Carbon is considered as the third most important element, after oxygen and hydrogen, for the existence of life on the earth. The name carbon is derived from the Latin word 'Carbo' which means 'coal'. The earth crust contains only (0.02%) carbon which is present as minerals (like carbonates, hydrogen-carbonates, coal and petroleum) and the atmosphere has 0.03% of carbon dioxide. Fuels (like wood, kerosene, coal, LPG, CNG, petrol etc.), clothing material (like cotton, nylon, polyester), paper, rubber, plastics, leather, drugs and dyes are all made up of carbon. All the living things (plants and animals) are made up of carbon compounds. **Covalent Bond in Carbon:** The bonds which are formed by the sharing of an electron pair between the atoms either same or different atoms are known as covalent bonds. Atomic number of carbon (C) is 6. So, its electronic configuration= 2, 4. Thus, there are 4 electrons in its outermost shell and its octet can be completed by the following two ways:

(i) It could lose 4 electrons and form C^{4+} cation. But a large amount of energy required to remove 4 electrons leaving behind a carbon cation with 6 protons L1 its nucleus holding on just two electrons together, which is not possible

(ii) It could gain 4 electrons and can form C^{4}anion. But for a nucleus have 6 protons, it would be difficult to hold on 10 electrons, i.e. 4 extra electrons.

Therefore, in order to overcome this problem, carbon shares its valence electrons with other atoms of carbon or with atoms of other elements. These shared electrons belong to the outermost shells of both the atoms and in this way, both atoms attain the noble gas configuration. This type of bonding is call covalent bonding.

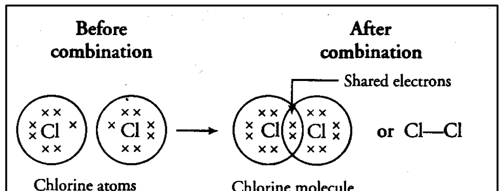
Some Examples Depicting Covalent Bonding:

1. Formation of Hydrogen Molecule (H_2): Atomic number of H = 1

Single bond showing H_2 molecule

Electronic configuration = 1. It has 1 electron in its K-shell and needs 1 more on to fill the K-shell completely. Two H-atoms share each of their electrons a molecule of H_2 and thus, each H-atom attains the nearest noble gas configuration, i.e. configuration hum (having two electrons in its K-shell). Valence electrons are depicted by using crosses. The shared pair of electrons constitutes a single bond m the two H-atoms, which is represented by a line between the two atoms.

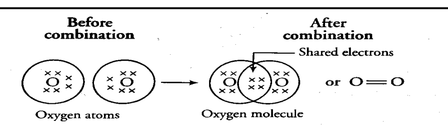
2. Formation of Chlorine Molecule (Cl_2): Atomic number of Cl =17



Covalent bonding in Cl_2 molecule

Electronic configuration = 2, 8, 7. It has 7 electrons in its outermost shell and thus requires 1 more electron to fulfill its outermost shell. This is achieved by sharing 1 electron with another m, forming a chlorine diatomic molecule (Cl_2).

3. Formation of Oxygen Molecule (O_2): Atomic number of O = 8

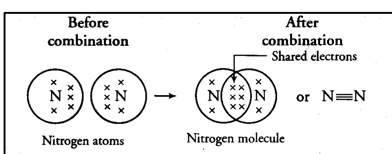


Covalent bonding in O_2 molecule

Electronic configuration= 2, 6. It has 6 electrons in its outermost shell thus; require 2 electrons to complete of its octet for attaining noble gas configuration. This is achieved by sharing 2 electrons with another oxygen atom. The two electrons contributed by each oxygen atom give rise to two shared pairs of electrons.

Here, a double bond is formed between two oxygen atoms thereby forming an oxygen molecule. The above figure represents the sharing of 4 electrons.

4. Formation of Nitrogen Molecule (N_2): Atomic number of N = 7.



Covalent bonding in N_2 molecule

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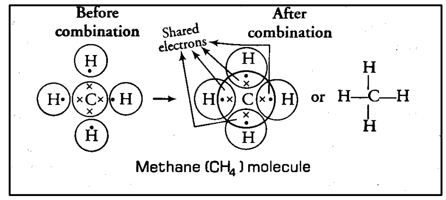
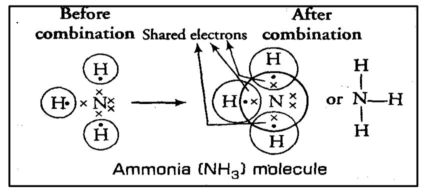
Electronic configuration = 2, 5. It needs 3 more electrons to attain noble gas configuration. Thus, 2 nitrogen atoms share 3 each of their electron, forming a triple bond between two nitrogen atoms thereby forming nitrogen molecule.



Methane (CH_4) molecule

5. Formation of Methane (CH_4): In the formation of a methane molecule, one carbon atom shares its 4 electrons with four hydrogen atoms (one electron of each hydrogen atom). It shows carbon is tetravalent because it possesses 4 valence electrons and hydrogen is monovalent because it has only 1 valence electron.

Note: Methane is a carbon compound which is also called marsh gas. It is used as a fuel and a major component of CNG (Compressed Natural Gas) and biogas. It is one of the simplest compounds formed by carbon.

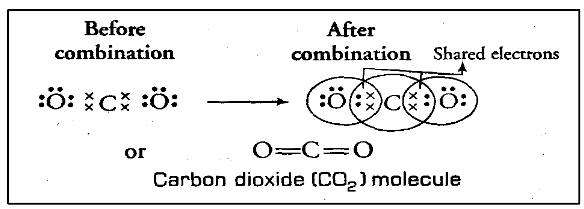


Ammonia (NH_3) molecule

6. Formation of Ammonia (NH_3): Atomic number of N = 7. Electronic configuration = 2, 5. Atomic number of H = 1. Electronic configuration = 1. To attain the electronic configuration of the nearest noble gas, nitrogen needs 3 electrons and hydrogen needs 1 electron. When a molecule of ammonia is to be formed, one atom of nitrogen shares its three electrons, one with each of the three atoms of hydrogen.

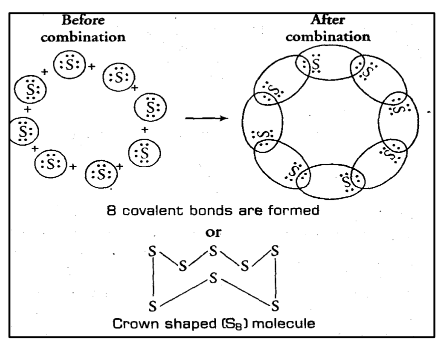
Note Ammonia gas (NH_3) can be used as refrigerant.

7. **Formation of Ammonia (H_2O):** Atomic number of O = 8
Electronic configuration = 2, 6. Atomic number of H = 1
Electronic configuration = 1. To attain the stable electronic configuration of the nearest noble gas, hydrogen needs 1 electron and oxygen needs 2 electrons. In case of a water molecule, each of the two hydrogen atoms share an electron pair with the oxygen atom such that hydrogen acquires a duplet configuration and oxygen an octet, resulting in the formation of two single covalent bonds.



Carbon dioxide (CO_2) molecule

8. **Formation of Carbon Dioxide (CO_2)**:
Atomic Number of C = 6
Electronic configuration =2, 4. Atomic number of O = 8
Electronic configuration 2, 6. To attain the stable electronic configuration, carbon needs 4 electrons, while oxygen needs 2 electrons. So, in CO_2, each of oxygen atom share two electrons from carbon. Thus, oxygen and carbon both attain octet.



Crown shaped (S_8) molecule

9. Formation of Sulphur Molecule (S_8): Atomic number of S = 16. Electronic configuration = 2, 8, 6. To attain the electronic configuration of the nearest noble each sulphur needs 2 electrons.

Q1: Carbon a group (14) element in the periodic table, is known to form compounds with many elements. Write an example of a compound formed with:
(i) chlorine (group 17 of periodic table)
(ii) oxygen (group 16 of periodic table)

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ALLOTROPES OF CARBON AND THEIR PROPERTIES: Allotropy is the property by virtue of which an element exists in more than one form and each form has different physical properties but identical chemical properties. These different forms are called allotropes. Carbon exists in different allotropic forms some of which are:

(i) Crystalline form, e.g. diamond, graphite and fullerene.

(ii) Micro-crystalline form or amorphous form, e.g. coal, lampblack and charcoal.

Diamond

General Properties

• It is a colourless transparent substance with extra ordinary brilliance due to its high refractive index.

• It is quite heavy and extremely hard (hardest natural substance known).

It does not conduct electricity (because of the absence of free electrons) but it has high thermal conductivity and high melting point.

Structure: It is a giant molecule of carbon atom is linked to four other carbon atoms by strong covalent bonds forming a rigid three-dimensional network structure, which is responsible for its hardness. Moreover, a lot of energy is required to break the network of strong covalent bonds in the diamond crystal, thus its melting point is very high.

Uses

• Due to its hardness it is used as knives for cutting marble, granite and glass.

• It is used for the purpose of ornaments studded as precious stones.

Note: Diamond can be prepared artificially by subjecting pure carbon to very high pressure and temperature. These synthetic diamonds are small but are indistinguishable from natural diamonds.

Graphite

General properties

• It is a greyish black, opaque substance.

• It is lighter than diamond, feels soft, smooth and slippery to touch.

• It is a good conductor of electricity (due to the presence of free electrons) but bad conductor of heat.

Structure: A graphite crystal consists of layers of carbon atoms or sheets of carbon atoms. Each carbon atom in a graphite layer is joined to three other carbon atoms by strong covalent bonds to form flat hexagonal rings. However, the fourth electron of each carbon atom is free which makes it good conductor of electricity. The various layers of carbon atoms in graphite are held together weak Van Der Waals' forces so these can slide over one another and therefore, graphite is slippery to touch.

Uses

• It is used as a powdered lubricant for the parts of machinery.

• It is used for making electrodes of cells and lead for pencils as it can mark paper black. It is therefore called black led or plumbago.

Fullerenes: These are recently discovered allotropic forms of carbon which were prepared for the first time by H W Kroto, Smalley and Robert Curt by the action of laser beam on the vapours graphite. The first known fullerene was C_{60} which contains 60 carbon atoms (C_{60}) with traces compounds containing even upto 370 carbon atoms. Fullerene (C_{60}) was named **buckminster fullerene** after American architect **Buckminster Fuller** because in C_{60} carbon atoms are arranged in the shape of a soccer ball and it bold like the geodesic dome designed by Buckminster Fuller.

Versatile nature of carbon: The estimated number of carbon compounds known today about three million. But now the question is, which property or properties of carbon is/are

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responsible for the formation of such a large number of carbon compounds. The main reasons for this huge number of carbon compounds are:

1.**Catenation:** The property of self linking of elements mainly C-atoms ugh covalent bonds to form long, straight or branched and rings of different sizes is called catenation. Carbon shows maximum catenation in the periodic table due to its small size and high strength of C — C bonds.

Note: Elements other than carbon like sulphur, silicon also have a tendency to show the property of self linking, i.e. catenation but to a much lesser extent, due to less bond energy or strength.

2.**Tetravalency of Carbon:** Carbon belongs to group 14 of the periodic table. Its atomic number is 6 and the electronic configuration is 2, 4. Thus, it has four electrons in the outermost shell. Hence, its valency is i.e. it is capable of bonding or pairing with four other carbon atoms or with the atoms of some other mono-valent elements like hydrogen, halogen (chlorine, bromine) etc.

3.**Tendency to Form Multiple Bonds:** Due to its small size carbon has a strong tendency to form multiple bonds (double and triple bonds) by sharing more than one electron pair with its own atoms or with the atoms of some other mono – valent elements like oxygen, nitrogen, sulphur etc. As a result, it can from a variety of compounds that are exceptionally stable .

<u>**Organic compounds:**</u> The compounds of carbon except its oxides, carbonates and hydrogen carbonate salts, are known as organic compound compounds were initially extracted from natural substances and it was thought that these carbon compounds could only be formed within a living system. Thus, it was postulated that a 'vital force' was necessary for their synthesis. In 1828, German chemist Friedrich Wohler accidently prepared urea from ammonium cyanate when he was trying to prepare ammonium cyanate by heating ammonium sulphate and potassium cyanate. Thus, synthesis of urea discarded the vital force theory.

$$\underset{\text{Ammonium sulphate}}{(NH_4)_2SO_4} + \underset{\text{Potassium cyanate}}{2KCNO} \xrightarrow{\Delta} \underset{\text{Ammonium cyanate}}{2NH_4CNO} + \underset{\text{Potassium sulphate}}{K_2SO_4}$$

$$\underset{\text{Ammonium cyanate}}{NH_4CNO} \xrightarrow[\text{(Rearrangement)}]{\Delta} \underset{\text{Urea}}{NH_2CONH_2}$$

HYDROCARBONS: The organic compounds containing only carbon and hydrogen are called hydrocarbons. e.g. CH_4, C_2H_6, C_2H_4 and C_2H_2. These are the simplest organic compounds and are regarded as parent organic compounds.

All other compounds are considered to be derived from them by the replacement of one or more hydrogen atoms by other atoms or groups of atoms. The major source of hydrocarbons is petroleum. The hydrocarbons can be classified as:

1. Saturated hydrocarbons
2. Unsaturated hydrocarbons

Saturated Hydrocarbons: The hydrocarbons in which all the carbon atoms are linked by only single bonds are called saturated hydrocarbons or alkanes or paraffins. The general formula of these compounds is $C_nH_{2n}+ _2$, where, n = number of carbon atoms in one molecule of a hydrocarbon. e.g. if there is only one carbon atom then its formula should be C_1H_{2*1+2} = CH_4 (methane). Similarly, if there are two carbon atoms in the saturated hydrocarbon (alkane), its formula must be C_2H_{2*2+2} =C_2H_6 (ethane)

These compounds are chemically inert, i.e. less reactive and burn with blue and non-smoky flame due to their complete combustion. These compounds generally show substitution reactions.

Unsaturated Hydrocarbons: Those carbon compounds in which atleast one double or triple bond (or multiple bond) is present along with single bonds are called **unsaturated compounds**. These compounds generally burn with sooty or smoky flame due to their incomplete combustion. These are more reactive than saturated hydrocarbons and generally undergo addition reactions. Unsaturated compounds are further divided into following two classes:

(a) **Alkenes** or **Olefins:** Those carbon compounds which have atleast 1 double bond alongwith single bonds are called alkenes. (A double bond is formed by the sharing of 2 pairs of electrons between the 2 carbon atoms). General formula of these compounds is C_nH_n e.g. if an alkene have 2 carbon atoms, i.e. n =2, its formula is $C_2H_{2*2} = C_2H_4$ (ethene).

(b) Alkynes: Those unsaturated hydrocarbons which have one or more triple bonds alongwith the single bonds are called alkynes. (A triple bond is formed by the sharing of 3 pairs of electrons between 2 carbon atoms). General formula of these compounds is C_nH_{2n-n} e.g. if an alkyne have 2 carbon atoms, then its formula is $C_2H_{2*2-2} = C_2H_2$ (ethyne). If there are 3 carbon atoms in the alkyne then its formula must be $C_3H_{2*3-2}=C_3H_4$ (propyne).

Note: The minimum number of carbon atoms present in an unsaturated compound is 2 because formation of double or triple bonds is possible only between 2 carbon atoms.

How to Draw the Structure of Saturated and Unsaturated Compounds?

Step 1: First connect all the carbon atoms by a single bond

Step 2: After that use the hydrogen atoms to satisfy the remaining valencies of carbon (as carbon forms 4 bonds due to its 4 valency)

Step 3: If number of available H-atoms are less than what is required, satisfy the remaining valency by using double or triple bond.

Difference between Covalent and Ionic Compounds

Ionic Compounds		*Covalent Compounds*	
Property	*Reason*	*Property*	*Reason*
Nature		**Nature**	
Their constituent particles are ions. They are hard solids consisting of ions.	These have strong intermolecular forces of attraction between their ions, which cannot be separated easily.	Their constituent particles are molecules. These are gases, liquids or soft solids (except graphite and diamond).	They have weak forces of attraction between their molecules.
Boiling point and melting point		**Boiling point and melting point**	
These are non-volatile, with high boiling point and melting point.	There exists a strong force of attraction between the oppositely charged ions, so a large amount of energy is required to break the strong bonding force between ions.	These are volatile with low boiling and low melting point.	They have weak forces of attraction between the binding molecules, thus less energy is required to break the force of bonding.
Electrical conductivity		**Electrical conductivity**	
They do not conduct electricity in the solid state. But act as a good conductor in the fused or molten state.	Intermolecular force of attraction (i.e. electrostatic forces) between ions in the solid state are very strong, which gets weaken in fused or molten state. Hence, ions become mobile.	They are non-conductors of electricity in solid, molten or aqueous state.	Due to the absence of free ions or charged particles.
Solubility		**Solubility**	
These are soluble in water but insoluble in organic solvents.	Water is a polar solvent, it decreases the intermolecular forces of attraction, resulting in free ions in aqueous solution. Hence, they dissolve.	These are insoluble in water but dissolve in organic solvents.	As organic solvents are non-polar, hence, these dissolve in non-polar covalent compounds.

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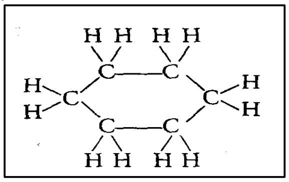
How to Draw Structure of Cyclic Compounds? Some carbon compound also exist in cyclic or ring structure. To draw the structure of cyclic or ring compounds:

Step 1: First connect the available carbon atoms by a single bond in the cyclic form.

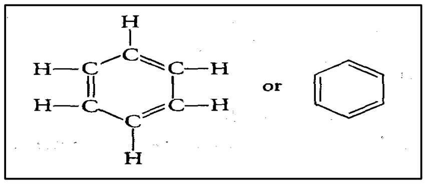
Step 2: Try to satisfy the tetravalency of each carbon with the available hydrogen atoms.

Step 3: Now check the valency of each carbon. If it is found unsatisfied, use double or triple bond to satisfy it.

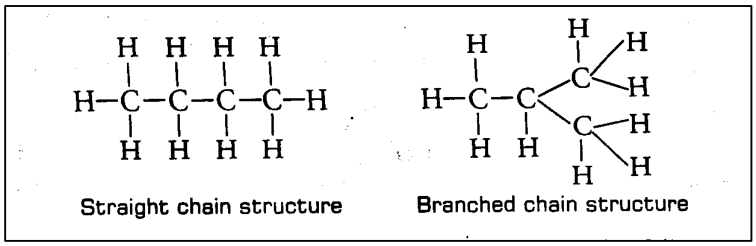
Structure of Cyclohexane:



Structure of Benzene:

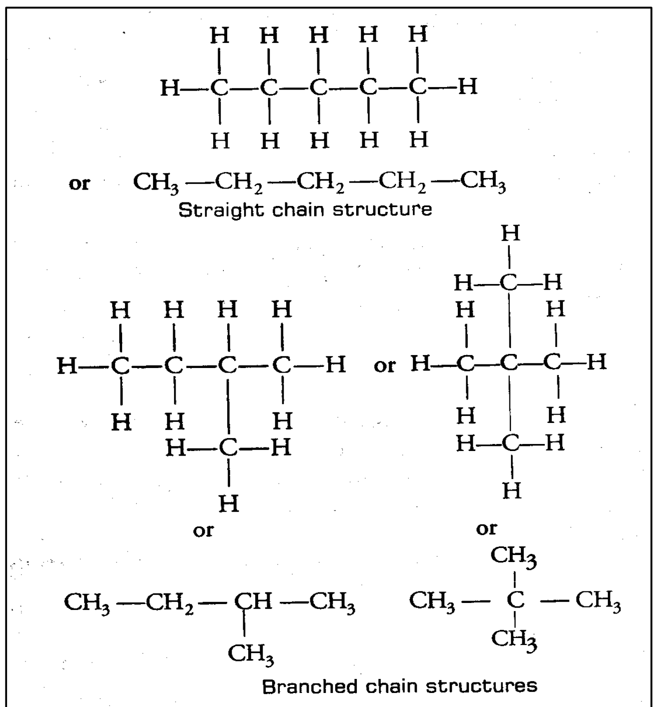


Isomerism: Organic compounds with same molecular formula but different chemical and physical properties are called isomers. This phenomenon is called isomerism. The difference in properties of these compounds is due to the difference in their structures. Such compounds with identical molecular formula but different structure are called structural isomers. This phenomenon of isomerism is called structural isomerism. E.g. following two structural isomers are possible for butane, an alkane with four C-atoms (C_4H_{10}).



Similarly, molecular formula C_5H_{12} accounts for the following isomers:

Q: Write the structural formulae of all the isomers of an alkane with six C-atoms (C_6H_{14}).



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