CONTENT

1. PHYSICAL CHEMISTY

States of matter

Matter: The matter is that substance which occupies space, has a definite mass, can exert pressure, can produce physical resistance, has the virtue of inertia, states may be transformed through the energy, which can be decomposed or divided and whose existence be realised by our sence organs.

Types of matter

Broadly the matter has been divided into two categories:

(i) On the basis of physical composition.

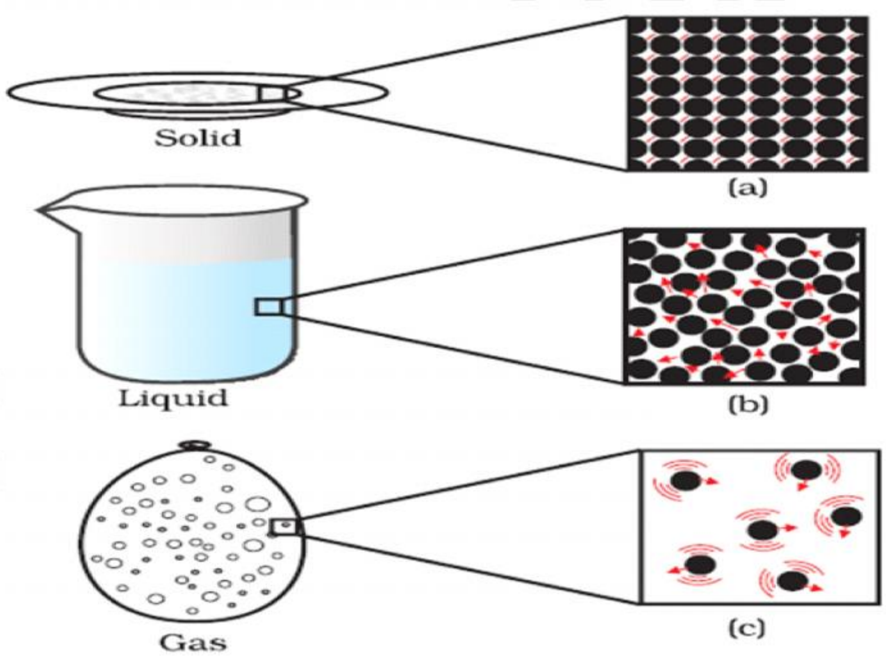
(ii) On the basis of Chemical composition.

(i) Physical composition of the matter: On the basis of physical composition, the matter is divided into three groups–solid, liquid and gas. The physical composition of matter totally depends on intermolecular forces existing among their molecules.

Solid: The solid is that state of a substance or a matter whose shape and volume (hence size) both are definite and fixed like table, book, stone pieces etc. When the intermolecular forces of attraction among the molecules of the substance is stronger than forces of separation then the substance is said to be in the solid state. Due to stronger intermolecular forces the molecules of the solid substance are compressed in dense form whose locations are fixed. At this position the molecules of the solid vibrate or oscillate about this position in intermolecular domain. That's why all solids have a definite shape and size.

Liquid: The liquid is that state of a substance or a matter whose volume (hence size) is definite but shape is not definite and fixed like water, milk, oil, wine etc. The substance which can flow is called fluid that's why all the liquids are fluids. It is also observed that whatever be the shape of the liquid but its upper surface is always plane. When the intermolecular forces of attraction among the molecules are only slightly greater than the corresponding forces of separation then the substance or matter is in the state of the liquid. Thus the molecules of the liquid are less densely compressed and these are free to move randomly but inside the substance. Although the intermolecular separation is not too large that's why it can change its shape but not its volume.

Gas: The gas is that state of the substance or matter whose shape and size (volume) both are indefinite and uncertain like air, H_2, N_2, O_2 etc. The gases also have no any own shape and size but only occupy the shape and size of the container in which these are kept. Also all gases are flowing, forces of attraction are weaker than corresponding forces of separation, the substance is found to be in the gaseous state. The molecules in the gas are remotely distributed and so intermolecular separation are too large and molecules are free to move randomly that's why it has no any definite shape and size.



(ii) Chemical composition of the matter: On the basis of the chemical composition, the matter is divided into three groups–element, compound and mixture.

Element: The element is that fundamental substance or matter which cannot be decomposed or divided into two or more different components which have different properties or characteristics by any physical or chemical process. In other words the element is that fundamental matter which is composed from identical atoms and any element also cannot be composed by any complex synthesis of two or more different components by any physical or chemical process.

On the basis of electronic configuration an element is that substance whose atoms have same nuclear charges. The examples of element are H_2, O_2, N_2, Fe, Cu, Ag etc. The element is of two types–Metals and Nonmetals. The metals are usually good conductors of electricity and heat and mostly found is solid states which are malleable and ductile. The examples of metals are Fe, Cu, Al, Ag, Pt, Au etc. The non-metals are usually bad conductors of electricity and heat, and these are brittle. One the basis of physical composition since matter is found to be in solid, liquid and gas that's why elements are also found in these three states.

Most of the elements found are solids like Fe, Cu, C, S, Ag, etc, while some are found as liquids like Hg, Br etc and some others are found as gases like H_2, O_2, N_2, Cl_2 etc. At present there are 114 elements which have been come into their existence. Out of 114 elements, 92 elements are naturally occurring and the rest elements are artificially made by the complex synthesis at the various laboratories in the world.

Compound: The compound is that pure substance which is formed by the chemical combination of two or more elements composed in a definite ratio. Also the physical and chemical properties of the formed compound are different than that of its constituents or component elements.

The examples of the compound are CO_2, H_2O, $KmnO_4$, H_2SO_4 etc. Obviously if we consider H_2O (water) then this compound is formed by the chemical combination of 2 atoms of hydrogen and 1 atom of oxygen but by weight it has the ration of 1:8. The physical and chemical properties of the water are different from hydrogen and oxygen.

Mixture: The mixture is that impure substance which is formed by two or more than two pure elements by the means of only a physical combination without any definite ratio. The examples of the mixture are air, brass (copper + zinc) etc, Air us the mixture of various gases like N_2, O_2, CO_2, etc. and water vapour.

Types of mixture: On the basis of the nature of constituents or components elements and on the properties and the composition of the mixture it is categorised into two groups–

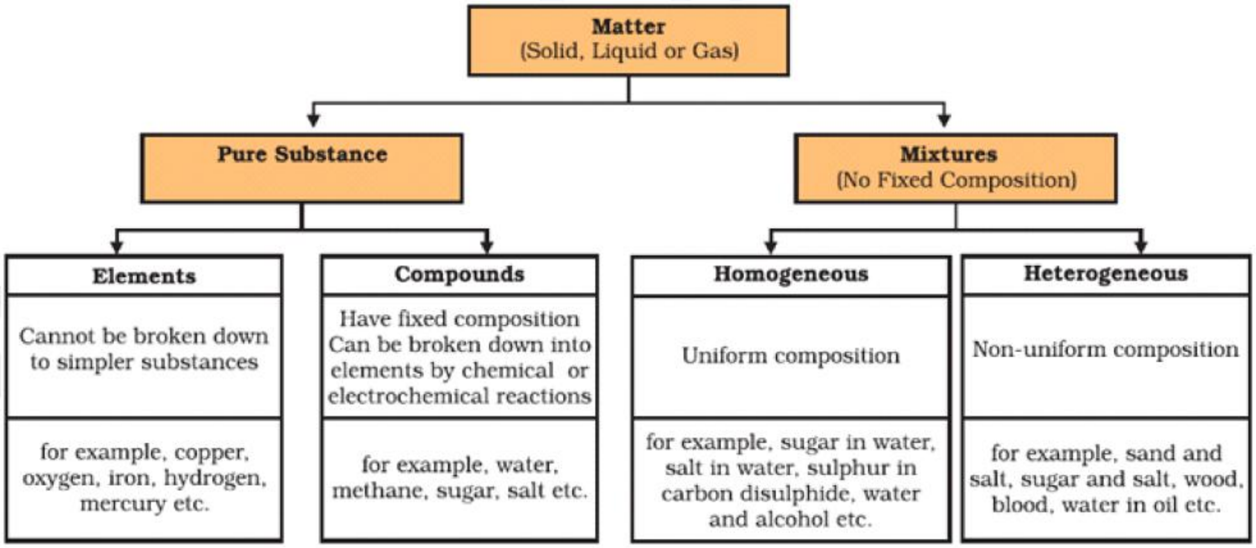
(i) Homogenous mixture: The mixture in which the every part has the same composition and properties as that of its component elements is called homogenous mixture.

The examples of homogeneous mixture are the electrolyte of sugar in water, the electrolyte of sulpher in carbon disulphide, the electrolyte of NH_3 in air etc.

(ii) Heterogeneous mixture: The mixture in which the every part has not the same composition and the properties as that of its component elements is called heterogeneous mixture.

The examples of heterogeneous mixture are the mixture of iron and sulpher, the mixture of silica (sand) and salt, the mixture of dust particles in air etc.

It is also observed that the component elements of the heterogeneous mixture can be easily separated than the component elements of the homogeneous mixture.



The component or constituent particles of the substance or matter:

Molecule: The smallest particle of the substance (element or compound) which can exist in free state but doesn't take part in chemical reactions and the properties of the substance (element or compound) are exactly present in it, called molecule.

The molecules of the substance are identical (same mass, shape, size) in every aspect but two different substances have different molecules in mass, shape and size.

For example water (H_2O) has all identical molecules and similarly common salt (NaCl) has also identical molecules but a molecule of H_2O is not identical as molecules of NaCl. The forces operative within these molecules are called intermolecular forces of attraction and due to these forces substances exist as solid or liquid, while in gas the existence of these forces become insignificant.

Types of molecule: There are two types of molecules—molecule of the element and the molecule of the compound. When the atoms of the same element are composed together then the smallest independent particles form and these particles are called molecules of the element. For example the molecule of the nitrogen (N_2) has been composed from two atoms of the nitrogen. Also the atoms of the element are identical in every respect for a particular element.

But when the atoms of more than one elements compose the smallest independent particles then these particles are called molecules of the compound. For example, each molecule of ammonia (NH_3) has been composed from one atom of nitrogen and three atoms of hydrogen.

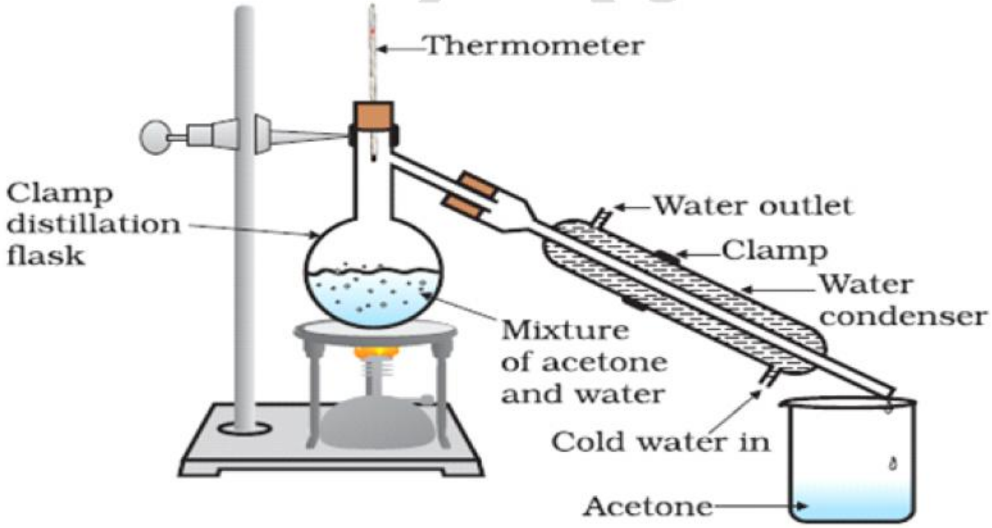
Atom: The smallest particle possible in any substance or element which doesn't exist in free state but takes part in chemical reactions and all characteristics of the substance or element are present in it is called the atom of the substance or the element.

Earlier theories of atomic models assumed that the atom is the ultimate smallest particle of the substance (matter) or element and it cannot be divided or decomposed further. Dalton also supported this view but later atomic theories clearly speculated and asserted that the atom is divisible and it is basically composed or constituted from electron, proton and neutron. The atoms of an element are identical in every respect but these are different from the atoms of other element. Thus the atoms of carbon is not identically same as the atoms of Nitrogen.

Separation of mixture: The components (constituents) of the mixture are separated by the various processes which are follows:

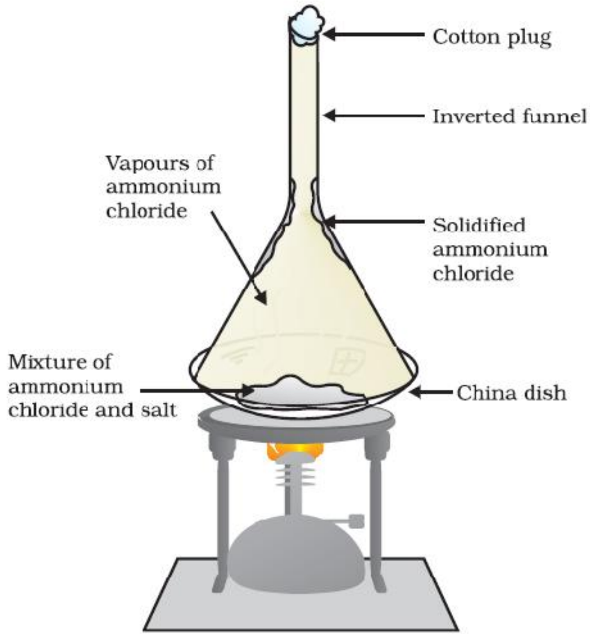
(i) Process of crystallisation: By the process of crystallisation the components present in inorganic solids are separated and purified. By this process impure solid or mixture is mixed with a suitable solvent and heated and at this position the solution is filtrated by a suitable filter (say, funnel). After filtration the solution is cooled and no cooling pure substance is separated in the form of crystal from the solution. The impurities of the mixture dissolve into the solution and these crystals are filtered, dried and separated.

(ii) Process of distillation: By the process of distillation mainly the mixture of the liquids are separated and especially those components mixtures are separated which have a substantial gap among the boiling points of the liquid mixture. In this process the component liquids are vapourised and transported to another place where these are cooled and transformed into the liquid state. Thus liquid mixtures are separated and purified and in the complete process two processes vapourisation and condensation are involved.



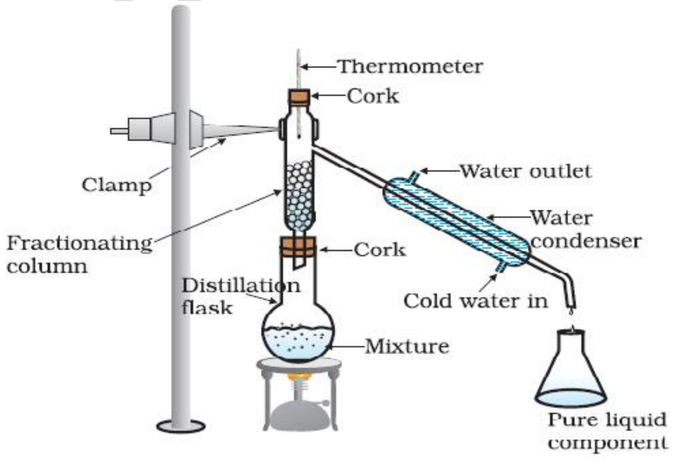
(iii) Process of sublimation: Normally when solid substances are heated, then it converts into liquid and on further heating this liquid is transformed into gas, but there are certain substances (solid) which are when heated convert directly into vapours or gases and on cooling (condensation) transform into solid directly. This is called sublimation and the corresponding substance is called sublimate.

Thus by the process of sublimation the mixture of two those solids are separated and purified in which one solid is sublimate. In this process the mixture is heated in which sublimate substance is vapourised and this vapour is collected separately and ultimately cooled. Thereby two solid substances are separated and the mixture is purified. The substances like Nefthelin, ammonium chloride, camphor Anthrasin, Benzoic acid etc. are sublimates.



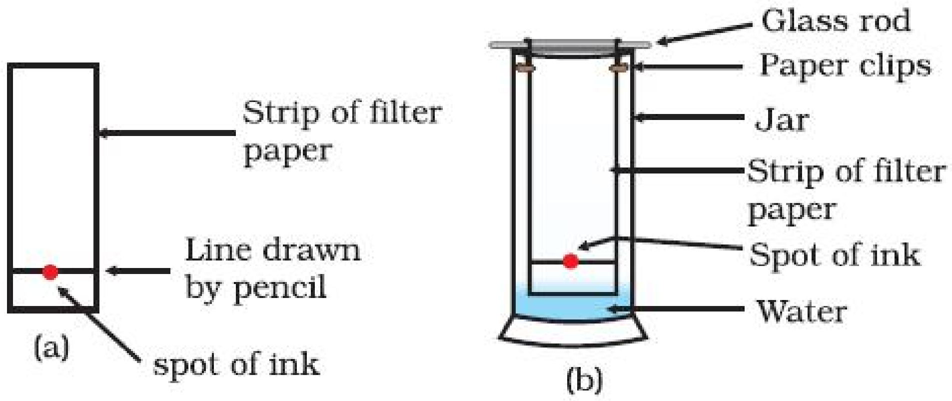
Separation of ammonium chloride and salt by sublimation

(iv) Process of fractional distillation: By the processes of fractional distillation those mixture of liquids are separated and purified which have a very narrow gap between their boiling points. Thus this process is applied for the mixture of those liquids which have nearly same boiling points. The extracted composite oil from the earth's crust through which petrol, diesel, K-oil etc are separated by the fractional distillation. The various gases from the aqueous air are also separated by this process.



Fractional distillation

(v) Process of chromatography: This process is basically applies for those mixtures whose various components have various absorption capacity and absorption is made at various distances and ultimately separated.



Separation of dyes in black ink using chromatography

(vi) Process of steam distillation: By the process of steam distillation those mixtures of organic substances are separated which are insoluble in water and vapourise with vapour. Also those organic substances are purified by this process which decompose at their respective boiling points. The organic substances (compounds) like Acetone, Acetaldehyde, Methyl alcohol etc. are purified by this process.

Difference between Mixtures and Compounds. In order to find out whether a given substance is a mixture or a compound, the following points of difference between the two may be kept in mind.

(i) A mixture can be separated into its constituents by physical processes, while this is not possible in case of compounds.

(ii) A mixture shows the properties of its constituents, while the properties of a compound are entirely differently from those of its constituents.

(iii) The preparation of a compound generally involves absorption or giving out of energy in the form of heat or light.

(iv) The composition of a mixture is variable; its consituents can be present in any proportion by weight. The composition of a compound is fixed, the constituents being present in fixed proportion by weight.

(v) A mixture does not have a fixed melting point, boiling point, etc., while a compound has a fixed melting point, boiling point, etc.

(vi) A mixture does not have a definite formula, whereas a compound has a definite formula.

2. ATOMIC THEORY OF MATTER

An Indian philosopher kanad was one of the first persons to propose that matter is made up of very small particles called 'parmanu' John Dalton called these particles 'atoms'. The word 'atom' means 'something which cannot be cut or divided'. In 1808, Dalton gave his atomic theory of matter which was confirmed by experiments. According to Dalton's atomic theory:

1. Each element (or other matter) is made up of very small and indivisible particles called atoms.
2. Atoms of the same element are identical in every respect, having the same mass, size and chemical properties. Atoms of different elements differ in mass, size and chemical properties.
3. Atoms of one element cannot be changed into atoms of others elements by chemical reactions. Atoms can neither be created nor destroyed in a chemical reaction.
4. Atoms of different elements combine to form compounds.
5. The 'number' and 'kind' of atoms in a given compound is fixed.

One of the drawbacks of Dalton's atomic theory is that atoms were thought to be indivisible (which cannot be divided). We now know that atoms can be divided). We now know that atoms can be further divided into still smaller particles called electrons, protons and neutrons. So, atoms are themselves made up of three particles: electrons, protons and neutrons.

Law of chemical combination. We shall now state three important laws of chemical combination and try to explain them on the basis of Dalton's atomic theory.

1. Law of conservation of matter (or mass). According to this law: "Matter can neither be created nor destroyed in a chemical reaction". This law means that the mass of the substances before a chemical reaction is exactly equal to the mass of the substances after the reaction. That is, the mass of reactants is exactly equal to the mass of the products and there is no change in mass in a chemical reaction.

Explanation: Dalton's atomic theory says that "atoms can neither be created nor destroyed in a chemical reaction". Since all the matter is made up of atoms, we can also say that "matter can neither be created nor destroyed in a chemical reaction".

The reaction between silver nitrate solution and sodium chloride solution can be written as:

$AgNO_3$ + NaCl AgCl
(Silver nitrate) (Sodium choride) (Silver Chloride)
+ $NaNO_3$
(Sodium nitrate)

When silver nitrate reacts with sodium chloride, there is simply a rearrangement of atoms, the total number of atoms before the reaction and after the reaction, remains the same. So the mass or matter is conserved in this reaction.

2. Law of constant composition or Law of definite proportion. According to this law: "The composition of a pure compound is always the same". This law can also be stated as: "A compound always contains the same elements combined together in the same proportion by weight". This law means that whatever be the source from which a compound is obtained, it is always made up of the same elements in the same percentage.

Explanation. According to one of the postulates of Dalton's atomic theory: "The number and kind of atoms in a given compound is fixed". Since the number of atoms and the type of atoms in a given compound is fixed, a compound will always have the same percentage of the same elements, hence it will have a constant composition.

Water molecule (H_2O) always contains 2 atoms of hydrogen and 1 atom of oxygen. Since water molecule always contains the same number of hydrogen and oxygen atoms, hence it always contains the same percentage of the two elements. So, water has a constant composition.

3. Law of Multiple Proportions. This law states that when two elements combine to form two (or more than two) compounds, then the weights of one of these elements which combine with a fixed weight of the other element, bear a simple ratio to one another.

Explanation. According to Dalton when two elements combine to form more than one compound, if we fix the weight of one, we also fix the number of atoms of that element. In each compound with that number of atoms, a whole number of atoms of other element will combine. For example, peroxide (H_2O_2) by the combination of hydrogen and oxygen atoms.

In water two atoms of hydrogen combine with one atom of oxygen. In hydrogen peroxide, two atoms of hydrogen combine with two atoms of oxygen. Hence the ratio of oxygen combining with the fixed amount of hydrogen is 1:2 between water and hydrogen peroxide. This is also the ratio of their weights.

Law of Equivalent Weights. Each elements has a characteristic combining weight by which it can be represented whenever calculating the weight relationships expected for chemical reactions. The chemist defines this equivalent weight as equal to the atomic weight divided by valence. In the case of oxygen this is $16_{+}2 = 8$; for hydrogen it is $1_{+}1 = 1$; for chlorine it is $35.5_{+}1 = 35.5$.

AVOGADRO'S HYPOTHESIS

In 1811 Amedeo Avogadro proposed that 'equal volumes of different gases at the same temperature and pressure contain equal number of molecules'. This statement was initially known as Avogadro's hypothesis which is now firmly established and is known as Avogadro's law. This hypothesis gave a relationship between gram molecular mass, volume and number of molecules present therein. It was found that at STP (Standard Temperature and Pressure i.e. at 0ºC and 760 mm of mercury) one gram molecular mass or one mole of all the gases occupy a volume of 22.4 litres or 22400 ml. This volume of the gas is known as standard molar volume. Now we can say that: At constant temperature and pressure, the volume of gas is directly proportional to number of molecules. This may be expressed as:

V á n (P and T constant), where n is the number of moles. According to Avogadro's hypothesis, equal volume of gases contain equal number of molecules. A gram molecule of any substance (not only gases) will contain the same number of molecules. No doubt, in the case of a gas this number of molecules always occupies the same volume, but this not so for liquids and solids. The actual number of molecules in a gram-molecule is known as Avogadro's number and its value is 6.023×10^{23} molecules.

MOLE CONCEPT

A group of 6.023×10^{23} particles (atoms or molecules) of a substance is called a mole of that substance.

1 mole of atoms = 6.023×10^{23} atoms

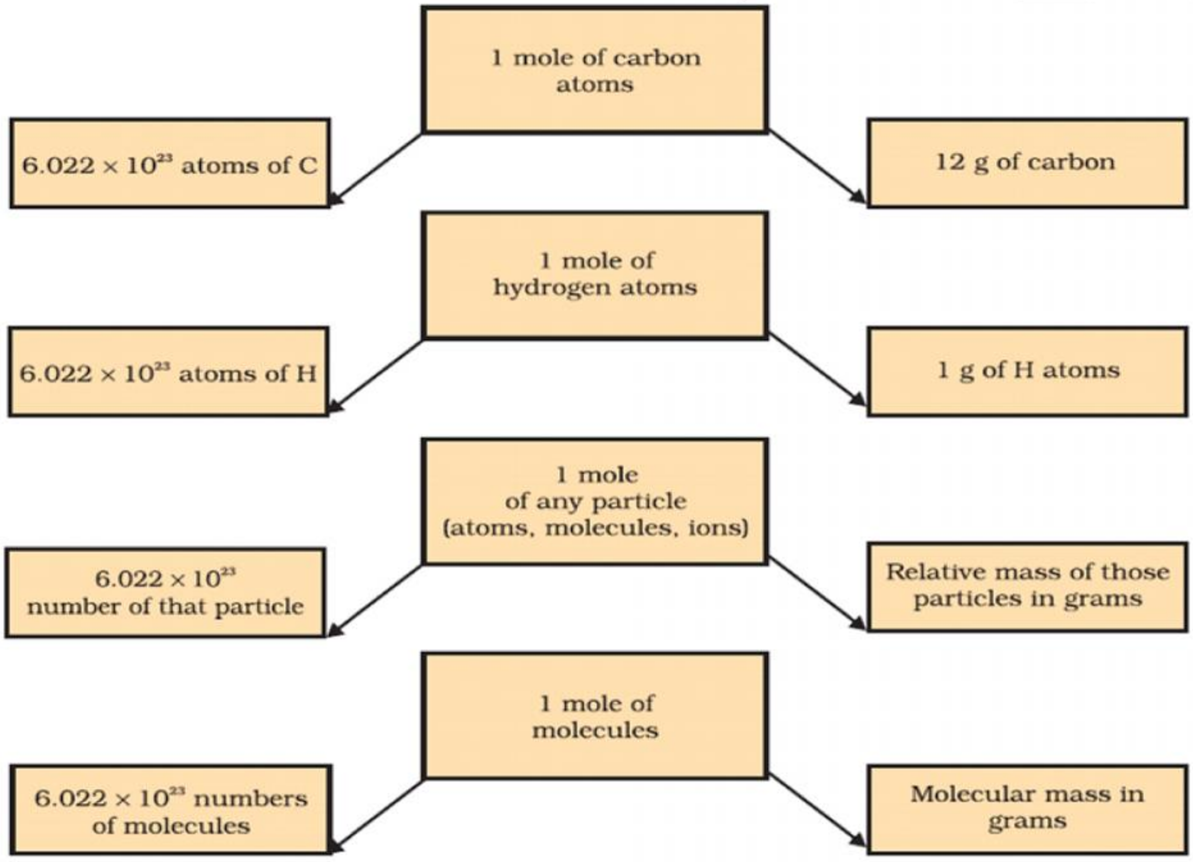
1 mole of molecules = 6.23×10^{23} molecules

Mole of Atoms. One mole of atoms of an element has a mass equal to the gram atomic mass of the element. For example:

1 mole of oxygen atoms (O) = Gram atomic mass of oxygen (O) = 16g.

Mole of Molecules. One mole of molecules of a substance has mass equal to the gram molecular mass of the substance. For example 1 mole of oxygen molecules (O_2) = 32g (Since molecular mass of O_2 is 32).

From the above discussion a mole of a substance may also be defined as that amount of substance which contains the same number of particles (atoms or molecules) as there are carbon-12 atoms in 12 grams of carbon-12 element. Thus, the unit of amount of a substance is mole which is represented as mol.



3. STRUCTURE OF ATOM

Up to the end of 19th century, the Dalton's atomic model remained undisputed. But the new discoveries towards the end of 19th century and early 20th century showed that atom has a complex structure and is not indivisible. The studies also showed that the atoms are made up electrons, protons and neutrons. Properties of elements are explained on the basis of negatively charged electrons around a positively charged mass, situated at the centre of the atom, called nucleus. The positively charged nucleus containing protons and neutrons occupies much less space in an atom compared to the large space in which the electrons are distributed.

Table

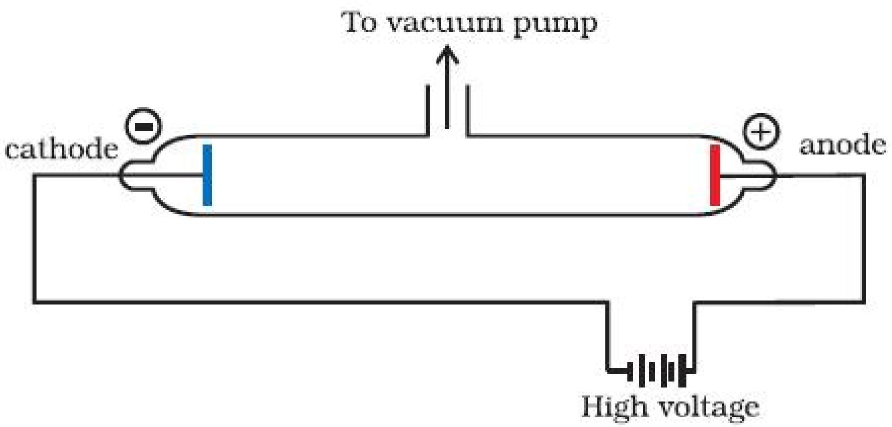
Positions, relative masses and relative charges of electrons, protons and neutrons

Name	Symbol	Absolute charge/C	Relative charge	Mass/kg	Mass/u	Approx. mass/u
Electron	e	-1.6022×10^{-19}	-1	9.10939×10^{-31}	0.00054	0
Proton	p	$+1.6022\times10^{-19}$	$+1$	1.67262×10^{-27}	1.00727	1
Neutron	n	0	0	1.67493×10^{-27}	1.00867	1

ELECTRONS

After the Dalton's atomic model, one of the significant advances was made by J.J. Thomson. This was the discovery of charged particles called electrons. They are extremely small in size. The existence of electrons is proved by experiments using discharge tubes. When an electric discharge at a very high voltage is passed through a gas contained in a glass tube at a very low pressure, a particular type of rays emanate from the cathode which are known as cathode rays. These rays travel in straight lines. The particles constituting these rays possess significant amounts of kinetic energy. When these rays are allowed to pass through a strong electric field, they are deflected away from the negative plate. These facts lead to the conclusion that cathode rays consist of rapidly moving negatively charged particles. These particles are known as electrons. They are present in all atoms around the nucleus in definite energy levels.

The absolute mass of electron is $9.1\text{x}10^{-31}$ kg which is approximately 1/1840 of the mass of a proton or a hydrogen atom. The absolute charge of electron is 1.6t02 x 10^{-19} coulomb of negative charge. This has been taken to be one unit of negative charge.



PROTONS

Like electrons, protons also present in all atoms. Presence of protons was observed by Goldstein in 1896 in a discharge tube with a perforated cathode. It was observed that a stream of protons passed through the holes in the cathode in a direction away from the anode. A beam of protons (or any other positively charged particles) is also known as positive rays.

Experiments carried out by Lord Rutherford showed that positive particles produced in a discharge tube containing hydrogen gas are same as protons.

Protons are positively charged particles. Mass of each proton is same as that of a hydrogen atom. But the mass of hydrogen atom is 1 a.m.u., therefore the relative mass of a proton is 1 a.m.u. However, the absolute mass of a proton is 1.6×10^{-27} kg. The charge of proton is equal and opposite to the charge of an electron. So, the absolute charge of a proton is 1.6×10^{-19} coulomb of positive charge which has been taken to be one unit of positive charge.

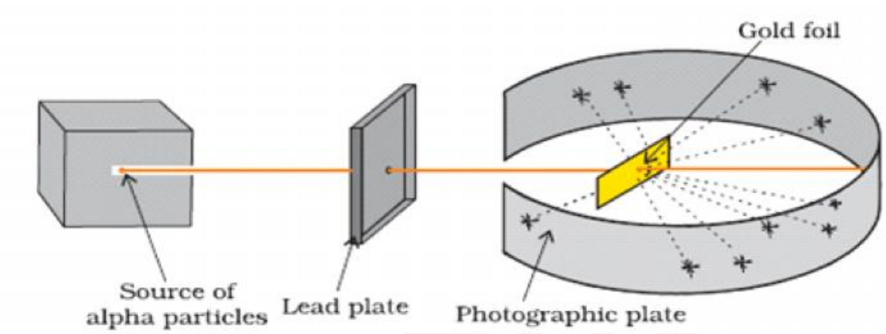
NEUTRONS

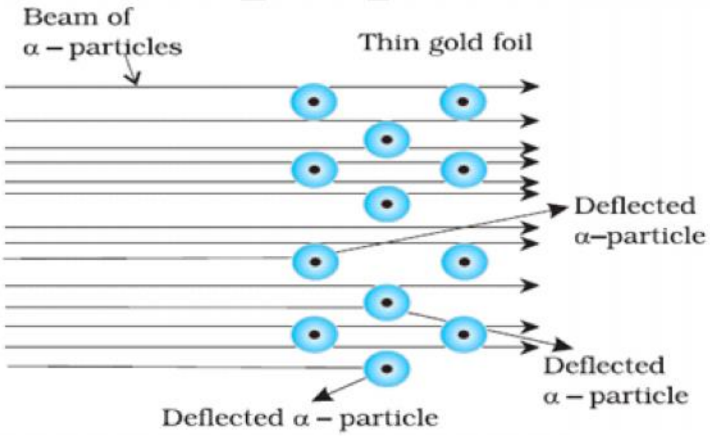
One atom of hydrogen has one proton and one electron. One atom of helium has two protons and two electrons. Therefore, the relative atomic mass of helium should be twice that of hydrogen. But in fact the relative atomic mass of helium in 4 and not 2.

This discrepancy was removed by the discovery of neutrons by James Chadwick in 1932. Chadwick's experiments showed that apart from protons, nuclei of all atoms except that of hydrogen atom, contain another type of particles which have the same mass as hydrogen atoms or protons. These particles do not carry any electric charge i.e., they are electrically neutral. Thus an atom of helium contains 2 protons and 2 neutrons which make its relative mass equal to 4.

RUTHERFORD'S EXPERIMENT–ATOMIC MODEL

In 1911, Lord Rutherford bombarded a gold leaf with a stream of alpha-particles (an alpha-particle is a positively neutrons). He observed that whereas most of the alpha-particles penetrated the gold leaf, some of them were deflected from their path; some alpha-particles were even repelled by the gold leaf.





Concluding the results of his experiment, Rutherford suggested that:

1. The central part of an atom, called nucleus, is positively charged;
2. Nearly total mass of the atom is concentrated in the nucleus of the atom;
3. The space occupied by the central part (nucleus) of the atom is much less than the much larger space in which the electrons revolve around the nucleus.

Based on the above experiment, Rutherford proposed that each atom consisted of a positive nucleus around which negatively charged electrons are revolving. Since an atom is electrically neutral, therefore, the number of electrons in the atom of an element should be the same as the number of protons in its nucleus. Accordingly, in an atom of hydrogen, the lightest element, helium, two electrons and two protons are present.

ATOMIC NUMBER AND MASS NUMBER

Atomic Number. The number of positive charge carried by the nucleus of an atom is termed as atomic number or charge number (Moseley 1913) is represented by symbol Z. Since the charge on the nucleus is equal to the number of the protons (P) in it which in turn is equal to the number of electrons (e) in the atom, the atomic number is defined as the number of protons or the number of electrons for a neutral atom in the atom.

Mass Number. The total number of the protons and neutrons present in the nucleus of the atom is known as the mass number of the atom.

BOHR'S MODEL OF AN ATOM

In 1913, Niels Bohr put forward his theory to explain the structure of an atom. According to Bohr's theory:

1. The nucleus of an atom is situated at its centre.
2. The electrons in an atom revolve around the nucleus in definite circular paths known as energy levels.
3. Each energy level has a fixed amount of energy.
4. The energy levels are either designated at K,L,M, N, etc. or numbered n = 1, 2, 3, 4 etc. outwards from the nucleus.
5. The change in the energy of an electron takes place only when it jumps from a higher energy level to a lower energy level (loss of energy), or, when it jumps from a lower energy level to a higher energy level (gain of energy).
6. Thus, as long as electrons continue to revolve in the same energy level, they neither lose nor gain energy and the atom remains stable.

DISTRIBUTION OF ELECTRONS IN DIFFERENT ENERGY LEVELS

The distribution of electrons in different energy level is governed by a scheme known as Bohr-Bury scheme which states that:

(i) The maximum number of electrons that can be accommodated in any energy level in 2n2 where n is number of that energy level. The energy levels are also known as shells. Thus,

(ii) K- shell (n=1) can have $2x1^2 = 2$ electrons.

(iii) L- shell (n=2) can have $2x\ 2^2 = 18$ electrons.

(iv) M- shell (n=3) can have $2x3^2 = 18$ electrons.

(v) N- shell (n=4) can have $2x4^2 = 32$ electrons.

(vi) The electrons first occupy the shell with the lower energy.

(vii) The outermost shell of an atom cannot have more than 8 electrons and next to the outermost shell cannot have more than 18 electrons.

The systematic distribution of electrons in different energy shell is called the electronic configuration of the atom.

VALENCE SHELL AND VALENCE ELECTRONS

The outermost orbit of an atom is called its valence shell. The electrons present in the outermost shell of an atom are known as the valence electrons. Only valence electrons of an atom take part in chemical changes and determine its combining capacity which is known as valency of the atom.

ISOTOPES AND ISOBARS

Istopes. In 1919, F.W. Aston discovered that the atoms of some naturally-occuring elements were not exactly alike. He observed that these atoms of the same element had different masses. Such types of atoms of the same element are known as isotopes. All the isotopes of any element have the same atomic number because their nuclei contain the same number of protons, but their mass numbers are different because the numbers of neutrons in their nuclei are different. Since the isotopes of any element contain the same number of electrons, therefore, they have the same chemical properties. However, as the number of neutrons in the nuclei of the atoms of different isotopes is different, their physical properties like densities and melting and boiling points are slightly different. Examples of isotopes of some elements are:

Hydrogen – Protium (${}^{1}_{1}H$), Deuterium, Tritium (${}^{3}_{1}H$)

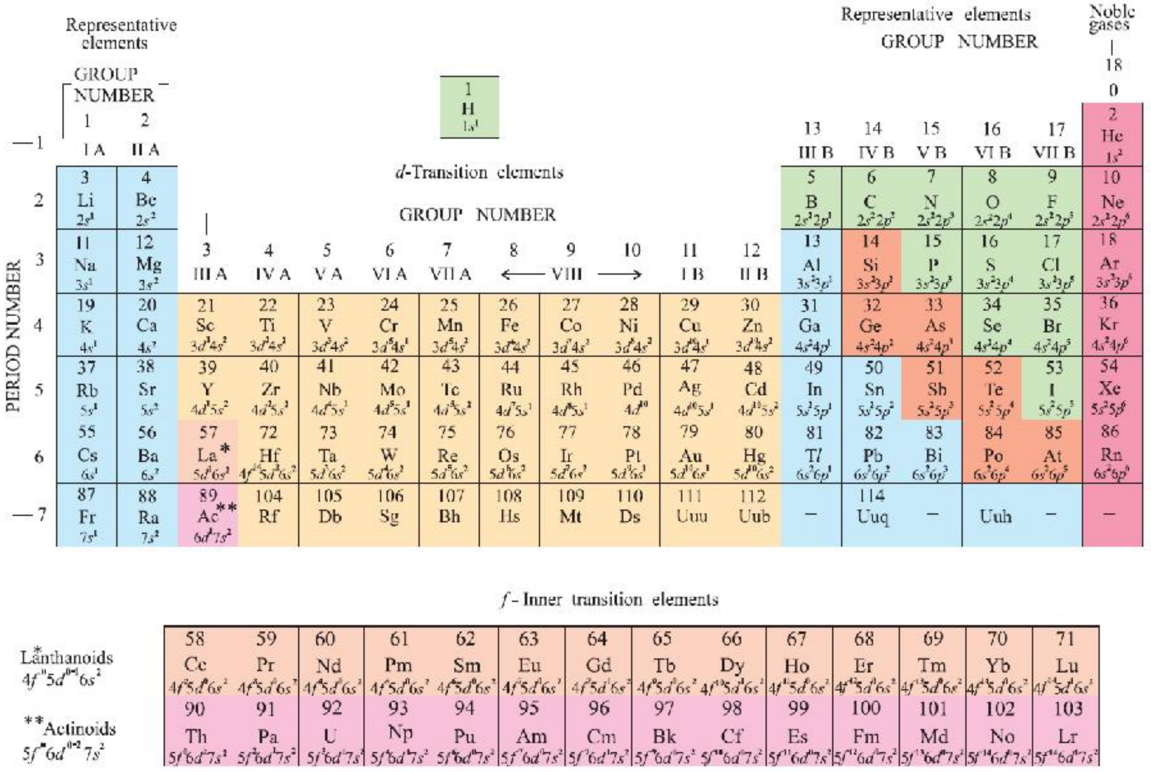
Chlorine – Chlorine-35 (${}^{35}_{17}Cl$), Chlorine-37 (${}^{37}_{17}Cl$)

Carbon – Carbon-12 (${}^{12}_{6}C$), Carbon -14 (${}^{14}_{6}C$)

Isobars. It is a well known fact that the atomic number of no two elements is same. In general, the mass numbers of the different elements are also different. However, there are some cases, like argon (${}^{40}_{18}Ar$) and calcium (${}^{40}_{20}Ca$), where the mass number is the same, and as the elements are different, the atomic numbers are different. Such pairs of elements are known as isobars. Hence, isobars may be defined as those elements which have the same mass number (atomic mass) but different atomic numbers.

4. PERIODIC CLASSIFICATION OF ELEMENTS

In 1869, a Russian chemist, Dmitri Ivanovich Mendeleev gave a very handy and useful concept to chemists. He stated that elements, if arranged according to their atomic weight, show a distinct periodicity of their properties. Based on this statement, Mendeleev arranged all elements in periodic table in the ascending order of their atomic weights (or atomic numbers). There are horizontal and periods (horizontal columns are also called zero group and sub-groups–these have numbers 1A-7A, 1B-7B, and 8 (three columns). The properties of all elements in one sub-group are the same.



PERIOD NUMBER	1 I A	2 II A	3 III A	4 IV A	5 V A	6 VI A	7 VII A	8	9 VIII	10	11 I B	12 II B	13 III B	14 IV B	15 V B	16 VI B	17 VII B	18 0
1							1 H $1s^1$											2 He $1s^2$
2	3 Li $2s^1$	4 Be $2s^2$											5 B $2s^22p^1$	6 C $2s^22p^2$	7 N $2s^22p^3$	8 O $2s^22p^4$	9 F $2s^22p^5$	10 Ne $2s^22p^6$
3	11 Na $3s^1$	12 Mg $3s^2$											13 Al $3s^23p^1$	14 Si $3s^23p^2$	15 P $3s^23p^3$	16 S $3s^23p^4$	17 Cl $3s^23p^5$	18 Ar $3s^23p^6$
4	19 K $4s^1$	20 Ca $4s^2$	21 Sc $3d^14s^2$	22 Ti $3d^24s^2$	23 V $3d^34s^2$	24 Cr $3d^54s^1$	25 Mn $3d^54s^2$	26 Fe $3d^64s^2$	27 Co $3d^74s^2$	28 Ni $3d^84s^2$	29 Cu $3d^{10}4s^1$	30 Zn $3d^{10}4s^2$	31 Ga $4s^24p^1$	32 Ge $4s^24p^2$	33 As $4s^24p^3$	34 Se $4s^24p^4$	35 Br $4s^24p^5$	36 Kr $4s^24p^6$
5	37 Rb $5s^1$	38 Sr $5s^2$	39 Y $4d^15s^2$	40 Zr $4d^25s^2$	41 Nb $4d^45s^1$	42 Mo $4d^55s^1$	43 Tc $4d^55s^2$	44 Ru $4d^75s^1$	45 Rh $4d^85s^1$	46 Pd $4d^{10}$	47 Ag $4d^{10}5s^1$	48 Cd $4d^{10}5s^2$	49 In $5s^25p^1$	50 Sn $5s^25p^2$	51 Sb $5s^25p^3$	52 Te $5s^25p^4$	53 I $5s^25p^5$	54 Xe $5s^25p^6$
6	55 Cs $6s^1$	56 Ba $6s^2$	57 La* $5d^16s^2$	72 Hf $4f^{14}5d^26s^2$	73 Ta $5d^36s^2$	74 W $5d^46s^2$	75 Re $5d^56s^2$	76 Os $5d^66s^2$	77 Ir $5d^76s^2$	78 Pt $5d^96s^1$	79 Au $5d^{10}6s^1$	80 Hg $5d^{10}6s^2$	81 Tl $6s^26p^1$	82 Pb $6s^26p^2$	83 Bi $6s^26p^3$	84 Po $6s^26p^4$	85 At $6s^26p^5$	86 Rn $6s^26p^6$
7	87 Fr $7s^1$	88 Ra $7s^2$	89 Ac** $6d^17s^2$	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Uuu	112 Uub	–	114 Uuq	–	Uuh	–	–

f - Inner transition elements

*Lanthanoids $4f^{n}5d^{0-1}6s^2$	58 Ce $4f^25d^06s^2$	59 Pr $4f^35d^06s^2$	60 Nd $4f^45d^06s^2$	61 Pm $4f^55d^06s^2$	62 Sm $4f^65d^06s^2$	63 Eu $4f^75d^06s^2$	64 Gd $4f^75d^16s^2$	65 Tb $4f^95d^06s^2$	66 Dy $4f^{10}5d^06s^2$	67 Ho $4f^{11}5d^06s^2$	68 Er $4f^{12}5d^06s^2$	69 Tm $4f^{13}5d^06s^2$	70 Yb $4f^{14}5d^06s^2$	71 Lu $4f^{14}5d^16s^2$
**Actinoids $5f^{n}6d^{0-2}7s^2$	90 Th $5f^06d^27s^2$	91 Pa $5f^26d^17s^2$	92 U $5f^36d^17s^2$	93 Np $5f^46d^17s^2$	94 Pu $5f^66d^07s^2$	95 Am $5f^76d^07s^2$	96 Cm $5f^76d^17s^2$	97 Bk $5f^96d^07s^2$	98 Cf $5f^{10}6d^07s^2$	99 Es $5f^{11}6d^07s^2$	100 Fm $5f^{12}6d^07s^2$	101 Md $5f^{13}6d^07s^2$	102 No $5f^{14}6d^07s^2$	103 Lr $5f^{14}6d^17s^2$

Periodic Trends in Properties

(i) Valency The valency depends on the number of electrons present in the valence or outermost orbit of an atom. In some cases, valency is equal to the number of electrons in the valence orbit of the atom, while in others it is equal to 8 minus valence electrons.

Sodium (2, 8, 1) has valency 1 and chorine (2, 8, 7) also has valency 1, i.e. (8-7).

Group Valency of all elements in a group is same.

Period From moving left to right in a period, valency first increases from 1 to 4 (valence electrons) and then decreases from 4 to 0 (8 minus valence electrons).

(ii) Atomic Size The atomic size is the radius of an atom.

Group Atomic size increases down the group because the number of orbits occupied by electrons increase.

Period Atomic size decreases from moving left to right in a period because of increase in the effective nuclear charge (no. of protons) which pulls the electrons inwards.

(iii) Electro positivity is defined as the tendency of the atom of form positive ions or losing electrons.

$$\rightarrow M^+ + e^-$$

Group Electro positivity increases down the group because of increasing atomic size.

Period Electro positivity decreases across the period because of the decrease of atomic size.

(iv) Electro negativity is the tendency of the atom of an element to form negative ions by accepting electrons.

$$X^+ e^- \rightarrow X^-$$

If follows the reverse trend down the group and across the period than that of electro positivity for the same reasons.

5. CHEMICAL BONDING

The chemical reactions between atoms of different elements take place as a result of bond formation between them to give new molecules. When two or more atoms come together and react with each other, a chemical bond of some kind is formed between them. This bond is formed between the electrons in the outermost orbit of the atom reactions and chemical bonding). It is seen that the elements of the zero group (inert gases or noble gases) do not react with any other atom—their outermost orbits contain eight electrons. Hence, atoms of different elements combine or undergo chemical reactions (or bonding) to attain eight electrons in their outermost orbits. There are basically two ways in which this can be attained.

Electrovalent (Ionic) Bond An electrovalent bond is formed when electrons from one atom are completely transferred to another atom of a different element. It is also called an ionic bond.

Consider the formation of sodium chloride (NaCl) by combination of one atom of sodium with one atom of chlorine:

Electronic configuration of sodium (Z=11) is 2, 8, 1 or $1s^2$, $2s^2$, $2p^6$, $3s^1$.

Electronic configuration of the nearest noble gas, neon (Z=10) is 2, 8, or $1s^2$, $2s^2$, $2p^6$.

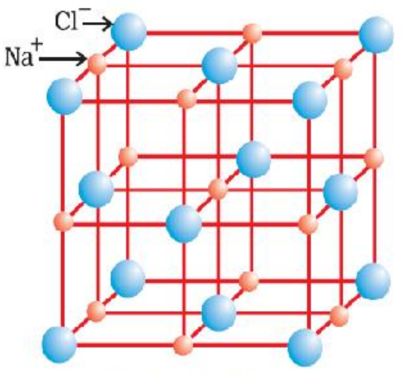
Electronic configuration of the nearest noble gas, argon (Z=18) is 2, 8, 7 or $1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^5$.

Electronic configuration of the nearest noble gas, argon (Z=18) is 2, 8, 8 or $1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^6$.

Sodium attains the nearest noble gas electronic configuration (of neon) by losing its outermost, $3s^1$ electron. The result of the loss of this electron is that sodium develops a positive charge because atom as a whole is electrically neutral. Chlorine attains the nearest noble gas configuration of argon by accepting the electron released by sodium. The result of the acceptance of the electron by chlorine is that it gets a negative charge (because electron is negatively charged).

$$\begin{array}{lcl}
\mathrm{Na} & \rightarrow & \mathrm{Na^+} + e^- \\
[\mathrm{Ne}]\ 3s^1 & & [\mathrm{Ne}] \\
\mathrm{Cl} + e^- & \rightarrow & \mathrm{Cl^-} \\
[\mathrm{Ne}]\ 3s^2\ 3p^5 & & [\mathrm{Ne}]\ 3s^2\ 3p^6 \text{ or } [\mathrm{Ar}] \\
\mathrm{Na^+} + \mathrm{Cl^-} & \rightarrow & \mathrm{NaCl} \text{ or } \mathrm{Na^+Cl^-}
\end{array}$$

Such structures which show arrangement of valence electrons of various atoms are called Lewis structures. The sodium ion (Na^+) and chloride ions (Cl^-), thus formed, are held together by the strong electrostatic forces of attraction as they are oppositely charged ions. The diagrammatic representation of formation of NaCl from sodium and chlorine atoms is shown in Fig. 5.1. In all electrovalent compounds, the different species are held together by such forces.



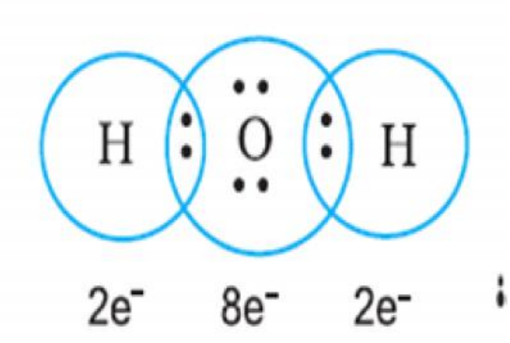
Rock salt structure

Fig 5.1

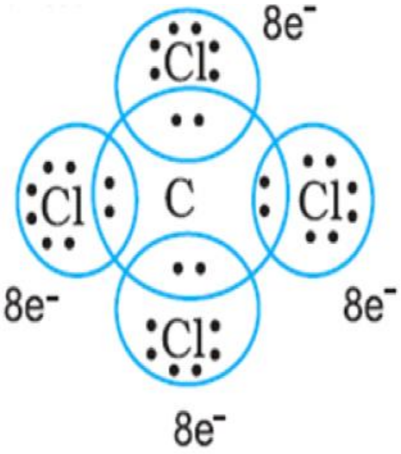
Covalent (Chemical) Bond A bond formed by the sharing of a pair of electrons between two atoms of the same or different elements, when each atom contributes one electron pair is called a covalent bond.

Consider the formation of hydrogen molecule (H_2). Electronic configuration of the nearest nobel gas (He) (Z = 2) is $2s^2$.

The outer shell of hydrogen atom has one electron which is one short of nearest noble gas (He). Therefore, hydrogen atoms combine to give hydrogen molecule (H_2), in which the hydrogen atoms contributing one electron to the shared pair. In this way, both the hydrogen atoms attain the nearest noble gas configuration, i.e. of helium as shown in Fig. 5.2. Similarly, the formation of water, ammonia and carbon tetrachloride can be represented as shown in Fig. 5.2.



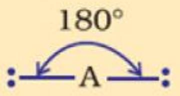
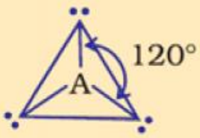
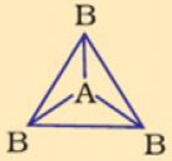
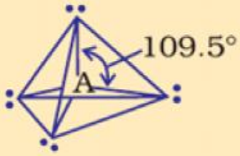
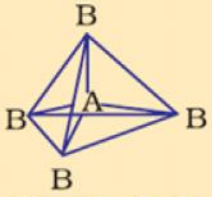
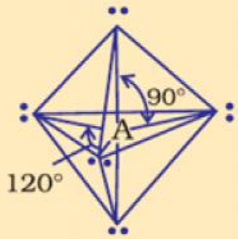
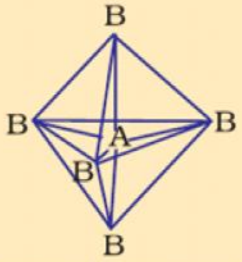
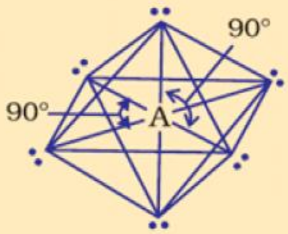
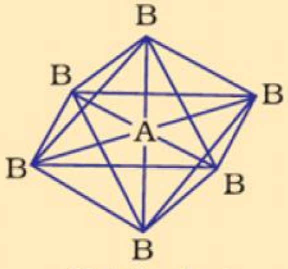
H atoms attain a duplet of electrons and O, the octet



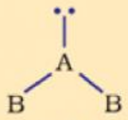
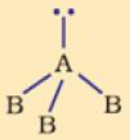
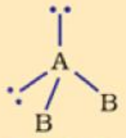
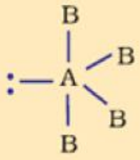
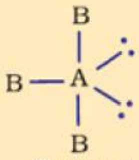
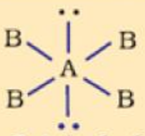
Each of the four Cl atoms along with the C atom attains octet of electrons

Shapes of Molecules We have discussed that ionic bonds arise due to electrostatic attractions. Since the forces of attraction between oppositely charged species are non-directional, i.e. the strength of interaction between two charges depends on the distance but not on the direction, the structure is determined almost entirely by the relative sizes of the ions. Covalent bonds are, however, directional and the shape of a covalently bonded molecule is decided by the directions of the covalently bonded molecule is decided by the direction of the covalent bonds. Molecules showing different geometrical patterns, viz. Linear, round, flat and spiral shapes are known. Also known are linear, triangular, square planar, pyramidal, octahedral and many other arrangements. Many physical and chemical properties are the result of the shape that a molecule has. For example, some of the unique properties of the water molecule are due to the angular shape of H2O, a linear arrangement of the three atoms would drastically alter these properties. Similarly, the biologically important DNA molecule partly owes its physicochemical behavior to its double spiral shape. Also, proteins owe their catalytic activity to their special helical shape.

Geometry of Molecules in which the Central Atom has No Lone Pair of Electrons

Number of electron pairs	Arrangement of electron pairs	Molecular geometry	Examples
2	 Linear	B—A—B Linear	BeCl$_2$, HgCl$_2$
3	 Trigonal planar	 Trigonal planar	BF$_3$
4	 Tetrahedral	 Tetrahedral	CH$_4$, NH$_4^+$
5	 Trigonal bipyramidal	 Trigonal bipyramidal	PCl$_5$
6	 Octahedral	 Octahedral	SF$_6$

Shape (geometry) of Some Simple Molecules/Ions with Central Ions having One or More Lone Pairs of Electrons(E).

Molecule type	No. of bonding pairs	No. of lone pairs	Arrangement of electron pairs	Shape	Examples
AB_2E	2	1	 Trigonal planar	Bent	SO_2, O_3
AB_3E	3	1	 Tetrahedral	Trogonal pyramidal	NH_3
AB_2E_2	2	2	 Tetrahedral	Bent	H_2O
AB_4E	4	1	 Trigonal bi-pyramidal	See saw	SF_4
AB_3E_2	3	2	 Trigonal bi-pyramidal	T-shape	ClF_3
AB_5E	5	1	 Octahedral	Square pyramid	BrF_5
AB_4E_2	4	2	 Octahedral	Square planar	XeF_4

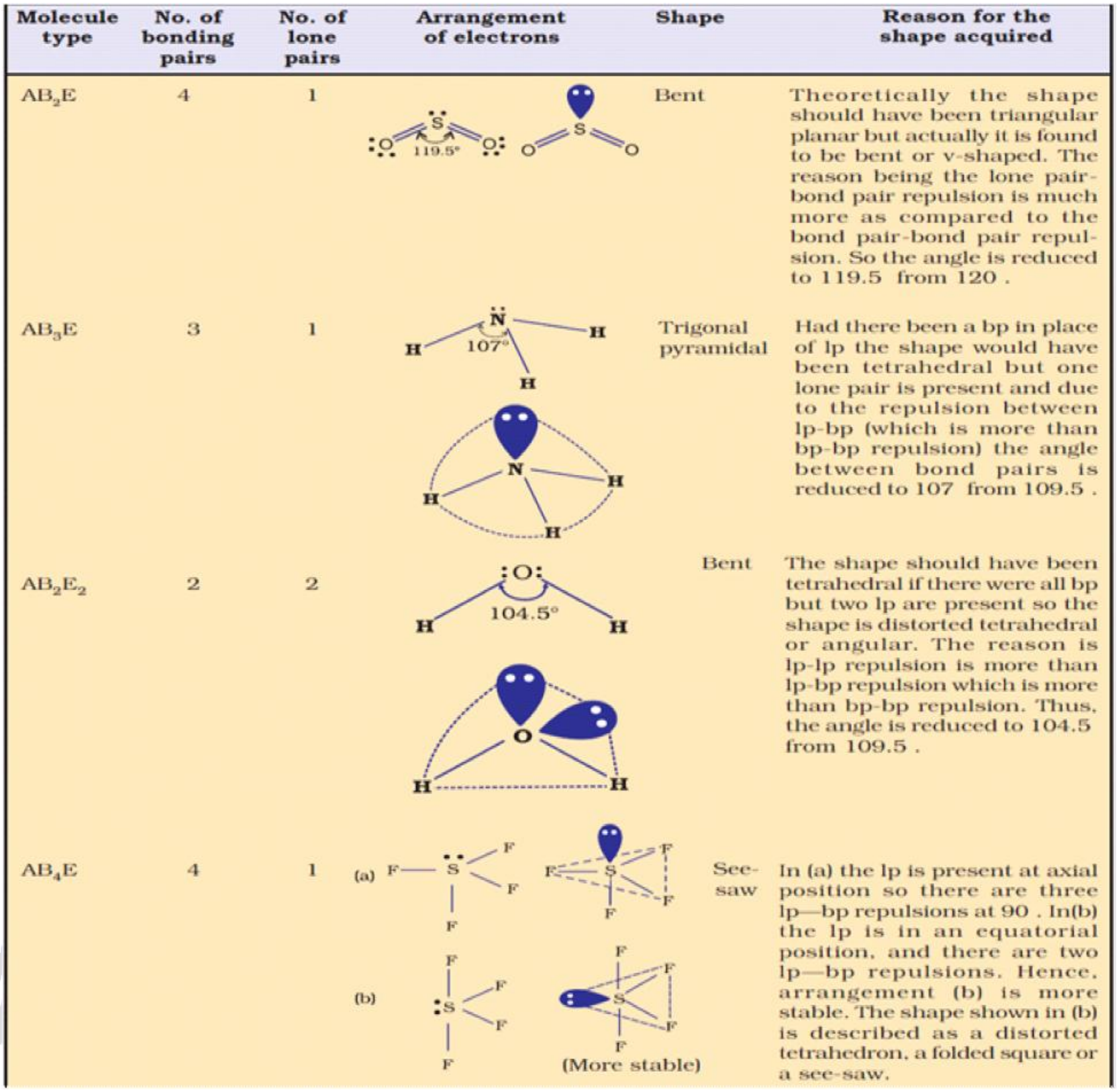
Theories of Chemical Bonding

There are mainly two theories to explain the geometries of chemical compounds.

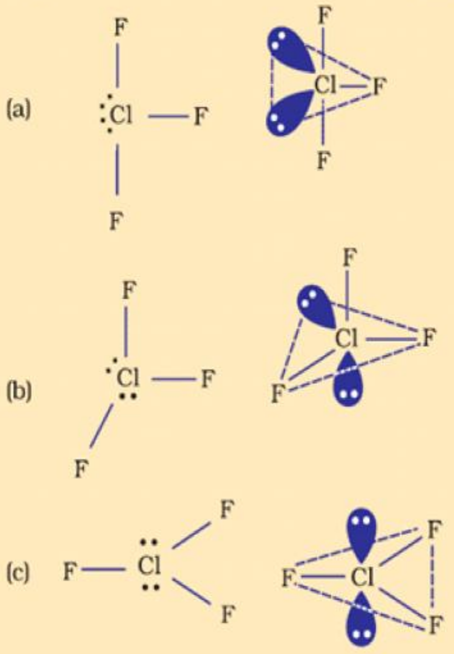
1. MO (Molecular Orbital) Theory According to this theory, a covalent bond is formed when two half filled orbitals of the two atoms come nearer and overlap each other to form a new bigger orbital known as molecular orbital (MO). When two atomic orbitals overlap each other, two MOs are produced, namely bonding (having lesser energy than the energies of the separate atomic orbitals) and anti bonding (having higher energy than the energies of the two separate atomic orbitals). These two new MOs spread over both the atoms and either may contain two electrons.

It overlap of the two atomic orbits takes place along their axis, the resulting bonding MOs are known as sigma (ó) orbitals and the bond formed is called a ó bond. On the other hand, if overlapping of the two atomic orbitals takes place sideways, the resulting MOs are known as pi (ð) orbitals and the bond formed by them is called a ð bond.

Shapes of Molecules containing Bond Pair and Lone Pai



Molecule type	No. of bonding pairs	No. of lone pairs	Arrangement of electrons	Shape	Reason for the shape acquired
AB_2E	4	1		Bent	Theoretically the shape should have been triangular planar but actually it is found to be bent or v-shaped. The reason being the lone pair-bond pair repulsion is much more as compared to the bond pair-bond pair repulsion. So the angle is reduced to 119.5 from 120 .
AB_3E	3	1		Trigonal pyramidal	Had there been a bp in place of lp the shape would have been tetrahedral but one lone pair is present and due to the repulsion between lp-bp (which is more than bp-bp repulsion) the angle between bond pairs is reduced to 107 from 109.5 .
AB_2E_2	2	2		Bent	The shape should have been tetrahedral if there were all bp but two lp are present so the shape is distorted tetrahedral or angular. The reason is lp-lp repulsion is more than lp-bp repulsion which is more than bp-bp repulsion. Thus, the angle is reduced to 104.5 from 109.5 .
AB_4E	4	1	(a) (b) (More stable)	See-saw	In (a) the lp is present at axial position so there are three lp—bp repulsions at 90 . In(b) the lp is in an equatorial position, and there are two lp—bp repulsions. Hence, arrangement (b) is more stable. The shape shown in (b) is described as a distorted tetrahedron, a folded square or a see-saw.

Molecule type	No. of bonding pairs	No. of lone pairs	Arrangement of electrons	Shape	Reason for the shape acquired
AB_3E_2	3	2		T-shape	In (a) the lp are at equatorial position so there are less lp-bp repulsions as compared to others in which the lp are at axial positions. So structure (a) is most stable. (T-shaped).

OXIDATION AND REDUCTION

Oxidation is a process in which a substance adds on oxygen or loses hydrogen. The current definition of oxidation is the process in which a substance loses electrons. Reduction, on the other hand, is a process in which a substance adds on hydrogen or loses oxygen. In modern terms, reduction is the process in which a substance gains electrons.

Oxidation and reduction always occur simultaneously. If one substance is oxidised, another is reduced. The reaction in which this oxidation-reduction process occurs is called a redox reaction.

Oxidising agents are substances which bring about the oxidation of other substances, e.g. potassium permanganate, potassium dichromate, nitric acid, hydrogen peroxide, etc.

Reducing agents are substance which bring about the reduction of other substances, e.g. hydrogen sulphide, hydrogen, carbon, sulphur dioxide, etc.

There are a number of oxidation-reduction reactions that are of industrial use. The production of metals from their ores invariably involves these two processes. Organic compounds are also synthesised by various oxidation-reduction techniques.

METALLIC CORROSION

Many metals when exposed to atmosphere, react with air or water in the environment to form undesirable compounds on their surfaces. This process is called corrosion. Almost all metals except the least active metals such as gold, platinum undergo corrosion. In the case of iron, the corrosion is called rusting. The red or orange coating that forms on the surface of iron when exposed to air and moisture is called rust. Chemically, rust is a hydrated form of ferric oxide, $Fe_2O_3\ xH_2O$ Rusting of iron is gradually caused by moisture, CO_2 and O_2 present in air. It is observed that rusting takes place only when iron is in contact with moist air. The reaction may be written as:

$4Fe + 3O_2 + 3H_2O$

$Fe_2O_3 + 2Fe(OH)_3$

Iron Oxygen Water Iron oxide Iron hydroxide

(from air)

$Fe_2O_3 + xH_2O \quad Fe_2O_3\,xH_2O$

Rust

Iron does not rust in dry air and in vacuum. The process of corrosion is speeded up when the two metals are in contact with each other. Rusting of iron can be prevented by coating it with form zinc compounds and protect the iron from rusting. This type of coated iron is called galvanized iron or G.I.

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

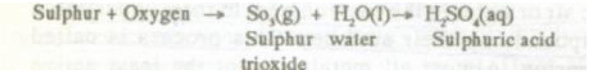
Non-metals have usually low densities, are brittle and do not give sheets (non-malleable) or wires (non-ductile). They don't posses Lustre and cannot be polished.

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.



Sulphur + Oxygen → $So_3(g)$ + $H_2O(l)$ → $H_2SO_4(aq)$
Sulphur trioxide   water   Sulphuric acid

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)

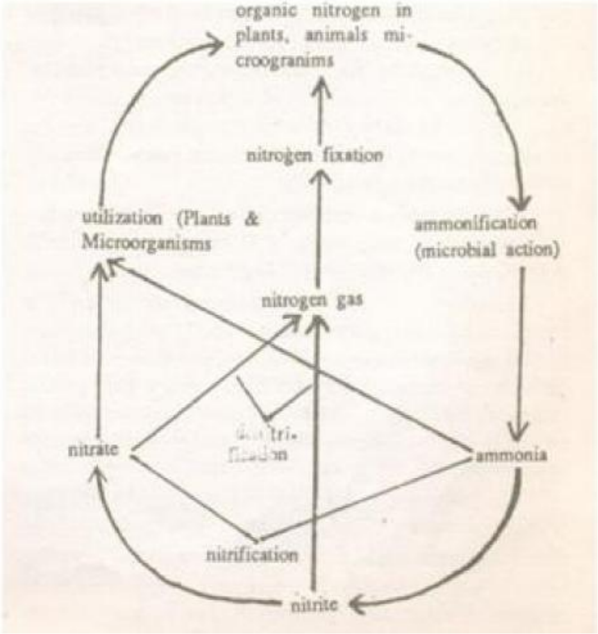
Ammonia

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 = 30^0C	Ignition temperature = 260^0C
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 44^0C	Melts between 500^0C and 600^0C

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.

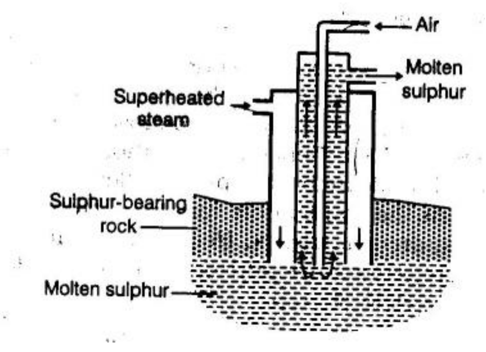
Position in the periodic table Sulphur belongs to group VI and is placed below oxygen in the periodic table.

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

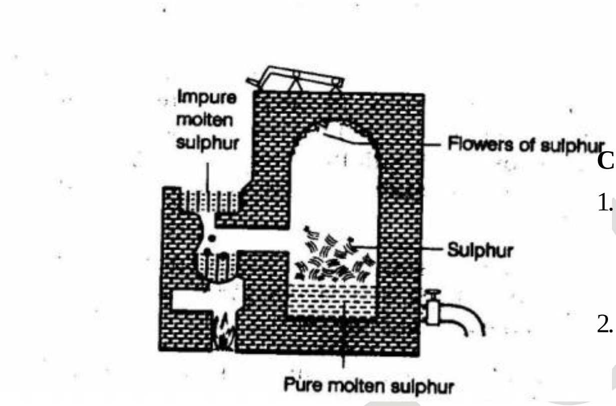
1. ***Frasch process*** This process is used to mine underground sulphur. In this process, a hole is bored down to the sulphur beds. Three concentric pipes are sunk through the hole. Superheated steam is forced down through the outermost pipe. Due to this superheated steam, sulphur in the bed melts. 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



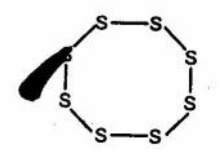
The sulphur obtained is purified by melting in an iron pot. The molten sulphur flows down to a retort where sulphur begins to boil. The vapours of sulphur are condensed in a chamber in the form of fine powder. This is known as *flowers of sulphur.* When the walls become hot, sulphur melts and collects 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

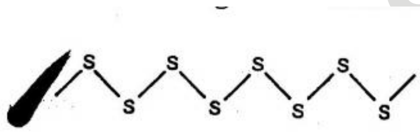
Physical Sulphur is a pale yellow solid. It exists in different allotropic forms. Ordinary sulphur does not dissolve in water. It, however, dissolves readily in carbon disulphide. It is a bad conductor of heat and electricity. It melts at 114°C and boils at 444°C.

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.

$$Fe + S \rightarrow FeS$$

$$Zn + S \rightarrow ZnS$$

$Cu + S$ ì 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.

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

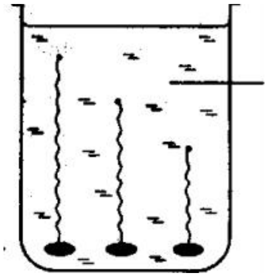
8. **Reaction with caustic soda** Silicon dissolves in hot sodium hydroxide solution with the evolution of H_2 gas.

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

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.

7. METAL

OCCURRENCE OF METALS

Metals occur in nature, in the native (in free state) as well as in the combined state. Those occurring in the free state are very few e.g. gold, silver and platinum.

Whether a given metal occurs in nature in a native or combined state, it is always contaminated with impurities–mostly clays and siliceous matter. Naturally occurring materials containing metals are called minerals. A mineral from which a given metal is obtained economically is called on ore. The natural occurrence of some selected metals is given in Table .

Natural Occurrence of Selected Metals

Element	Nature of Ore	Mineral	Composition
	Sulphides		
Iron (Fe)		Iron pyrites	FeS_2
Copper (Cu)		Copper pyrites	$CuFeS_2$
Silver (Ag)		Argentite	Ag_2S
Zinc (Zn)		Zinc blende	ZnS
Mercury (Hg)		Cinnabar	Hgs
Lead (Pb)		Galena	PbS
	Oxides		
Iron (Fe)		Haematite	Fe_2O_3
		Magmetite	Fe_2O_4
Aluminium (Al)		Bauxite	$Al_2O_3.2H_2O$
Titanium (Ti)		Rutile	TiO_2
Manganese (Mn)		Pyrolusite	MnO_2
Copper (Cu)		Cuprite	Cu_2O
Tin (Sn)		Cassiterite	SnO_2
	Carbonates		
Magnesium (Mg)		Dolomite	$CaCO_3.MgCo_3$
		Magnesite	$MgCO_3$
Calcium (Ca)		Lime stone	$CaCO_3$
Zinc (Zn)		Calamine	$ZnCO_3$
	Halides		
Sodium (Na)		Rock salt	NaCl
Magnesium (Mg)		Camallite	$KCl.MgCl_2.6H_2O$
	Sulphates		
Calcium (Ca)		Gypsum	$CaSO_4.2H_2O$
Magnesium (Mg)		Epsom salt	$MgSO_4.7H_2O$

A variety of minerals are found in India, some in huge quantities and some in small.

Properties of Metals

Physical Properties Mercury is the only liquid metal, all other are solids. They have high melting and boiling points. They are malleable and ductile. They are quite lustrous and are good conductors of heat and electricity.

Chemical Properties Metals are electropositive and form positive ions by losing electrons. They combine with oxygen to form basic oxides. They react with dilute mineral acids to liberate hydrogen gas. With halogens they form halides. Their reactivity varies. The first group of elements, that is alkali metals are most reactive.

Mineral Wealth of India

State	**Mineral**
Andhra Pradesh	Diamonds, Limestone, asbestos, copper, mica, gold
Bihar	Asbestos, bauxite, chromite, coal, graphite, haematite, limestone, manganese ore, mica
Gujarat	Gypsum, manganese ore, fluorspar
Karnataka	Asbestos, gold, chromite, iron ore, magnesite, corundum
Kashmir and Himachal Pradesh	Gypsum
Kerala	Manazite, illmenite, rutile, garnet
Madhya Pradesh	Iron and manganess ores, bauxite, limestone, coal, dolomite
Maharashtra	Chromite and manganese ores
Orissa	Dolomite, limestone, graphite, haematite, chromite
Rajasthan	Copper, lead, manganese and zine ores, rock phosphate, barytes, gypsum, mica
Tamil Nadu	Iron and manganese ores, magnesite, mica, limestone, lignite
West Bengal	Coal, dolomite tungsten
Uttar Pradesh	Gypsum, magnesite, dolomite, rock phosphate

Extraction of Metals

Extraction of metals comprises the processing of natural raw materials to obtain elemental metals. The initial stages of this process involve three steps:

1. Concentration of the ore (or beneficiation)
2. Chemical or electrochemical reduction to the metal
3. Removal of impurities from the metal (i.e. purification or refining).

In certain cases these steps may overlap, for example, removal of impurities may be a part of the ore concentration process such that subsequent refining is not necessary.

Concentration of the Ore The ore usually contains rocky and siliceous matter called gangue. If the gangue is objectionable at a later stage, the first step in ore concentration is to remove it. To do so the ore is usually crushed and ground until the particles of the mineral are broken apart from the gangue. If possible, these particles are separated by physical means such as washing, magnetic attraction or froth floatation. These methods are based on differences between the physical properties of the mineral and the gangue.

If the ore cannot be sufficiently concentrated by these physical methods, chemical processes are used. Some examples are given below:

(i) In many cases the ore is roasted (heating in air) to drive off volatile impurities, burn off organic matter, and to from compounds that are more easily smelted. Roasting in air usually converts sulphides to oxides.

(ii) Concentration of bauxite ($A1_2O_3$. $2H_2O$) by hot aqueous sodium hydroxide. This method is based on the amphoteric nature of aluminium hydroxide. The crushed ore is treated with a hot aqueous solution of NaOH to dissolved alumina, $A1_2O_3$ or bauxite and impurities such as iron oxide and silicates remain unaffected. The solution is filtered, cooled and CO_2 gas is blown when aluminium hydroxide gets precipitated. On heating aluminium hydroxide, pure alumina is obtained.

(iii) Leaching of gold and silver ores with aqueous sodium cyanide in the presence of air to yield the metal cyano complexes.

(iv) Concentration of magnesium ions from sea water by calcium hydroxide. Mg $(OH)_2$ is converted into anhydrous $MgCl_2$ which is used for the electrolytic reduction for obtaining magnesium.

Calcination and Roasting When the ore has been sufficiently concentrated for the isolation of a metal, it is subjected either to calcination or roasting process depending on the nature of the ore. In these operations, volatile impurities are also removed.

Calcination is the heating of the ore in the absence of air. This method is employed for obtaining the metal oxides from carbonates and hydroxides.

Roasting is the heating of the ore in the presence of air. On roasting, part of the ore is oxidized to form an oxide. This oxide is then reduced to the metal.

Conversion of the ore into the oxide form is an important step in the final reduction to the metal. The reducing agent used should be easily available and cheap, the obvious choice is carbon.

Smelting The industrial reduction process for obtaining metal from the treated ore is called smelting. There are several chemical and electrochemical methods available which can be used to produce metals.

Ores generally contain considerable gangue even after concentration. To remove the last amounts of the gangue, a flux is added during the smelting process. Flux is a substance that combines with gangue and forms a molten material called slag as the mixture is heated in a furnace. At high temperatures, the slag is a liquid that is insoluble in the molten metal and it forms a separate layer. If the gangue is an acidic oxide, such as silica (SiO_2), a cheap basic oxide like quicklime (CaO) may be used as flux. Impurities and flux react in a furnace to form slag. If on the other hand, the gangue is basic, the flux to be added would be acidic.

Refining of Metals The purification or adjustment of the composition of impurities in crude metals is called refining. Metals with low boiling points, such as mercury, zinc and magnesium can be separated from most impurities by simple distillation. Like salts, metals can also be refined by fractional crystallization. Probably the most widely used refining method is the electrolytic method. Among modern purification methods, Zone refining, chromatographic, ion-exchanges and solvent extraction methods are also used for specific purpose.

COPPER

Symbol Cu

Atomic No. 29

Electronic *configuration* of copper

The atomic number of copper is 29. Thus, an atom of copper contains 29 electrons. The electronic configuration of copper is :

	K	L	M	N
Cu (29)	2	8	18	1

Copper atom has only one electron in its outermost shell.

Position in the periodic table.

Copper is a transition metal. It is placed in group IB along with silver and gold.

VIII			IB	IIB
Fe	Co	Ni	Cu	Zn
(26)	(27)	(28)	(29)	(30)
Ru	Rh	Pd	Ag	Cd
(44)	(45)	(46)	(47)	(48)
Os	Ir	Pt	Au	Hg
(76)	(77)	(78)	(79)	(80)

Being a member of the same subgroup **(IB),** copper shows some marked similarities in properties with those of silver and gold. Further, the properties of subgroup **(IB)** metals are entirely different from those of subgroup (**IA)** metals. Hence, the subdivision into **(IA)** and **(IB)** is justified.

Occurrence of copper

Copper is an unreactive metal. Hence, it occurs in\ nature in native or free state. It is also found in combined state in the form of sulphide, oxide, carbonate, etc. The important ores of copper are:

(i) Sulphide ores

Copper glance (chalcocite), Cu_2S Copper pyrites (chalcopyrite), $CuFeS_2$

(ii) Oxide ores Cuprite, Cu_2O

(iii) Carbonate ores Malachite, $CuCO_3.Cu(OH)_2$

Azurite, $2CuCO_3.Cu(OH)_2$

The most important ore of copper is copper pyrites ($CuFeS_2$).

Copper in India

In India, copper is found in Sikkim, Singhbhum in Bihar, Nellore in Andhra Pradesh and Khetri in Rajasthan. Copper is nowadays extracted through a modern process by The Indian Copper Corporation Ltd., Musabani, Ghatsila.

Extraction of copper from copper pyrites

Copper is obtained chiefly from the *pyrite ore.* This ore contains different materials. Hence, it needs to be concentrated or dressed.

1. **Dressing of the ore** The dressing of the ore is done by froth floatation process.
2. **Roasting** The dressed or the concentrated ore is roasted on the bed of a reverbveratory furnace in a current of air. As a result of this operation, a portion of sulphur burns to form SO_2 and the metals are partially oxidized. The residue *contains oxides and sulphides of copper and iron.*

$$\mathbf{2}CuFeS_2 + O_2 \rightarrow Cu_2S + 2FeS + SO_2$$

3. **Smelting** The roasted ore is mixed with a little coke and sand. The mixture is heated strongly in a blast furnace. Most of the ferrous sulphide is converted into ferrous oxide. The ferrous oxide forms a slag with the sand and is removed. The residue is almost pure copper sulphide and is called the *white metal.*

$$2FeS + 3O_2 \rightarrow 2FeO + 2SO_2$$

$$FeO + SiO_2 \rightarrow FeSiO_3 \text{ (ferrous silicate)}$$

slag

4. **Preparation of blister copper** The white metal is carefully heated in a reverberatory furnace where a portion of Cu_2S is oxidized to Cu_2O. As the temperature rises, Cu_2O reacts with the remaining portion of Cu_2S to form copper and SO_2.

$$2Cu_2O + Cu_2S \rightarrow 6Cu + SO_2$$

Due to the evolution of $S0_2$, copper obtained has a blister-like appearance. This copper is called *blister copper.*

5. **Refining of blister copper** Blister copper contains iron, sulphur, arsenic, lead, etc., as impurities. It is melted in a reverberatory furnace in a current of air. The impurities present are oxidized away as gases or they form **a** slag with **silica of** the furnace. The slag is removed. Anthracite coal is sprinkled on the surface. The molten mass is stirred with poles of green wood. Pure copper is obtained.

Very pure copper is, however, obtained by electrolysis. Sheets of impure copper are made the anode while thin plates of pure copper are made the cathode. A solution of copper sulphate is used as the electrolytic solution. On passing electric current, sheets of impure copper gradually dissolve. Pure copper is deposited on the cathode. The impurities settle down at the bottom or remain in the solution.

$$Cu^{2+} + 2e \rightarrow Cu \text{ (at cathode)}$$

$$Cu \rightarrow Cu^{2+} + 2e \text{ (at anode)}$$

At the cathode, Cu^{2+} ions are taken from the copper sulphate solution while Cu^{2+} ions go into the solution at the anode. In this way, pure copper is transferred from the anode to the cathode.

Properties of Copper

Physical properties

Copper is a reddish, shining metal. It melts at 1083°C. Its density is 8.95 g/cm^3. It is ductile and malleable. It is a good conductor of heat and electricity.

Chemical properties

1. Valency Copper exhibits variable valencies. The valencies of copper are 1 and 2. Thus, copper forms *monovalent ions* (Cu^{2+}) *and divalent ions* (Cu) *. The mono- valent ion* (Cu) *is* Known as cuprous ion and the divalent ion (Cu^{2+}) is known as *cupric* ion. Compouds corresponding to cuprous and cupric ions are called cuprous compounds and cupric compounds respectively .The cupric ion (Cu^{2+}) is more stable than cuprous (Cu^+).

An atom of copper does not easily lose its electrons to form ions. Thus, the reactivity of copper is very low and it is treated as an uncreative metal. Copper lies very low in the activity series of metals.

2. Action of air Dry air has no action on copper. When the metal is exposed to moist air, its surface gradually gets covered with a green layer of basic copper carbonate $CuCO_3\ Cu(OH)_2$. When copper is heated in air at about **300°C it** combines with oxygen to form black cupric oxide.

300°C

$$2Cu + 0_2 \rightarrow 2CuO$$

At a temperature of about 1000°C, cuprous oxide is formed.

1000°C

$$4Cu + O^2 \rightarrow 2Cu_2O$$

3. Action of water Copper does not react with water or steam.

4. Action of acids Copper lies below hydrogen in the electrochemical series. Hence, it cannot displace hydrogen from acids.

Copper, however reacts with boiling concentrated HCl in presence of air or some oxidizing agent, with the evolution of hydrogen.

$$2Cu + 2HCl \rightarrow 2CuCl + H_2$$

Copper does not react with dilute hydrochloric dilute sulphuric acid.

$$CuCl + CI^- \rightarrow [CuCl_2]^-$$

This is the only reaction in which copper displaces H_2 from HCl.

Copper reacts with dilute H_2SO_4 only in the presence of air:

$$2Cu + 2H_2SO_4 + O_2 \rightarrow 2CuSO_4 + 2H_2O$$

When copper is heated with concentrated sulphruic acid, copper sulphate, sulphur dioxide and water are formed.

$$Cu + 2H_2SO_4 \rightarrow CuSO_4 + SO_2 + 2H_2O$$

With dilute nitric acid copper reacts to form nitrate and nitric oxide gas.

$$3Cu + 8HNO_3 \rightarrow 3Cu(NO_3)_2 + 2NO + 4H_2O$$

5. Action of chlorine When copper is heated in a current of chlorine, cupric chloride is produced.

$$Cu + Cl_2 \rightarrow CuCl_2$$

6. **Action of sulphur** When copper is heated with sulphur, cupric sulphide is formed.

$$Cu + S \rightarrow CuS$$

7. Displacement of metals Copper displaces some such as silver, gold, platinum, etc., from the solutions of their salts.

$$Cu + 2AgNO_3 \rightarrow Cu(NO_3)_2 + 2Ag$$

It should be noted that only those metals are displaced from their salt solutions which lie below copper in the elecrochemical series.

8. Action of aqueous ammonia Copper dissolves in aqueous ammonia in the presence of air, forming complex compound, tetra ammine cooper (II) hydroxide.

$$Cu + H_2O + 1/2O_2 \rightarrow Cu^{2+} + 2OH^-$$

$$Cu^{2+} + 4NH^3 \rightarrow [Cu(NH_3)_4]^{2+}$$

$$[Cu(NH_3)_4]^{2+} + 2OH^- \rightarrow [Cu(NH_3)_4]\text{- }(OH)_2$$

Test for copper (II) salts or cupric ions (Cu^{2+})

When a copper (II) salt solution or a solution containing Cu^{2+}ions is treated with ammonium hydroxide, a pale blue precipitate of copper (II) hydroxide is obtained , On adding excess of ammonium hydroxide, the precipitate dissolves to produce a deep blue solution.

Uses of copper

1. Copper is largely used in electrical industry for making electric wires, electric motors, dynamos and several other electrical goods.
2. Copper is used in electroplating and electrotyping.
3. Copper is also used in making household utensils.
4. An important use of copper is in making alloys with metals. Some of the alloys and their compositions; given in Table.

Table Alloys of copper

	Alloy	Composition	Uses
(i)	Brass	Cu= 80%, Zn=20%	Utensils, cartridges, condenser tubes, etc
(ii)	Bronze	Cu= 80%, Zn=10%, Sn= 10%	Utensils, statues, coins, etc.
(iii)	German silver	Cu= 60%, Zn=20%, Ni= 20%	Utensils, resistance , coils, etc
(iv)	Bell metal	Cu= 80%, Sn=20%	Bells , etc.
(v)	Gun metal	Cu= 87%, Sn=10% , Zn= 3%	Bearings, machine parts Formerly use for cannons.

IRON

Symbol: Fe **Atomic no. 26**

Electronic configuration of iron

The atomic number of iron is 26. This means that an atom of iron contains 26 electrons in its shells. The electronic configuration of iron is:

	K	L	M	N
Fe (26)	2	8	14	2

Thus, an atom of iron contains two electrons in its outermost shell.

Position of iron in the periodic table

The electronic configuration of iron shows that there are two electrons in its outermost shell or the valence shell. So, it can be reasonably expected that iron should have a place in group II of the periodic table. But it is not so. Since iron is a transition metal, its properties are different from the normal elements of group II. In fact, iron has been assigned a place in group VIII of the periodic table. It is a member of the first transition series in the fourth period known as a triad.

Group VIII

Fourth period	Fe	Co	Ni
Fifth period	Ru	Rh	Pd
Sixth period	Os	Ir	Pt

Occurrence of iron

Iron is the second most abundant metal in the earth's crust, the first one being aluminium. Free iron has been found in most meteorites. It is also believed that a core of iron is present in the centre of the earth.

Iron is a reactive metal. So, it does not occur free in nature. In combined state, it occurs as oxide, sulphide, carbonate, etc. The important ores of iron are:

(i) *Haematite*, Fe_2O_3
(ii) *Magnetite*, Fe_3O_4
(iii) *Limonite*, $2Fe_2O_3.3H_2O$
(iv) *Siderite*, $FeCO_3$
(v) *Iron pyrites*, FeS_2

The most important ore of iron is haematite, which is used most commonly in the extraction of iron. The pyrite ore (FeS_2) is not used for the extraction of iron on account of its high sulphur content.

Iron in India

In India, large deposits of iron ores are found in Bihar, Orissa, Madhya Pradesh, Tamilnadu and Sikkim. The important iron and steel plants are located at Bhillai, Bokaro, Jamshedpur, Rourkela, Durgapur, Asansole and Bhadravati.

Extraction of iron from haematite

1. **Dressing of the ore** The big, lumps of the ore are broken into small pieces and then washed with water to remove clay, sand and other adhering impurities. The ore thus becomes ready for treatment in the blast furnace.
2. **Smelting in the blast furnace** The concentrated ore is mixed with coke and limestone. The mixture is charged at the top of the blast furnace. The following reactions occur in the blast furnace:

(i) As the charge comes down to the 600°C region, the iron oxide is reduced by the ascending carbon monoxide gas produced by the burning of coke.

$$2C + 0_2 \rightarrow 2CO$$

$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$

The iron thus obtained is called *spongy iron.*

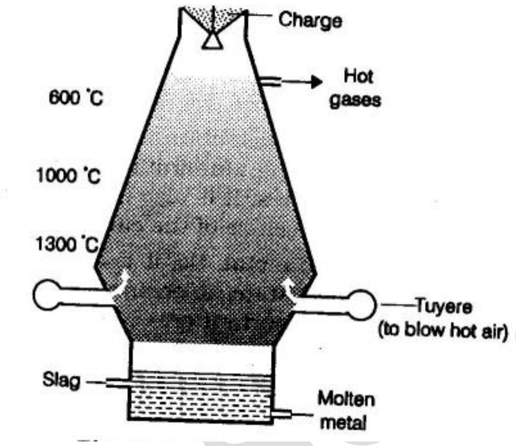
(ii) At the 1000°C region, the silica is converted to slag.

$$CaC0_3 \rightarrow CaO + CO_2$$

$$CaO + SiO_2 \quad CaSiO_3$$

slag

(iii) At the 1300°C region, spongy iron melts and dissolves carbon, phosphorus, silica, etc. The slag also fuses. The molten mass collects at the base of the furnace. The slag floats over it. The molten iron is taken out as required. This iron is called *pig iron.*



Function of limestone Limestone is decomposed to give quicklime.

$CaCO_3$ ® $CaO + CO_2$

quicklime

Quicklime combines with impurities like sand to form a molten slag (calcium silicate)

$CaO + SiO_2$ ® $CaSiO_3$

slag

The slag floats on the surface of molten iron. It is taken out through a hole from time to time. The of calcium silicate as slag, not only removes unwanted silica but also keeps iron away from being oxidized.

Varieties of iron

1. **Pig iron and Cast iron** The iron produced in the blast furnace is pig iron. It contains a comparative percentage of carbon due to which it is hard and brittle. It also contains phosphorus, silicon and manganese as impurities. Pig iron is melted, mixed with steel scrap and allowed to cool in moulds to

give *cast iron.* Cast iron is impure and is hard and brittle.

2. **Wrought iron** It is almost pure form of iron. It contains only 0.*12* to 0.25% carbon. It melts at a higher temperature (1500°C) than that at which cast Iron melts. It is obtained by melting cast iron on a hearth lined with ferric oxide (Fe_2- - O_3). The impurities, such as carbon, phosphorus, silicon and manganese, are oxidized by Fe_2O_3.

$$Fe_2O_3 + 3C \quad 2Fe + 3CO-$$

Wrought iron is soft, grey and tough. It is malleable and ductile. Hence, it can be drawn into sheets and stretched into wires. It is used in making chains, wires, anchors and cores of electromagnets.

3. **Steel** It is an alloy of iron and carbon. It contains about 0.1 to 0.15% of carbon. There are different types of steel.

(a) **Mild steel** It contains about 0.15% carbon. It is used for making sheets and wires.

(b) **Hard steel** It contains higher percentage (1.5%) carbon. It is used in making tools and instruments.

(c) **Alloy steels** Alloy steels are prepared by adding small amounts of nickel, cobalt, chromium, tungsten, molybdenum, manganese and silicon to steel. Alloy steels are used extensively in making rock crushing machinery, helmets, armour plate, cutlery, springs, etc.

(d) **Medium steel** It contains 0.1% carbon. It is hard and is used in making rails, bridges, etc.

Table: Typical percentage compositions of the three types of iron

	C	Si	S	P	Mn
Cast iron	2-4.5%	0.7-3.5%	0.7-3.5%	0.05-1.5%	0.5-1.0%
Wrought	0.12-0.25%	0.03-2.0%	0.03-2.0%	0.04-0.04%	0.1-4%
Mild steel	0.15%	0.03%	0.05%	0-0.05%	0-50%

Tempering

The hardness of steel can be controlled by heat treatment. The steel is heated to a temperature below redness. It is then cooled slowly. The process is called *tempering of steel*. It is used to bring the steel to a state of hardness and elasticity.

Annealing of steel

Hard steel can be softened by heating it to a high temperature *and* then allowing it to cool down slowly. This *called* annealing.

Quenching of steel

Hard steel is heated to a high temperature. It is then suddenly cooled by plunging it into oil or water. Steel becomes as hard and brittle as glass. This is known as *quenched steel*, and the process of obtaining such a steel is known as *quenching or hardening of steel*

Properties of Iron

Physical properties

Pure iron has a grey color. It is malleable and ductile, conductor of heat and electricity. It melts at 1525°C and has a density of 7.86 g/cm^3.

Chemical Properties

1. **Valency** Iron shows variable valency. It shows valancies of 2 and 3, i.e., it forms divalent ion (Fe^{2+}) as well trivalent ion (Fe^{3+}). The compounds in which iron shows are known as ferrous compounds, whereas the compounds in which iron shows trivalent are known as ferric compounds. For example, in $FeCl_2$ the valency of iron is 2. So, it is called ferrous chloride. In $FeCl_3$, the valency of iron is 3. So, it is called ferric chloride.

2. **Action of air** In the presence of moist air and carbon dioxide, iron gets covered with a thin deposit of rust. The rust consists of hydrated ferric oxide ($2Fe_2O_3.3H_2O$).

3. **Action of water** Red hot iron decomposes steam, forming ferrosoferric oxide and evolving hydrogen gas.

$$3Fe + \quad 4H_2O \rightarrow \quad Fe_3O_4 \qquad + \ 4H_2$$

Iron steam ferrosoferric hydrogen
oxide

4. **Action of acids** Iron lies above hydrogen in the chemical series. So, it can displace hydrogen from the hydrochloric acid or dilute sulphuric acid. The corresponding ferrous salts are also produced.

(i) **With hydrochloric acid** (a) Iron dissolves in dilute hydrochloric acid forming ferrous chloride with the evolution of hydrogen gas.

$$Fe + 2HC1 \rightarrow FeCl_2 + H_2$$

(b) Concentrated hydrochloric acid also evolves Hydrogen with iron.

(ii) **With sulphuric acid** (a) Iron dissolves in dilute sulphuric acid forming ferrous sulphate. Hydrogen gas is evolved in the reaction.

$$Fe + H_2SO_4 \rightarrow FeSO_4 + H_2$$

(b) Iron reacts with concentrated sulphuric acid to form ferrous sulphate with the evolution of sulphur oxide. There is no formation of hydrogen gas.

$$Fe + 2H_2SO_4 \rightarrow FeSO_4 + SO\text{-}_2 + 2H_2O$$

Some ferric sulphate is also formed due to the oxidation of $FeSO_4$ by concentrated H_2SO_4.

$$2FeSO_4 + 2H_2SO_4 \rightarrow Fe_2(SO_4)_3 + 2H_2O + SO_2$$

(iii) **With nitric acid** (a) Iron reacts with dilute nitric acid to form ferrous nitrate and ammonium nitrate.

$$4Fe + 10HNO_3 \rightarrow 4Fe(NO_3)_2 + NH_4NO_3 + 3H_2O$$

(b) With concentrated nitric acid, iron is rendered passive due to the formation of insoluble ferrosoferric *oxide* (Fe_3O_4) *on the surface of iron.*

5. **Action of halogens** halogens combine with heated iron, forming the halides of iron. For example, chlorine combines with heated iron to form ferric chloride.

$$2Fe + 3C1_2 \rightarrow 2FeCl_3$$

6. **Action with sulphur** When iron filings are heated with sulphur, iron sulphide is produced.

$$Fe + S \rightarrow FeS$$

7. **Displacement of less electropositive metal** When an iron piece is dipped in a solution of copper sulphate, copper is displaced from the salt and gets deposited on the surface of iron. This is because copper is less electropositive than iron.

$$Fe + CuSO_4 \rightarrow Cu + FeS0_4$$

or

$$Fe + Cu^{2+} \rightarrow Cu + Fe^{2+}$$

Tests to distinguish between ferrous and ferric salts

1. When a ferrous salt solution is treated with a solution of sodium hydroxide, a greenish precipitate of ferrous hydroxide is obtained.

$$FeSO_4 + 2NaOH \rightarrow Fe(OH)_2 + Na_2SO_4$$

When a ferric salt solution is treated with a solution of sodium hydroxide, a brown precipitate of ferric hydroxide is produced.

$$Fe_2(SO_4)_3 + 6NaOH \rightarrow 2Fe(OH)_3 + 3Na_2SO_4$$

2. The ferrous salts are generally green-coloured, whereas the ferric salts are brown in colour.

Rusting

When iron is exposed to moist air, a reddish-brown coating of a mixture of ferric oxide (Fe_2O_3) and ferric hydroxide ($Fe(OH)_3$) is deposited on the surface of the metal. This reddish-brown coating is known as rust, and this process is known as rusting. Thus, the slow conversion of iron into a mixture of Fe_2O_3 and $Fe(OH)_3$, by water and atmospheric oxygen, is known as rusting.

Rusting of iron is an oxidation reaction which occurs due to the attack of water and oxygen. It has been found that rusting does not take place in air-free water. It also does not occur due to oxygen alone. Both water and oxygen are essential for rusting. Thus, the following conditions are necessary for rusting:

(i) Presence of oxygen or air

(ii) Presence of water or moisture

The process of rusting is continuous. The strength of iron decreases gradually and finally the metal is destroyed completely.

Prevention of rusting

Iron can be prevented from rusting by keeping it out of contact with air and water, and also by converting it into an alloy. This can be achieved in the following ways:

1. By covering the surface of iron with grease, paint, varnish, enamel, etc.
2. By galvanizing Iron: a thin coating of zinc is deposited on the surface of the iron object. This is done by electroplating. Since zinc does not corrode on exposure to air, zinc metal prevents iron from rusting.
3. By coating the surface of the iron object with chromium, tin, nickel or aluminium. These metals resist corrosion. Hence, they protect iron from rusting.
4. By converting it into an alloy with chromium and nickel. This alloy is called stainless steel.

Uses of iron

1\. Iron is used in making household utensils and equipment.

2\. Wrought Iron and cast iron are largely used in the manufacture of locomotives, railway lines, springs, tubes, etc.

1\. Iron finds wide application in house construction, e.g., in the reinforcement of roofs and other parts of buildings.

ALUMINIUM

Symbol Al **Atomic no. 13**

History Aluminium was first prepared in 1827. Impressed by its properties, scientists all over the world attempted to develop a process for the commercial production of the metal. But it remained a costly metal till 1886, when Heroult in France and Hall in USA succeeded in developing independently a process for the extraction of aluminium. Since then, large-scale production of aluminium began in several parts of the world. It came into large-scale use towards the end of the nineteenth century.

Electronic configuration of aluminium

The atomic number of aluminium is 13. This means that an atom of aluminium contains 13 electrons in its shells. The electronic configuration is then,

	K	L	M
A1 (13)	2	8	3

Thus, the outermost shell or valence shell of an aluminium atom has 3 electrons.

Position in the periodic table

First period	IA	IIA	IIIA
	H (1)		
Second period	Li (3)	Be (4)	B(5)
Third period	Na (11)	Mg (12)	Al (13)
Fourth period	K(19)	Ca (20)	Ga (31)

Occurrence of aluminium

Aluminium comes third amongst the most abundant elements in nature. But aluminium is the most abundant metal in the earth's crust. It is a reactive metal, hence does not occur native or free in nature. In the state, it is widely distributed in nature in the form of compounds. Some of its important minerals are:

i. Cryolite, $Na3AlF\text{-}_6$

ii. Corundum, $A1_2O_3$

iii. Bauxite, $A1_2O_3.2H_2O$

iv. *Felspar*, $KAlSi_3O_8$

However, bauxite is the only mineral from which aluminium is obtained profitably. Hence, bauxite is an ore of aluminum.

In India, Hindustan Aluminium Corporation, Indian Aluminium Company and the Bharat Aluminium Corporation produce aluminium from bauxite.

Extraction of aluminium from bauxite

The extraction of aluminium from bauxite consists of the following steps:

1. **Preparation of alumina** Crude bauxite is finely powdered and treated with a concentrated caustic soda at 150°C. The bauxite goes into forming sodium aluminate while the behind undissolved.

$Al_2O_3.2H_2O + 2NaOH \rightarrow 2NaAlO_2 + 3H_2O$

bauxite **sodium** **sodium** **water**

hydroxide aluminate

The solution is filtered. The filtrate is diluted with water and a little freshly precipitated aluminium hydroxide is added to cause precipitation. Sodium aluminate gets hydrolyzed to produce a white precipitate of aluminium hydroxide.

$NaAlO\text{-}_2 + 2H_2O$ ì $Al(OH)_3 + NaOH$

Sodium water aluminium sodium

Aluminate hydroxide hydroxide

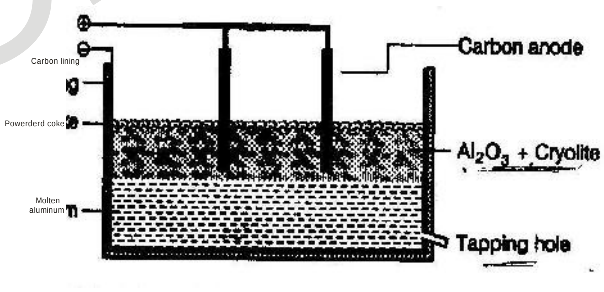
The precipitate of $Al(OH)_3$ is filtered off, washed, dried and ignited to get pure aluminium oxide.

$2Al(OH)_3$ ì $Al_2O_3 + 3H_2O$

Aluminium aluminium water

Hydroxide oxide

1. **Electrolytic reduction of alumina** Alumina is mixed with cryolite. The mixture is melted in an iron cell.



Alumina melts at 200°C. It is a bad conductor of electricity. But when mixed with cryolite and some calcium fluoride, the mixture becomes a good conductor of electricity, and melts at 900-950°C. The iron cell is lined inside with gas carbon which serves as cathode. Carbon rods act as anode. The electrolyte, thus, contains Na^+, $Al^{3+,}$ F^- and O^{2-} ions.

On passing electric current, Al^{3+} ions are discharged at the cathode and the O^{2-} ions at the anode.

$Al^{3+} + 3e \rightarrow Al$ (at cathode)

$2O^{2-} \rightarrow O_2 + 4e$ (at anode)

Some quantity of oxygen formed escapes and some reacts with the anode to form CO_2.

$c + o_2 \rightarrow co_2$

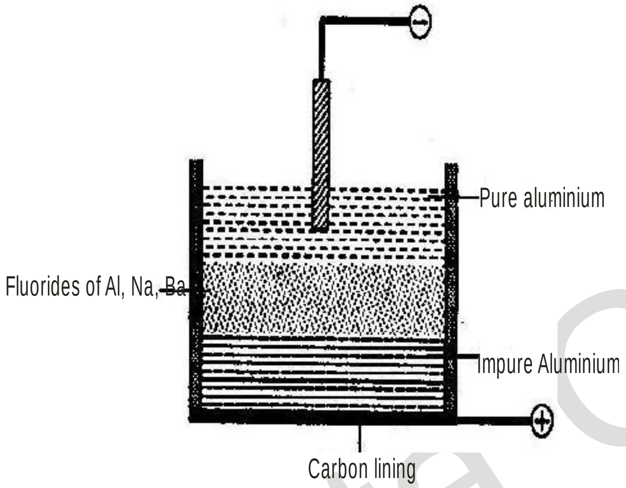
Hence, the anode has to be replaced from time to time. This increases the cost of production of aluminum. Molten aluminium sinks to the bottom, and is taken out from there.

3. **Electrolytic refining of aluminium** Aluminium thus obtained is 99% pure. It contains iron and silicon as impurities. It is purified by further electrolysis using *Hope's method.* The electrolysis is carried out in an iron box lined with carbon. Three layers, differing in densities, are placed in the box.

Bottom layer It consists of impure aluminium. It acts anode.

Middle layer It consists of a mixture of the fluorides of Al, Na and Ba. It serves as electrolyte.

Upper layer It consists of pure molten aluminium and serves as cathode.



On passing electric current, aluminium ions from the middle layer are discharged at the cathode. An equivalent amount of aluminium goes into the middle layer from the bottom layer. The impurities are left behind. Oxygen is liberated at the anode. Oxygen reacts with the carbon anode. Hence, the anode is gradually consumed.

Properties of Aluminium

Physical properties

Aluminium possesses a bluish white lustre. It is a light metal of density 2.7. It is malleable and ductile. It melts at 660°C. It is a good conductor of heat and electricity.

Chemical properties

1. **Valency** The outermost shell or the valence shell of aluminium contains 3 electrons. These three electrons can be given up to form aluminium ion, Al^{3+}. Thus, the valency of aluminium is 3, i.e., aluminium is a trivalent metal.

2. **Action of air** Aluminium is a very reactive metal. Yet it does not get corroded when exposed to air. Dry air has no action on aluminium. In moist air, a thin film of its oxide is formed over its surface. This prevents the metal from further attack by air or water or even by dilute acids. The film of the oxide can be removed by rubbing the surface of the metal with mercury. Then rapid corrosion by moist air occurs. The oxide film may also be removed by sodium chloride. That is why aluminium rusts in coastal areas.

When heated to 800°C in air, aluminium burns with a brilliant light. In this reaction, aluminium oxide and a little aluminium nitride are formed.

$4Al + 3O_2 \rightarrow 2\,Al_2O_3 + \text{Heat}$

aluminium oxygen aluminium oxide

$2Al$ + N_2 ® $2AlN$

Aluminium nitrogen aluminium nitride

3. **Action of water** Aluminium is a reactive metal. But it does not react with water. This is because the surface of aluminium remains covered with a thin film of unreactive oxide. The thin oxide film does not allow water to come in contact with aluminium.

If the thin oxide film is removed by rubbing with a sand paper then aluminium reacts with boiling water to produce aluminium hydroxide and hydrogen.

$2A1 + 6H_2O \rightarrow 2Al(OH)_3 + 3H_2$

aluminium water aluminium hydroxide hydrogen

4. **Action of acids** Aluminium reacts with acids to produce aluminium salts and hydrogen.

(i) **Reaction with hydrochloric acid** Aluminium dissolves in hydrochloric acid to form aluminium chloride and hydrogen.

$2Al + 6HCl$ - $2AlCl_3 + 3H_2$

aluminium hydrochloric aluminium chloride hydrogen

The reaction is slow with dilute hydrochloric acid but rapid with concentrated hydrochloric acid.

(ii) **Reaction with sulphuric acid** Aluminium dissolves in dilute sulphuric acid to form aluminium sulphate and hydrogen. The reaction is, however, slow.

$$2Al + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3H_2$$

Aluminium dissolves in hot concentrated sulphuric *acid to form aluminium sulphate with the evolution of* sulphur dioxide gas.

$2Al + 6H_2SO_4 \rightarrow Al_2(SO_4)_3 + 6H_2O + 3SO_2$

aluminium sulphuric acid aluminium sulphate water sulphur dioxide

(iii) Reaction with nitric acid In dilute or concentrated nitric acid, aluminium is rendered passive due to the formation of an insoluble layer of oxide. The oxide layer does not permit further reaction.

(iv) Action of alkalis Aluminium dissolves in caustic soda or caustic potash solution with the evolution of hydrogen, forming soluble sodium or potassium aluminate respectively.

$$2Al + 2NaOH + 2H_2O \rightarrow 2NaAlO_2 + 3H_2$$

$$2Al + 2KOH + 2H_2O \rightarrow 2KaAlO_2 + 3H_2$$

On account of these reactions, aluminum containers cannot be used to store alkali solutions.

(v). Action of chlorine When chlorine gas is passed over heated finely powdered aluminum, aluminium chloride is produced.

$$2Al + 3Cl_2 \rightarrow 2AlCl_3$$

(vi) Reducing action Aluminum is a powerful reducing agent. It reduces CO and CO_2 to Carbon .

$$3CO + 2Al \rightarrow Al_2 + 3C$$

$$3CO_2 + 4Al \rightarrow 2Al_2O_3 + 3C$$

It reduces many metal oxides to metals. For example, it reduces ferric oxide (Fe_2O_3) to iron metal.

$Fe_2O_3 + 2Al \rightarrow Al_2O_3 + 2Fe$

A large amount of heat is liberated in this reaction. As a result, temperature rises to about 3500^0C.

Tests for aluminium salts

1. **Charcoal test** A solid aluminium salt is heated the cavity of a charcoal block. A white residue is obtained. When this residue is moistened with cobalt nitrate solution, a blue mass is obtained.
2. When the aqueous solution of an aluminium salt is treated with ammonium hydroxide, a white gelatinous precipitate of aluminium hydroxide is produced.

$AlCl_3 + 3NH_4OH \rightarrow Al(OH)_3 + 3NH_4Cl$

Aluminium chloride ammonium hydroxide aluminium hydroxide ammonium chloride

Uses of aluminium

1. Aluminium is a good conductor of heat and it does not get corroded. Hence, it is widely used to make utensils like pans, kettles, etc.
2. Aluminium is a good conductor of electricity; it is extensively used in making electrical wires.
3. Aluminium foils are used for wrapping foodstuffs.
4. Aluminium is a light metal. Hence, it is used in making bodies and parts of aircraft, buses furniture, etc. Since pure aluminium is not very strong, alloys of aluminium are used for these purposes.
5. Aluminium powder is used in anti-corrosion paints and in explosives.
6. Aluminium powder is also used in alumino-thermic process for welding two iron objects.

USES OF METALS

From time immemorial, metals have been in the service of man for various purposes. We know has been using metals for the manufacture of tools and weapons. With the passage of time, the use became widespread.

Metals are used in three different forms:

1. As pure metals
2. As alloys
3. As compounds of metals

Uses of pure metals

1. Metals are good conductors of electricity. copper is used to make good quality electric wires. Aluminium is also used to make electric wires which are cheaper than copper wires.
2. Iron, aluminium and copper are used for making cooking utensils and factory equipment.
3. Mercury is used in thermometers and in the action of some medicines.
4. Silver and gold are used in jewellery.
5. Thin foils of aluminium are used for packaging
6. Iron, in the form of steel, wrought iron and cast iron is used for the manufacture of locomotives, railway lines, implements of war, springs, tubes, cranes, etc.
7. Gold, silver, copper, nickel, etc., are being used for coinage all over the world.
8. Zinc and tin are used for coating iron objects to prevent rusting.
9. Cadmium, titanium and zirconium are used in atomic energy and space research projects.
10. Nowadays, titanium is used in aerospace and aircraft industries for making aircraft frames and engines where its high strength to weight ratio is useful, in the manufacture of military hardware, and in chemical reactors and industries. It finds application in making marine instruments. It is also used for hardening of steel.

The large-scale use of titanium is due to (i) its high strength to weight ratio, (ii) its resistance to corrosion and (iii) its high melting point. Due to its specific (especially military and aerospace) application called a strategic element.

Uses of alloys

An alloy is a mixture of a metal with other metals or nonmetal. It has properties different from those of its constituents. The properties of a metal are much more improved and pronounced when the metal is transformed into an alloy. For example, aluminium is a light metal and it is not very strong. But an alloy of aluminium (duralumin) is light and very strong. Similarly, silver is soft, but a silver alloy is hard and more useful than pure silver.

In order to prepare an alloy we mix up various metals molten state. The molten mass is then cooled to room temperature. The solid substance formed is an alloy.

Some of the commonly used alloys, their composition various uses, are listed in Table.

	Alloy	**Composition**	**Uses**
1.	Brass	Copper = 80% zinc= 20%	Brass is harder than pure copper. It is used for making utensils, cartridges, etc.
2.	Bronze	Copper= 80%Zinc = 10%tin= 10%	It is used for making statues, medals, ships, coins, and machines,
3.	Solder	tin= 50%lead = 50%	It is used for joining metals, soldiering wires, electronic components. Etc.
4.	Duralumin	Aluminium= 94.4%silicon = 4%and Copper, Magnesium, manganese .	It is used for making bodies of aircraft and kitchenware
5.	German Silver	Copper = 60%Zinc=20%Nickel= 20%	It is used for making utensils, ornaments, etc.
6.	Monel metal	Nickel=70%Copper=30%Iron=2%	
7.	Nichrome	Nickel =67.5%Chromium=15%Iron =16% Manganese=1.5%	It is used for making coils of electric furnaces.
8.	Gun metal	CopperTinZinc	It is used for making bearing, valves, etc.
9.	Rose metal	SiliconLeadTin	It is used for making fuse wires.

21.5 SOME USEFUL COMPOUNDS OF METALS

Common Salt. Common salt is sodium chloride (NaCl). Common salt when kept open absorbs moisture from air. This is because of the presence of magnesium chloride in common salt. Magnesium chloride is deliquescent, that is, it absorbs water.

Sodium chloride is very important chemical. It is an essential ingredient in our daily meal. It can be converted into useful chemicals like caustic soda, washing soda and baking soda. It also yields hydrochloric acid, an important chemical used in chemical industry, and chlorine which is used as a bleaching agent.

Caustic Soda. Chemically caustic soda is sodium hydroxide (NaOH). It is obtained by electrolysis of brine (NaCI solution).

Sodium hydroxide is a deliquescent solid. On dissolving in water it gives a strong alkaline solution.

Washing Soda. Washing soda is sodium carbonate decahydrate Na2CO3 .10H_2O. Sodium carbonate (soda ash) is alkaline in nature and has detergent (cleaning) properties. In a crystalline state it possesses water of crystallization. On exposure to air, crystals lose water and turn into white opaque powder.

$$Na_2CO_3 . 10H_2O \rightarrow Na_2CO_3 . H_2O + 9H_2O$$

Such an action, that is the giving up of water of crystallization to the atmosphere is termed as efflorescence. Sodium carbonate is used as a cleansing agent for domestic purposes. It is also used for softening of hard water, in manufacturing of chemicals like borax, caustic soda, glass and water glass. It is a constituent of many dry soap powders.

Baking Soda. The chemical name of baking soda is sodium hydrogen carbonate (NaHCO3). Sodium bicarbonate is used in the manufacture of baking powders and health salts. In addition to sodium bicarbonate, baking powders contain tartaric acid (or a similar Compound.) When heated sodium bicarbonate reacts with acid producing carbon dioxide which causes cake to rise and become light.

Lime. Calcium oxide is commonly known as quicklime or just lime. It is prepared by heating lime stone ($CaCO_3$) in a kiln.

$$CaCO_3 \rightarrow CaO + CO_2$$

Calcium oxide reacts vigorously with water producing slaked lime [Ca(OH)2] which is used for making mortar and for white washing.

A solution of slaked lime is known as lime water which is used for testing carbon dioxide. Calcium oxide is used for making cement and glass.

Bleaching Powder. The chemical name of bleaching powder is calcium oxychloride ($CaOCl_2$). Bleaching powder is prepared by passing chlorine over solid slaked lime.

$$Ca(OH)_2 + Cl_2 \rightarrow \underset{\text{Bleaching powder}}{CaOCl_2} + H_2O$$

When exposed to air, bleaching powder deteriorates giving off chlorine.

Bleaching powder is commonly used for bleaching in laundries. It is used in paper and textile industries, for disinfecting water and for preparation of chloroform.

Plaster of Paris. It is a calcium sulphate hemihydrate $(CaSO\text{-}_4)_2\ H_2O$. It is prepared by heating gypsum ($CaSO_4\ 2H_2O$).

$$2(CaSO_4 \cdot 2H_2O) \rightarrow (CaSO_4)_2\ H_2O + 3H_2O$$

Plaster of paris has a remarkable property of hardening when mixed with proper quantity of water. The hardening of plaster of paris is due to its hydration to form gypsum. It is used in the laboratories for sealing the gaps, where sunlight arrangement is required. It is also used for making casts for statues, and in surgery to maintain joints in a fixed position

8. CARBON AND ITS COMPOUNDS

Carbon is chemical element (C) with an atomic number of 6 and atomic weight of 12.01115 and electronic configuration 2,4. It is estimated that carbon makes up 0.032% of the earth's crust. Carbon is unique in chemistry because it forms a vast number of compounds, larger than the sum total of all other elements combined. By far the largest groups of these compounds are those composed of carbon and hydrogen. It has been estimated that there are at least 1,000,000 known organic compounds, and this number is increasing rapidly every year.

A carbon atom has 4 electrons in its outermost shell and since one carbon atom requires 4 electrons to achieve the eight electron inert gas configuration, therefore the valency of carbon is 4.

ALLOTROPY OF CARBON

Allotropy is the existence of an element in two or more different forms in the same physical state. The different forms of elements are called allotropes.

Elemental carbon exists in two well-defined crystalline allotropic forms, diamond (the hardest naturally occurring substance) and graphite. Other forms, which are poorly developed in cyrstallinity, are charcoal, coke, and carbon black which are amorphous forms of carbon. Chemically pure carbon is prepared by the thermal decomposition of sugar (sucrose) in the absence of air. The physical and chemical properties of carbon are dependent on the crystal structure of the element.

While diamond is very hard, transparent and a nonconductor of electricity, graphite is black, soft, opaque and a good conductor of electricity. Another form of graphite is carbon black. This is not present in nature. It is obtained by burning compounds of carbon and hydrogen in a limited supply of air. Diamond is employed where hardness is desired, like in drilling bits and abrasives. Graphite finds use as a lubricant, for making lead pencils, high temperature crucibles, arc light and in dry cells. Carbon black is used to harden rubber for tyre manufacture and printing inks. The less pure forms of the elemental carbon-charcoal and coke- are widely used as fuels. Coke is also used as a reducing agent in metallurgy. Charcoal is used as an absorbent for gases and as a decolourising agent.

COMPOUNDS OF CARBON

Elemental carbon is a fairly inert substance. It is insoluble in water, dilute acids and bases, and organic solvents. At elevated temperatures, it combines with oxygen to form carbon monoxide or carbon dioxide. Of halogens, only flourine reacts with elemental carbon. A number of metals combine with the element at elevated temperatures to form carbides.

Carbon atoms also have a great capacity to link with more and more carbon atoms. They can thus form large chains or large rings of compounds. This property of carbon is called catenation.

Carbon forms three gaseous compounds with oxygen: carbon monoxide, CO; carbon dioxide, CO2 and carbon sub oxide, C3O2. The first two oxides are more important from an industrial standpoint. Carbon forms compounds with the halogens which have the general formula CX4where X is fluorine, chlorine, bromine, or iodine. At room temperature, carbon tetrafluoride is a gas, carbon tetrachloride is a liquid, and the other two compounds are solids. Mixed carbon tetrahalides are also known. Perhaps the most important of them is dichlorodifluoromethane CCl_2F_2, commonly called Freon.

Extensive amounts of carbon are found in the form of its compounds. In the atmosphere, carbon is present as carbon dioxide. Various minerals such as limestone, dolomite, marble, and chalk all contain carbon in the form of carbonate. All plant and animal life is composed of complex organic compounds containing carbon combined with hydrogen, oxygen, nitrogen, and other elements. The remains of plant and animal life are found as deposits of petroleum, asphalt, and bitumen. Deposits of natural gas contain compounds that are composed of carbon and hydrogen.

Carbon dioxide is a colourless, odourless, tasteless gas, formula CO2, about 1.5 times as heavy as air. Under normal conditions, it is stable, inert, and nontoxic. The decay (slow oxidation) of all organic materials produces CO2. Fresh air contains approximately 0.03% CO2 by volume. In the respiratory action (breathing) of all animals and humans, CO2 is exhaled.

Carbon dioxide gas may be liquefied or solidified. Solid CO2 is known as dry ice. Carbon dioxide is obtained commercially from four sources: gas wells, fermentation, combustion of carbonaceous fuels, and as a by-product of chemical processing. Most CO2 is obtained as a by-product from steam-hydrocarbon reformers used in the production of ammonia, gasoline, and other chemicals. Applications include use as a refrigerant, in either solid (dry ice) or liquid form, inerting medium, chemical reactant, neutralising agent for alkalies, and pressurizing agent.

Carbon dioxide does not support the combustion of a splint or candle, but magnesium ribbon burns with a crackle in carbon dioxide forming white magnesium oxide and black specks of carbon. Carbon dioxide turns calcium hydroxide solution (lime water) milky. This is due to the formation of calcium carbonate which is a white insoluble solid. When excess carbon dioxide is bubbled through the solution, calcium hydrogen carbonate is formed. This is soluble in water and the milkiness therefore disappears and the solution becomes clear.

Carbon monoxide is formed when carbon compounds burn in limited supply of air. Carbon monoxide is very poisonous and particularly dangerous because it has no smell. More people have been killed by carbon monoxide than by any other gas. Carbon monoxide is poisonous because it reacts with the haemoglobin in blood and prevents the blood from acting as an oxygen carrier. The gas can be produced accidentally by leaving a car engine running in a closed garage or by burning a fire or boiler with restricted ventilation. Carbon monoxide can act as a reducing agent. At higher temperatures it reduces the oxides of copper, lead, and iron to the metals. Carbon monoxide is the principal reducing agent in a blast furnace.

ORGANIC COMPOUNDS

Organic chemistry is the chemistry of carbon compounds. Most of these compounds are known as organic compounds because of their origin in the tissue of living organisms. As there are a very large number of carbon compounds, their study forms an entire branch of chemistry. Carbon and hydrogen are the essential components of all organic compounds while oxygen, nitrogen, sulphur, phosphorus and halogens may also be present. Organic compounds constitute major components of energy sources like petroleum and coal; components of food like proteins, fats, carbohydrates and vitamins, drugs like anaesthetics, antiseptic and antibiotics, materials like cotton, wool, silk and synthetic fibres (e.g. nylon and terylene).

It is possible to divide organic compounds into two main divisions depending on their structure: acyclic and cyclic. The acyclic compounds are those in which the carbon atoms are linked to each other in such a manner that the molecule is having an open chain structure. They are also known as open-chain compounds or aliphatic compounds. Examples: methane, ethane, ethylene, ethyl alcohol, acetone, acetic acid, etc. These open-chain compounds may have a straight or branched chain of carbon atoms and are accordingly referred to as straight chain or branched chain aliphatic compounds.

When the carbon atoms are linked to each other or to the atoms of some other elements in a manner so as to form a closed chain or ring type structure, the compounds are known as cyclic compounds. The compounds with only one ring of atoms in the molecule are known as monocyclic but those with more than one ring of atoms are termed as polycyclic. . Again the ring may be made up of only carbon atoms or it may contain different atoms like N, O, S, etc., besides the carbon in the ring. The former types of compounds are known as homocyclic or carbocyclic whereas the latter are referred to as heterocyclic. A large number of cyclic compounds having alternate single and double bonds show unusual stability towards addition reaction and undergo substitution reactions despite the unsaturation in the molecule. Such compounds are designated as arene or aromatic.

HYDROCARBONS

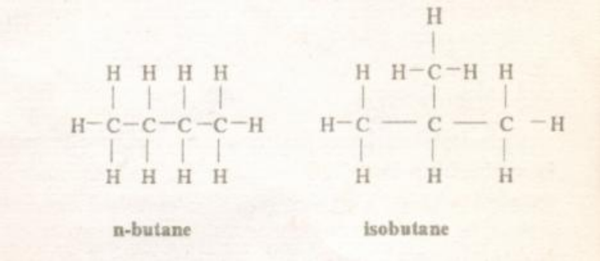
Hydrocarbons are organic compounds containing carbon and hydrogen only. Examples: methane, ethane, propane, butane, benzene. Hydrocarbons occur abundantly in nature, largely in petroleum, natural gas and coal. They can be considered as the parent organic compounds from which other organic compounds are derived. The major use of hydrocarbons is as fuels and as petrochemicals.

The simplest hydrocarbon is methane (CH_4). A molecule of methane has four hydrogen atoms linked to one central atom of carbon. We know that the valency of carbon is 4 (tetravalent). The carbon atom, therefore, forms a chemical bond with 4 atoms of hydrogen by sharing an electron with each of them. The valency of hydrogen is 1 (monovalent) and each of the hydrogen atoms also shares an electron with the carbon atom. A methane molecule thus formed by 4 hydrogen atoms surrounding a carbon atom (four single covalent bonds) in a chemical bond makes for a very stable arrangement. Like carbon dioxide, methane molecules also contribute to greenhouse effect. In fact, methane molecules trap 20 times as much heat as a molecule of carbon dioxide.

Hydrocarbons are of two types: saturated hydrocarbons and unsaturated hydrocarbons.

Saturated Hydrocarbons. A hydrocarbon, in which the carbon atoms are attached by single covalent bonds only, is called a saturated hydrocarbon. Alkanes (types of hydrocarbon) are saturated hydrocarbons. The general formula of alkanes is C_nH_{2n+2} where n is the number of carbon atoms in one molecule of alkane. The hydrocarbons methane (CH_4) ethane (C_2H_6) propane (C_3H_8) and butane (C_4H_{10}) form a series of carbon compounds belonging to a family, in which one member to another is called a homologous series. Alkanes are excellent fuels.

Isomerism. Compounds having the same molecular formula but different structural arrangement of atoms in them are known as isomers, and the phenomenon is known as isomerism. All members of alkanes, except first three methane, ethane and propane can have more than one structural formula. For example butane can have 2 different arrangements of atoms in its molecule as shown below.


n-butane
isobutane

Unsaturated Hydrocarbons. A hydrocarbon in which the two carbon atoms are attached by a double bond or a triple bond is called an unsaturated hydrocarbon. Unsaturated hydrocarbons are of two types: (1) those containing double bonds—alkenes, and (ii) those containing triple bonds— alkynes.

Alkenes. The general formula of alkenes is C_nH_{2n} where n is the number of carbon atoms in its one molecule. Ethylene, C2H4 or H2C=CH2 and propylene C_3H_6 or CH_2=CH- CH_3 are the two examples of alkenes. Alkenes are also known as olefins.

Alkynes. The general formula of alkynes is C_nH_{2n-2}, where n is the number of carbon atoms in its one molecule. Examples are acetylene, C_2H_2 or HCºCH; propylene C_3H_4 or HCºC-CH3, etc. It is to be noticed that there can be no alkenes or alkynes having only one carbon atom.

Unsaturated hydrocarbons are obtained mostly from petroleum by a process called cracking (means breaking down).

SOME COMPOUNDS OF CARBON, HYDROGEN AND OXYGEN

Alcohols. An alcohol is a compound containing hydroxyl group, —OH. It is produced by replacing one hydrogen atom of an alkane by a—OH group. Common examples are methanol (CH_3OH), ethanol (C2H_5OH), propanol (C_3H_7OH), etc. Alcohols also form homologous series with the general formula $C_nH_{2n+1}OH$. They are named after parent alkane by replacing the last letter E by OL. Most common alcohols are liquids.

Methanol is poisonous, mixed with ethanol it used in spirit lamps and as a solvent for wood polish. Methanol is also used for making perfumes and synthetic fibres. Ethanol is the most widely used alcohol. It is prepared by fermentation process whereby sugar and starch molecules are broken down into smaller molecules along with the formation of carbon dioxide. Ethanol is a constituent of beer, wine, whisky and other liquors. A mixture of alcohol and water known as antifreeze is used in radiators of vehicles in cold countries. Alcohols are used as fuels and solvents.

Organic Acids. Organic acids contain-COOH group (carboxyl group). Organic acids can be prepared by oxidation of alcohols. Acids are named after the respective alkane containing the same number of carbon atoms, by substituting the last letter E of the corresponding alkane by OIC ACID. For example HCOOH is methanoic acid (formic Acid), CH_3COOH is ethanoic acid (Acetic acid) etc. Lower acids are liquids. However those acids whose molecules contain large number of carbon atoms (>16) occur as solid, and are known as fatty acids. They are used as mild acids, in foods, cold drinks, drugs, perfumes and soaps.

Esters. Compounds which contain the functional group COO are called esters. Esters are formed when organic acids react with alcohols in the presence of sulphuric acid.

$$CH_3COOH + C_2H_5OH \xrightarrow[\text{(sulphuric acid)}]{\text{catalyst}} CH_3COOC_2H_5+H_20$$

Esters have a fruity smell. They are used in cold drinks, icecreams, sweets and perfumes. They are also found to occur in fruits.

PETROLEUM AND NATURAL GAS

Petroleum or rock oil (Petra—rock and oleum–oil) usually floats on a layer of salt water, deep below the rocks and has a layer of natural gas upon it. Natural gas contains about 80% methane and 10% ethane, the remaining 10% being a mixture of higher gaseous hydrocarbons. Compressed Natural Gas (CNG) is natural gas filled in cylinders under high pressure. Most of it is used as an industrial fuel, without purification. The propane-butane fraction is separated from the more volatile components by liquefaction: it is compressed into cylinders and sold as bottled gas or LPG (liquified petroleum gas) which is used as domestic fuel for cooking.

Mining of oil is done by drilling holes in the earth's crust and sinking pipes up to the oil bearing porous rock. As the pipe reaches the oil, it rushes up through the pipe due to the pressure of the gases inside. As the gas pressure gets low, the oil is pumped out by applying air pressure. The crude oil is obtained as a viscous, dark coloured liquid, often with a distinct odour. It consists of a mixture of gaseous, liquid and solid hydrocarbons. Besides hydrocarbons, small amounts of organic compounds containing oxygen, nitrogen and sulphur are also present. The hydrocarbons present in crude oil are paraffins (C1 to C40 alkanes), naphthenes (cycloalkanes), olefins and aromatic compounds in varying percentages. It is separated into various fractions by the process known as refining of petroleum. According to the nature of the main constituents present, the crudes are classified into three groups:

(a) **Paraffin-base** petroleum mainly consists of hydrocarbons of the paraffin series. On distillation, solid paraffin wax is left behind.

(b) **Asphalt-base** petroleum is rich in nonparaffinic hydrocarbons, like aromatic and naphthenic compounds, and on distillation asphalt or bitumen is left behind.

(c) **Mixed base** has a composition between the above two types.

The history of petroleum in India began with its accidental discovery in Digboi, Assam in 1889-90. After independence (1947), extensive oil exploration began which changed the picture of the petroleum industry in India. In 1956, Oil and Natural Gas Commission (ONGC) was set up. It has been very successful in locating new oil fields and mining the crude. The chief oil producing areas are Assam, Gujarat and Bombay High (offshore).

Refining of Petroleum The refining of crude oil involves separation into fractions with different boiling points. The distillation of petroleum is carried in tubular furnace with a tall steel fractionating column. The fractionating column consists of a vertical steel cylinder divided by horizontal plates into a number of sections. These plates are called trays. The trays have a large number of perforations, through which vapour pass in the upward direction. Each perforation in mounted by a short pipe and a cap, called the bubble cap. The system is such that the vapours have to pass through the liquid collected on one tray so that reasonably good contact between the two is accomplished.

Uses of Various Fractions

(a) **Gaseous Hydrocarbons** This fraction is mainly used as industrial or domestic fuel.

(b) **Petroleum Ether** It is used as solvent in perfumery and also for drycleaning clothes.

(c) **Gasoline** This fraction, when obtained directly from refining process is called straight run gasoline, commonly known as petrol. Crude petroleum contains only a small percentage of this low-boiling fraction. Its yield is therefore, increased by cracking of high boiling fractions, e.g. kerosene or diesel oil.

(d) **Kerosene** Kerosene was the most important petroleum product for almost fifty years since crude oil was first processed. Although it has now lost its leading place to gasoline, it is still in considerable demand. It is used in lamps, burners (stoves), and turbojet aircraft. It is also subjected to the process of cracking to meet the increasing demand for gasoline.

(e) **Diesel oil or Gas Oil** This fraction is used as fuel for diesel engines, for industrial heating (hence also called furnace oil) and as a feed stock for cracking processes where it is converted to high grade gasoline.

(f) **Lubricating oils and Greases** As the name indicates, they are chiefly used for lubrication. Lubricating greases are semi-solid substances made by thickening lubricating oils with soaps, clays, silica gel or other thickening agents.

(g) **Paraffin Wax** It is used in making candles, shoe polish, floor polish, waxed paper, etc. White petroleum jelly (Vaseline) is a paraffin wax with little oil content and is a major constituent of many ointments and cosmetics.

(h) **Asphalt and Coke** These are dark semisolid or solid residues of the distillation process. They are used for roofing, road building, making underground cables, battery boxes and electrodes, etc.

Other Fractions

Other fractions are less useful and are converted by various processes into useful chemicals, e.g. plastics, detergents, solvents, rubber, etc. All chemicals derived from petroleum fractions are called petrochemicals. Another way of converting the high-boiling fractions into useful gasoline is by cracking when smaller hydrocarbons $(C_2–C_5)$ are formed. The quality of petrol for use in car engines is denoted by their anti-knock properties. The anti-knock property of petrol samples are measured by the values of their octane numbers. The higher the octane number of a petrol sample, the more anti-knocking property it has and more useful it is. The highest octane number is 100. To increase octane number, tetra ethyl lead (TEL) is added to petrol.

9. ELECTRO CHEMISTRY

It is concerned with the relation between electrical energy and chemical change. It includes the study of formation and behaviour of ions in solution. An ion is an electrically charged atom or group of atoms; positively charged ions are called cations, while negatively charged ions are known as anions.

Substances, which in the liquid state or in the form of solutions in some solvent (mostly water) allow electricity to pass through are called electrolytes, e.g. water, common salt, molten salts, etc. Substances that do not allow electricity to pass through are called non-electrolytes, e.g. sugar, wax, naphthalene, etc.

The passage of electric current through an electrolyte is called electrolysis. During electrolysis, the electrodes become coated with a layer of metal; this process is called electroplating, and is useful in preventing rust formation and corrosion.

Electrolysis

The process of decomposition of an electrolyte (a compound formed by electrovalent bonds) by the passage of an electric current through its molten state or its aqueous solution is called electrolysis and the experimental arrangement used for this purpose is called an electrolytic cell.

This process of electrolysis can be explained by considering the decomposition of aqueous sodium chloride solution by an electric current as is explained below:

(i) The solution of sodium chloride in water contains sodium ions and chloride ions.

$$NaCl \xrightarrow{water} Na^+ + Cl^-$$

(ii) The sodium ions and chloride ions are moving aimlessly (random motion) in the solution.

(iii) When the two electrodes are connected with a battery, one electrode becomes positively charged and the other negatively charged.

(iv) The positively charged electrode (anode) attracts the negatively charged ions (anions, Cl^-) and the negatively charged electrode (cathode) attracts the positively charged ions (cations, Na^+).

(v) When the anions reach the anode, they give up their negative charge (electrons) to the anode and become neutral.

At anode:

$$Cl^- \qquad Cl + e^-$$

The neutral atoms (which are reactive) then combine to form molecules.

$$Cl + Cl \qquad Cl_2$$

(vi) When the cations reach the cathode, they accept electrons from it and become neutral atoms which may exist as an element.

At cathode :

$$Na^+ + e^- \qquad Na$$

Sodium obtained at cathode reacts with water to form sodium hydroxide, liberating hydrogen.

$$2Na + 2H_2O \qquad 2\,NaOH + H_2$$

It should be noted that an electrolyte is decomposed during electrolysis and the decomposition of the electrolyte takes place only at the electrodes and not in between the electrodes.

Characteristics of Electrolysis

(i) Electrolytic reaction or the process of electrolysis (that is a reaction in which an ion loses or gains electrons) starts as soon as the current is switched on and stops as soon as it is switched off.

(ii) The primary products of electrolysis, that is the products formed by the discharge of ions are liberated only at the electrodes.

(iii) Hydrogen and metals are usually set free at the cathode. Elements liberated at the cathode are said to be electropositive.

(iv) Non-metals are liberated at the anode. Elements liberated at the anode are said to be electronegative.

(v) The weight of a substance produced on an electrode during electrolysis is proportional to the quantity of electricity passed through the electrolye.

Applications of Electrolysis

The process of electrolysis is applied in a number of fields for various purpose. Some of the important applications are discussed below:

(i) **Electroplating** is a process of depositing one metal (generally a superior metal such as iron or copper) through the process of electrolysis.

Electroplating may be carried out for preservation or decoration. For example, articles, made of iron are electroplated with tin, nickel or chromium to prevent rusting. Similarly, many household articles such as tea sets and decoration pieces made of metals like copper and brass are electroplated with gold or silver to enhance their beauty.

(ii) **Electrorefining** Metals can be refined (purified) by the electrolytic method. A thick slab of impure metal is made the anode and a thin sheet of pure metal is made the cathode in the solution of a suitable salt of the metal to be purified.

On passing electricity, the anode goes on dissolving and the pure metal gets deposited at the cathode. The impurities are thrown down in the form and anode mud. Copper is industrially purified by this method.

(iii) **Electroprinting** In large-scale printing, impression of the ordinary type page is made on wax or plaster of paris. The wax plate is made a conductor by sprinkling graphite on it and then made cathode in copper plating bath. On passing electric current, copper deposits on the wax plate till a sufficient thickness of copper deposit is obtained. It is removed and strengthened by filling its back with type-metal. The mould obtained is an exact copy of the printer's page and is used in large scale printing.

(iv) **Electrometallurgy** The process of extraction of metal from its ore by electrolysis is called electrometallurgy. For example, sodium is obtained by electrolysis of fused sodium chloride, while aluminium is extracted by the electrolysis of bauxite in fused cryolite.

(v) **Industrial Preparations** A large number of chemicals used in industry and medicine are prepared electrolytically. For example, caustic soda, washing soda, chlorine, and so on is obtained by electrolysis of sodium chloride, while hydrogen and oxygen are manufactured by electrolysis of acidulated water.