a form available to plants and hence to animals and humans is called nitrogen fixation.

PHOSPHORUS

Phosphorus was discovered by Hennig Brand, a German alchemist, in 1669. As it glow in the dark, it was given the name phosphorus, meaning *light-bearing.*

Phosphorus is widely distributed in nature. If is present in all living organisms, both plants and animals. In human body, it is present in bones, muscles and nerve tissues. Metabolism and photosynthesis involve the hydrolysis of adenosinetriphosphate (ATP) to adenosine-diphosphate (ADP).

Phosphorus is an element belonging to group V in the periodic table, below nitrogen.

An atom of phosphorus contains 5 electrons in its outermost shell. Its atomic number is i5 and thus, its electronic configuration is 2, 8, 5.

Occurrence Being a highly reactive element phosphorus does not occur free in nature. In the comb state it occurs as:

1. *Phosphorite*, $Ca_3(P0_4)_2$
1. *Chtorapatite,* $3Ca_3(P0_4)_2CaCl_2$
1. *Fluorapalite*, $Ca_3(PQ_4)_2CaF_2$

Manufacture of phosphorus. Phosphorus is obtained from the mineral phosphorite or bone-ash. The mineral is mixed with coke and sand. The mixture is heated electric furnace. The following reactions occur:

$$Ca_3(PO_4)_2 + 3SiO_2 \rightarrow 3CaSiO_3 + P_2O_5$$

$$2P_2O_5 + 10C \rightarrow P_4 + 1OCO$$

The vapours of phosphorus are condensed under water.

Allotropic Forms of Phosphorus

The existence of an element in two or more forms is called *allotropy.*

Phosphorus occurs in various allotropic forms

a) White phosphorus (or yellow phosphorus)
b) Red phosphorus
c) Scarlet phosphorus
d) Black phosphorus
e) Violet phosphorus

Of these, white and red allotropic forms of phosphorus are important.

White phosphorus

This is the ordinary form of phosphorus unstable. It is insoluble in water but readily soluble carbon disulphide. It is poisonous and has a garlic-like odour.

White phosphorus glows in the dark in the air due to slow oxidation. This phenomenon is known as *phosphorescence.*

The ignition temperature of white phosphorus is very low (30°C). Hence, it easily catches fire in air, forming phosphorous pentoxide.

$$P_4 + 5O_2 \rightarrow 2P_2O_5$$

It is for these reasons that phosphorous is preserved under water.

It combines directly with chlorine, forming phosphorus trichloride.

$$P_4 + 6Cl_2 \rightarrow 4PCl_3$$

When white phosphorus is heated with a concentrated solution of sodium hydroxide, phosphine gas is produced, which is highly poisonous.

$$P_4 + 3NaOH + 3H_2O \rightarrow 3NaH_2PO_2 + PH_3$$

Phosphorus reduces nitric acid to nitrogen peroxide

$$P_4 + 20HNO_3 \rightarrow 4H_3PO_4 + 20NO_2 + 4H_2O$$

Red phosphorus

Red phosphorus is a stable variety of phosphorus. It is obtained by heating yellow or white phosphorus in an inert atmosphere. A trace of iodine is used as a catalyst, and temperature is kept at about 250°C. The mass obtained is led and boiled with caustic soda solution. Residual white phosphorus dissolves while red phosphorus is left behind. It is repeatedly washed with water and dried.

Properties

1. It is a red-coloured powder.
2. Its density is 2.1 and it melts at temperatures between 500°C to 600°C.
3. It is insoluble in both water and carbon disulphide.
4. It is not poisonous and does not smell like white phosphorus.
5. It is much less reactive than white phosphorus. It does not catch fire in air because it does not react with air at ordinary temperature. It does not show phosphorescence.
6. It does not react with chlorine at ordinary temperature. However, it reacts with chlorine when heated.

White phosphorus	Red phosphorus
1. Colourless solid	Red , opaque solid
2. Garlic-like odour	Odorless
3. Density = 1.8g/cm^3	Density = 2.2g/cm^3
4. Soluble in carbon disulphide	Insoluble in carbon disulphide
5. Poisonous	Nonpoisonous
6. Shows phosphorescence, ie. gets oxidized and glows in the dark.	Does noT show
7. Ignition temperature = 30^{0}C	Ignition temperature = 260^{0}C
8. Dissolves in hot concentrated caustic soda solution, producing phosphine.	No action with caustic soda solution
9. Combines with Cl_2 readily to form PCl_3 and PCl_5	Combines with Cl_2 when heated
10. Melts at 44^{0}C	Melts between 500^{0}C and 600^{0}C

Uses of phosphorus

1. One of the most important uses of phosphorous is in match industry. Formerly yellow phosphorus was used to manufacture Lucifer matches, but at present, scarlet phosphorus has taken its place. Red phosphorus is used to manufacture safety matches.
2. Phosphorous is used as a poison to kill rats.
3. Phosphorus is used in making phosphor bronzes which are alloys of phosphorus, copper and tin.
4. Phosphorus is used in making Holmes' signals.
5. Hypophosphates (salts of phosphorus) are used as tonics in medicine.

Phosphates as fertilizers

Green plants need phosphorus compounds to carry out photosynthesis. From the point of view of plant nutrition, phosphorus is a *macronutrient,* needed in large quantities. In the absence of phosphorus, leaves first get discoloured and then the plants die. Plants can only absorb from the soil soluble inorganic compounds which provide required nutrients. Hence, these nutrients in the form of compounds are added to the soil as fertilizers to increase the yield of crop.

Phosphorus is supplied to the plants through phosphate fertilizers which contain soluble compounds like $Ca(H_2P0_4)_2$ which is also called superphosphate. Superphosphate is manufactured from rock phosphate (a mineral) which contains calcium phosphate. Rock phosphate when treated with sulphuric acid gives Superphosphate

SULPHUR

Occurrence Sulphur occurs in nature in free state as well as in combined state. In the free state, it is found in the volcanic regions of sicily, Greece, Russia, Japan, etc. Large deposits of sulphur are found below the earth's surface in the states of Louisiana and Texas in the USA.

In the combined state, it is widely distrusted in nature as cinnabar (HgS), zinc blende (ZnS), copper pyrites ($CuFeS_2$) stibnite (SbS_2), etc.

Sulphur is also present in air as hydrogen sulphide and sulphur dioxide.

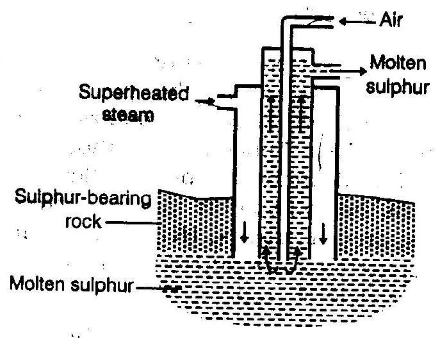
Position in the periodic table Sulphur belongs to group VI and is placed below oxygen in the periodic table.

Electronic configuration The atomic number of sulphur is 16. The electronic configuration of sulphur is 2, 8, 6. Thus, the outermost shell or the valence shell contains 6 electrons, it exhibits variable valences of 2, 4 and 6.

Methods of extraction

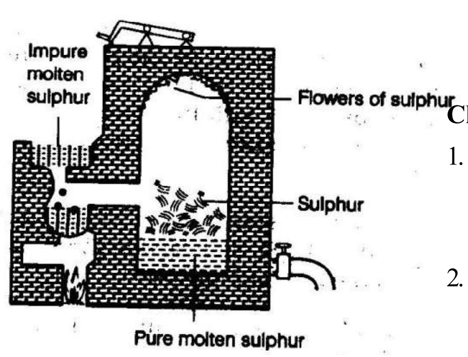
1. ***Frasch process*** This process is used to mine underground sulphur. In this process, a hole is bored down to the sulphur beds. Three concentric pipes are sunk through the hole. Superheated steam is forced down through the outermost pipe. Due to this superheated steam, sulphur in the bed melts. Through the innermost pipe, air at high pressure is forced down, which pumps up the molten sulphur through the middle pipe. Sulphur so obtained, 'is collected in wooden vats where it solidifies. This sulphur is found to be 99.5%

pure.



2. **Sicilian method** The crude sulphur found in Sicily contains limestone and rocky materials. Sulphur is obtained from it by heating it in Gill kiln. This kiln consists of closed brick chambers, having six interconnected compartments. Some of the sulphur is allowed to burn in one of the compartments. Hot air is allowed to cover the other compartments. As a result, sulphur melts and flows out, to be collected in wooden moulds.

Purification of Sulphur



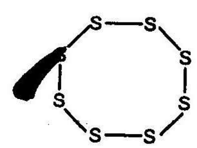
The sulphur obtained is purified by melting in an iron pot. The molten sulphur flows down to a retort where sulphur begins to boil. The vapours of sulphur are condensed in a chamber in the form of fine powder. This is known as *flowers of sulphur.* When the walls become hot, sulphur melts and collects on the floor of the chamber. Sulphur is drawn out from the floor and cast into sticks. The sulphur thus obtained is pure, and is called *roll sulphur.*

Properties of sulphur

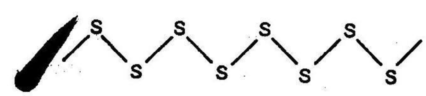
Physical Sulphur is a pale yellow solid. It exists in different allotropic forms. Ordinary sulphur does not dissolve in water. It, however, dissolves readily in carbon disulphide. It is a bad conductor of heat and electricity. It melts at 114°C and boils at 444°C.

Action of heat on sulphur On heating sulphur melts at 114°C to a pale yellow liquid. On further heating, sulphur becomes thicker arid darker. At 250°C, sulphur becomes almost immobile and does not flow down, even if the test-tube is inverted. On heating, it becomes mobile and boils at 444°C, producing) yellow vapours. On cooling, the above changes are reversed.

Explanation Sulphur molecules exist as S_8, i.e. a molecule of sulphur consists of 8 atoms of sulphur together, producing a ring-like structure. As more chains are formed, they become tangled and lengthened out. This causes the liquid to become highly viscous. On increasing the temperature the longer chains break up into smaller pieces and the mobility of the liquid increases again. At 444°C, the liquid becomes black and thin, and begins to boil.



When heated, the ring-like structure breaks up into chains .



Chemical

1. Reaction with oxygen: Sulphur burns in oxygen, forming sulphur dioxide.

$$s + o_2 \rightarrow so_3$$

2. Reaction with hydrogen: When hydrogen gas is passed into boiling sulphur, hydrogen sulphide is formed.

$$H_2 + S \rightarrow H_2S$$

3. Reaction with chlorine: When chlorine gas is passed into boiling sulphur, sulphur monochoride is formed.

$$Cl_2 + 2S \rightarrow S_2Cl_2$$

4. Reaction with carbon: When sulphur vapours are passed over red-hot carbon, carbon disulphide is formed.

$$C + 2S \rightarrow CS_2$$

5. Reaction with metals: When sulphur is heated with iron, zinc, copper, antimony, etc, the corresponding sulphides of metals are formed.

$$Fe + S \rightarrow FeS$$

$$Zn + S \rightarrow ZnS$$

$$Cu + S \rightarrow CuS$$

6. Action of acids: Sulphur is oxidized by oxidizing acids, like sulphuric acid and nitric and.

With hot and concentrated sulphuric acid it gives sulphuric dioxide.

$$S + 2H_2SO_4 \rightarrow 3SO_2 + 2H_2O$$

With concentrated nitric acid it forms sulphuric acid.

$$S + 6HNO_3 \rightarrow H_2SO_4 + 6NO_2 + 2H_2O$$

Uses of sulphur

1. In the manufacture of sulphuric acid
2. As antiseptic and as fungicide.
3. In the preparation of gunpowder
4. In the vulcanization of rubber

Uses of sulphur in vulcanization of rubber

Natural rubber is obtained from rubber trees. It is a polymer with long thread-like chains of molecules. The flexibility of the molecular chains allows rubber to be stretched, bent or coiled. However, crude rubber is weak and degrades with use, and exposure to air and sunlight, fore, crude rubber has to be processed and vulcanized.

The process of hardening rubber by heating it with sulphur is called vulcanization.

Sulphur added to crude rubber forms cross-links with the molecular chains , which make rubber hard and inhibits its elastic property.

The amount of sulphur added to rubber depends upon the end use. For example, a small amount of sulphur is added to the rubber used in rubber bands so that they can be stretched easily. On the other hand, tires used in vehicles have a large amount of sulphur to make them hard and durable.

SILICON

Occurrence It is the most common and widespread element on the earth. But it does not occur free in nature. It is always found as a compound, and almost always as an oxide. The simplest compound of silicon and oxygen is silicon dioxide which is commonly known as silica (or sand). Silicon also occurs in nature as quartz, flint and precious stones like opal, agate, etc.

Position in the periodic table Silicon belongs to group IV the periodic table. It is placed below carbon in the periodic table.

Electronic configuration The atomic number of silicon is 14. The electronic configuration is thus 2, 8, 4. Like carbon, it has 4 electrons in its outermost shell or valence sell. Hence, it is tetravalent.

Preparation of silicon Silicon is obtained from silicon dioxide. Silicon is separated from oxygen by the use of a reducing agent like coke which is one of the cheapest reducing agent.

Silicon dioxide is heated with coke in an electric

$$SiO_2 + 2C \rightarrow Si + 2CO$$

Properties of silicon

1. Silicon is a grey, hard and shining substance.
2. It melts at 1410^0C.
3. It is a crystalline solid, and its structure is similar to that of diamond. Each silicon atom is surrounded by four other silicon atoms. All the Si atoms are held together by a network of covalent bonds.
4. **Combination with oxygen** When heated in oxygen, silicon burns to produce a white solid, silica.

$$Si + O_2 \rightarrow SiO_2$$

5. **Reaction with chlorine** Amorphous silicon reacts with chlorine at 450°C to form silicon tetrachloride.

$$Si + 2C1_2 \rightarrow SiCl_4$$

6. **Reaction with water** When steam is passed over red-hot silicon, silicon dioxide and hydrogen are formed.

$$Si + 2H_2O \rightarrow SiO_2 + 2H_2$$

7. **Reaction with acid** Silicon reacts with hydrochloric acid, forming silicon tetrachloride with the evolution of hydrogen gas.

$$Si + 4HCl \rightarrow SiCl_4 + 2H_2$$

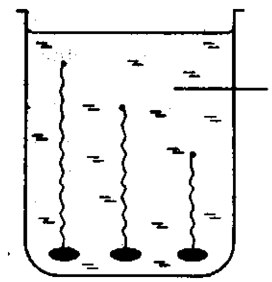
8. **Reaction with caustic soda** Silicon dissolves in hot sodium hydroxide solution with the evolution of H_2 gas.

$$Si + 2NaOH + H_2O \rightarrow Na_2SiO_3 + 2H_2$$

Uses of silicon

1. Silicon is used in the preparation of important polymers known as silicones.
2. Silicon is used in the preparation of various alloys of iron, aluminium, copper and manganese.
3. Silicon is used in semiconductor devices.
4. Silicon carbide (carborundum) is a very hard substance which is used in cutting and grinding tools.
5. Silicon dioxide is used in making glass and cement.

Silica garden



We can make an interesting display with sodium silicate (Na2S10$_3$) which is also called *water glass.* Take a dilute solution of water glass in a tall vessel. Now drop crystals of cobalt nitrate, ferrous sulphate and copper sulphate in such a way that they settle at different Points on the bottom of the vessel. Keep the vessel undisturbed overnight. You will see a colorful growth of crystals in vessel. This is called a silica garden and can be used as a decoration piece.

HALOGENS

The halogen family consists of the elements flourine, F; chlorine, Cl; bromine, Br; iodine, I; and astatine, At. All the halogen elements except astatine exist in the earth's crust and atompshere.

The halogens are the best-defined family of elements. They have an almost perfect gradation of physical properties. Flourine is pale yellow; chlorine, yellow green; bromine, dark brown and iodine, deep violet. Although all halogens generally undergo the same types of reactions, the extent and ease with which these reactions occur vary markedly. Flourine in particular has the usual tendency of the lightest member of a family of elements of exhibiting reactions not comparable to the other members.

Bromine and its compounds are used as disinfection and sanitizing agents in swimming pools and potable water. Bromine chemicals are used as intermediates in manufacturing organic dyes, in storage batteries and fire extinguishing systems.

Chlorine is used for purifying water. As a chemical compound, both organic and inorganic, chlorine has many uses. Some useful compounds are sodium chloride, calcium chloride, chloroform, methyl chloride, chlorobenzene, etc.

Flourine-containing compounds are used to increase the fluidity of melts and slags in the glass and ceramic industries It is also used as an additive to toothpastes and the nonsticking flouropolymer surfaces on frying pans.

The bactericidal properties of iodine and its compounds promote their use for treatment of wounds or purifying drinking water. Iodine compounds are also used to treat certain thyroid and heat conditions as a dietary supplement (iodised salt), and for X-ray contrast media.

NOBLE GASES

The noble gases are helium, neon, argon krypton, xenon and radon which, because of their low amount on the earth, have also been called rare gases. Due to their chemical inertness, they have been called inert or noble gases. All the noble gases, except radon, are present in atmosphere. (Radon is produced in the radioactive decay of radium). Helium is present in sun's atmosphere. All of them are colourles, odourless gases. As liquid these gases are used for providing very low temperature.

Argon is the most plentiful of these gases and is used as an inert atmosphere to surround aluminum, titanium and certain types of steel when they are welded. This means that the argon stops the metals from burnings or forming outside coating of oxide, which would make it difficult for them to be joined successful. Light bulbs also contain argon to prevent the filaments form burning out.

Neon is extensively used for making advertising signs. Tubes filled with the gas glow red when a high voltage is applied across the gas.

Helium is used as an alternative to hydrogen in meteorological balloons because it is a light gas, which, unlike hydrogen, does not burn. It is also used to dilute the oxygen which deep sea divers use because both pure oxygen and nitrogen are dangerous to breathe at the high pressures which exist under water.

Krypton and xenon are put into some electrical valves and T.V. tubes and in high powered lamps in lighthouses and miner's lamps.