9. Carbon Compounds

- Bonds in carbon compounds
- Hydrocarbons, Functional Groups and homologous series
- Chemical Properties of Carbon Compounds
- Carbon : A Versatile Element
- Nomenclature of Carbon compounds
- Macromolecules and Polymers

Can you recall?

1. What are the types of compounds ?
2. Objects in everyday use such as foodstuff, fibers, paper, medicines, wood, fuels, are made of various compounds. Which constituent elements are common in these compounds?
3. To which group in the periodic table does the element carbon belongs ? Write down the electronic configuration of carbon and deduce the valency of carbon.

In the previous standards we have seen that organic and inorganic compounds are the two important types of compounds. Except materials fabricated from metal and glass/soil several other materials from foodstuff to fuels are made up of organic compounds. The essential element in all the organic compounds is carbon. About 200 years back it was believed that organic compounds are obtained directly or indirectly from the organisms. However, after synthesis of the organic compound urea from an inorganic compounds in the laboratory, the organic compounds received a new identity as carbon compounds. All the compounds having carbon as a constituent element are called as organic compounds. The compounds carbon dioxide, carbon monoxide, carbide salts, carbonate salts and bicarbonate salts are exception; they are inorganic compounds of carbon.

Bonds in Carbon compounds

You have learnt about the ionic compounds in the previous chapter. You have seen that ionic compounds have high melting and boiling points and they conduct electricity in the molten and dissolved state. You have also seen that these properties of ionic compounds are explained on the basis of the ionic bonds in them. The table 9.1 shows melting and boiling points of a few carbon compounds. Are these values higher or lower as compared to the ionic compounds?

Generally the melting and boiling points of carbon compounds are found to be lower than 300 ^{0}C. From this we understood that the intermolecular attractive forces are weak in carbon compounds.

In the previous standard on testing the electrical conductivity of carbon compounds, glucose and urea you have observed that they are not electrical conductors. Generally most of the carbon compounds are found to be bad conductors of electricity. From it we understand that structures of most of the carbon compounds lack ionic bonds. It means that the chemical bonds in carbon compounds do not produce ions.

Compound	Melting point ^{0}C	Boiling point ^{0}C
Methane (CH_4)	- 183	- 162
Ethanol (CH_3CH_2OH)	- 117	78
Chloroform ($CHCl_3$)	- 64	61
Acetic acid (CH_3COOH)	17	118

9.1 Melting and Boiling Points of a few carbon compounds

Can you tell?

1. What is meant by a chemical bond?
2. What is the number of chemical bonds that an atom of an element forms called?
3. What are the two important types of chemical bonds?

In the previous standards you have learnt about the relationship between electronic configuration and valency of an element, and also about the ionic and covalent bonds. Let see at the background of electronic configuration of carbon and the covalent bonds formed. (See Table 9.2).

Carbon atom	Electronic Configuration	Number of electron in the Valence shell	Nearby noble gas and the ele ctronic configuration	
			He	Ne
$_6C$	2, 4	4	2	2,8

9.2 Background of bond formation by carbon

You have seen that the driving force behind the formation of bond by an atom is to attain the stable electronic configuration of the nearby noble gas and obtain stability. As the valence shell of carbon contains 4 electrons, there can be many alternative routes to attain a noble gas configuration.

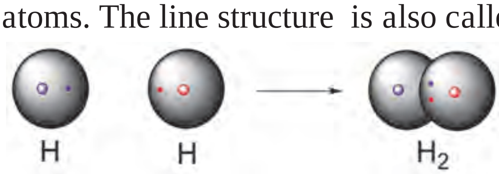
(i) To attain the configuration of noble gas helium (He) by losing one after another all the four valence electrons : In this method the net positive charge on the carbon atom goes on increasing during loss of every electrons. Therefore to lose the next electron more energy is required, which makes the task more difficult. Moreover, the C^{4+} cation that would ultimately form in this process becomes unstable in spite of its noble gas configuration, because it has a small size with high net charge. Therefore carbon atom does not take this route to attain a noble gas configuration.

(ii) To attain the stable configuration of the noble gas neon (Ne) by accepting one by one ass the four electrons in the valence shell. In this method the net negative charge on the carbon atom goes on increasing while accepting every new electron. Therefore, more energy is required for accepting the next electron by overcoming the increasing repulsive force making the task more and more difficult. Moreover the C^{4-} anion ultimately formed would be unstable in spite of its noble gas configuration, as it would have a small size with high net charge making it difficult for the nuclear charge +6 to hold 10 electrons around it. Therefore, carbon atom does not take this route to attain a noble gas configuration.

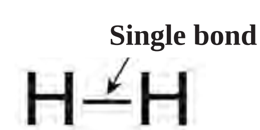
(iii) To attain the configuration of neon by sharing four electrons of valence shell with four valence electrons of other atoms: In this method two atoms share valence electrons with each other. Valence shells of both the atoms overlap and accommodate the shared electrons, As a result, both the atoms attain a noble gas configuration without generating any net charge on them, which means that atoms remain electrically neutral. Due to these factors atoms attain stability. Therefore, carbon atom adopt this route to attain a noble gas configuration.

The chemical bond formed by sharing of two valence electron between the two atoms is called covalent bond.

A covalent bond is represented clearly by drawing an electron - dot structure. In this method a circle is drawn around the atomic symbol and each of the valence electrons is indicated by a dot or a cross. The covalent bond formed between the atoms is indicated by showing the circles around the atomic symbols crossing each other. The shared electrons are shown in the overlapping regions of the two circles by dot or cross. The electron - dot structure is also drawn without showing the circle. One pair of shared electrons constitutes one covalent bond . A covalent bond is also represented by a small line joining the symbols of the two atoms. The line structure is also called structural formula.



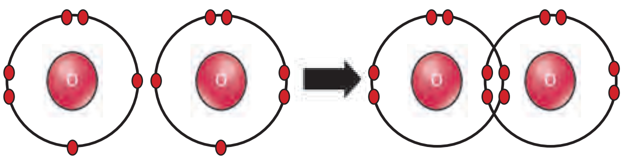
H : H

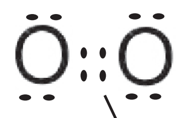


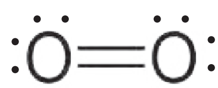
9.3 Electron dot structure and line structure of hydrogen molecule with a single bond

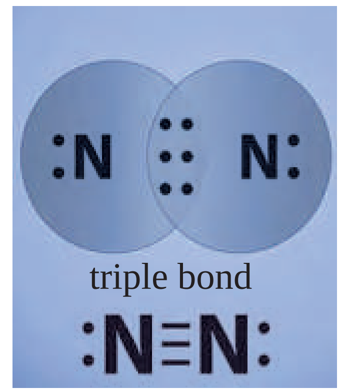
Let us first look at the hydrogen molecule which is the simplest example of a molecule formed by covalent bonding. You have already learnt that the atomic number of hydrogen being 1, its atom contains 1 electron in K shell. It requires one more electron to complete the K shell and attain the configuration of helium (He). To meet this requirement two hydrogen atoms share their electrons with each other to form H_2 molecule. One covalent bond, that is a single bond is formed between two hydrogen atoms by sharing of two electrons. (see fig 9.3).

The O_2 molecule is formed by chemical combination of two oxygen atoms; and N_2 molecule is formed by the chemical combination of two nitrogen atoms. On drawing the electron-dot structures of these two molecules, it becomes clear that the two oxygen atoms in O_2 molecule are joined with each other by two covalent bonds, that is, a double bond, while the two nitrogen atoms in the N_2 molecule are joined with each other by three covalent bonds, that is, a triple bond (See figure 9.4)









9.4 Double Bond and Triple Bond

Use your brain power !

1. Atomic number of chlorine is 17.
   What is the number of electron in the valence shell of chlorine?
2. Molecular formula of chlorine is Cl_2. Draw electron-dot and line structure of a chlorine molecule.
3. The molecular formula of water is H_2O. Draw electron-dot and line structures for this triatomic molecule. (Use dots for electron of oxygen atom and crosses for electrons of hydrogen atoms.)
4. The molecular formula of ammonia is NH_3. Draw electron-dot and line structures for ammonia molecule.

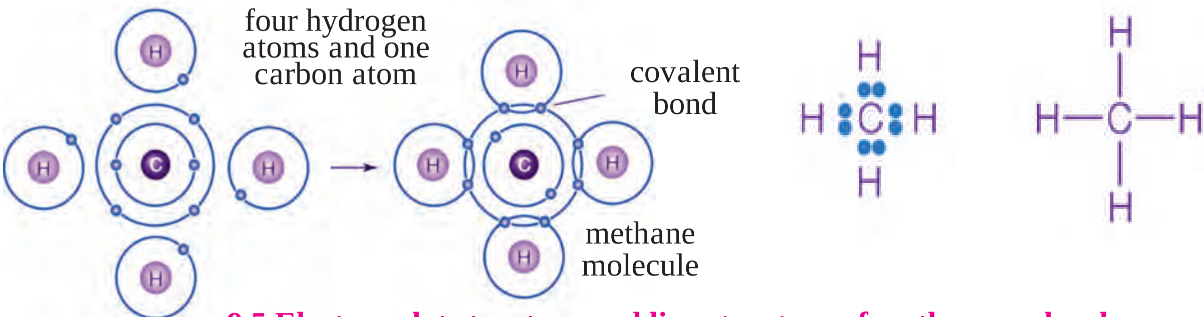
Now let us consider a carbon compound methane (CH_4). You have learnt about the occurrence, properties and uses of methane molecule in the previous standard. Just now we saw that carbon atom forms four covalent bonds using the four valence electrons and attain the configuration of the nearby noble gas neon (Ne) and obtains stability: Fig 9.5 shows the line structure and also the electron-dot structure of methane.

Do you know ?

To understand the structures of carbon compounds various types of molecular models are used. The fig 9.6 shows ball and stick model and space filling model of methane molecule.

Use your brain power !

1. The molecular formula of carbon dioxide is CO_2. Draw the electron-dot structure (without showing circle) and line structure for CO_2.
2. With which bond C atom in CO_2 is bonded to each of the O atoms?
3. The molecular formula of sulphur is S_8 in which eight sulphur atoms are bonded to each other to form one ring. Draw an electron-dot structure for S_8 without showing the circles.

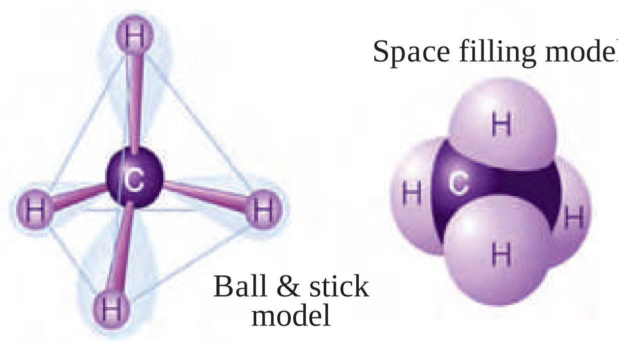


9.5 Electron-dot structure and line structure of methane molecule

Carbon : A Versatile Element

We saw that carbon atoms, like some other atoms, share the valence electrons to form covalent bonds. Similarly, we also saw the structure of the simple carbon compound, methane. But carbon is different than the other elements; the number of compounds formed from carbon is extremely large. In the beginning we saw that except for the objects formed from metals and glass/soil all the other objects are made from carbon. In short, brief the entire living kingdom is made from carbon, our body is also made from carbon. Millions of molecules ranging from the small and simple methane molecule to the extremely big D.N.A. molecule are made from carbon. The molecular masses of carbon compounds range up to 10^{12}. This means that carbon atoms come together in a large number to form extremely big molecules. What is the cause of this unique property of carbon? It is due to the peculiar nature of the covalent bonds formed by carbon, it can form large number of compounds. From this we come to know the following **characteristics of carbon**.

a. Carbon has a unique ability to form strong covalent bonds with other carbon atoms; this results in formation of big molecules. This property of carbon is called catenation power. The carbon compounds contain open chains or closed chains of carbon atoms. An open chain can be a straight chain or a branched chain. A closed chain is a ring structure. The covalent bond between two carbon atoms is strong and therefore stable. Due to the strong and stable covalent bonds carbon is bestowed with catenation power.



9.6 Models of methane molecule

Till now the number of known carbon compounds is about 10 million. This number is larger than the total number of compounds formed by all the other elements. The range of molecular masses of carbon compounds is 10^1 - 10^{12}.
(See table 9.7)

Use your brain power !

1. Hydrogen peroxide decomposes on its own by the following reaction

   $$H\text{-}O\text{-}O\text{-}H \longrightarrow 2H\text{-}O\text{-}H + O_2$$

   From this, what will be your inference about the strength of O-O covalent bond?
2. Tell from the above example whether oxygen has catenation power or not.

Carbon Compound	Molecular mass
Methane CH_4 (The smallest carbon compound)	16
Cooking gas ($C_3H_8 + C_4H_{10}$)	44/58
Benzene (C_6H_6)	78
Camphor ($C_{10}H_{16}O$)	152
Penicillin ($C_{16}H_{18}N_2O_4S$)	334
Sugar ($C_{12}H_{22}O_{11}$)	342
Sodium dodecyl benzene sulphate (a detergent)	347
Fat	~ 700
Starch	~ 10^3
Cellulose	~ 10^5
Protein	~ 10^5
Polyethylene	~ 10^6
D.N.A.	~ 10^{12}

9.7 Carbon compounds and molecular masses

b. Two carbon atoms can be bonded together by one, two or three covalent bonds. These are called single bond, double bond, and triple bond respectively. Due to the ability of carbon atoms to form multiple bonds as well as single bonds, the number of carbon compounds increases. For example, there are three compounds, namely, ethane (CH_3-CH_3), ethene (CH_2=CH_2) and ethyne ($CH \equiv CH$) which contain two carbon atoms.

c. Being tetravalent one carbon atom can form bonds with four other atoms (carbon or any other). This results in formation of many compounds. These compounds possess different properties as per the atoms to which carbon is bonded. For example, five different compounds are formed using one carbon atom and two monovalent elements hydrogen and chlorine : CH_4, CH_3Cl, CH_2Cl_2, $CHCl_3$, CCl_4. Similarly carbon atoms form covalent bonds with atoms of elements like O, N, S, halogen & P to form different types of carbon compounds in large number.

d) Carbon has one more characteristics which is responsible for large number of carbon compounds. It is 'isomerism'. Shortly, we will learn about it.

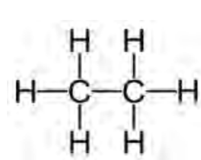
Hydrocarbons : Saturated and Unsaturated

Carbon compounds contain many elements. The element hydrogen is present to a smaller or larger extent in majority of carbon compounds. The compounds which contain carbon and hydrogen as the only two elements are called hydrocarbons. Hydrocarbons are the simplest and the fundamental organic compounds. The smallest hydrocarbon is methane (CH_4) formed by combination of one carbon atom and four hydrogen atoms. We have already seen the structure of methane. Ethane is one more hydrocarbon. Its molecular formula is C_2H_6. The first step in writing the line structure (structural formula) of a hydrocarbon is to join the carbon atoms in the molecule with single bonds, and then in the second step use the hydrogen atoms in the molecular formula so as to fulfil the remaining valencies of the tetravalent carbon atoms. (See fig. 9.8), Fig. 9.9 shows electron-dot structure using two methods.

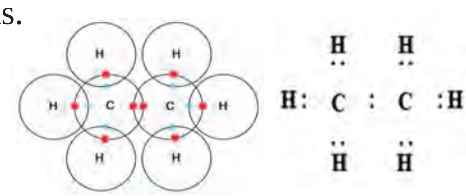
Ethane : Molecular formula C_2H_6

Step 1 : Join the two carbon atoms with single bonds C - C

Step 2 : Use the 6 hydrogen atoms in the molecular formula for fulfilling the tetravalency of both the carbon atoms.



9.8 Line structure / structural formula of ethane



9.9. Electron-dot structure of ethane

Use your brain power !

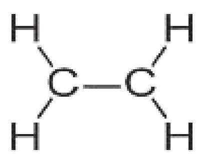
Molecular formula of propane is C_3H_8 . From this draw its structural formula.

From the structural formula of ethane & propane it is seen that the valencies of all the atoms are satisfied by the single bonds. Such compounds are called saturated compounds. Ethane & propane are saturated hydrocarbons. Saturated hydrocarbons are also called 'Alkanes' .

There are two more hydrocarbons that contain two carbon atoms, namely, ethene (C_2H_4) and ethyne(C_2H_2). Let us see the method to draw the structural formula (line structure) of ethene (C_2H_4). (Fig 9.10)

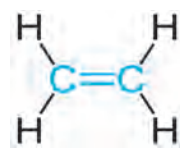
Step 1 : Join the two carbon atoms with single bond C-C.

Step 2 : Use the 4 hydrogen atoms in the molecular formula for satisfying tetravalency of both the carbon atoms.

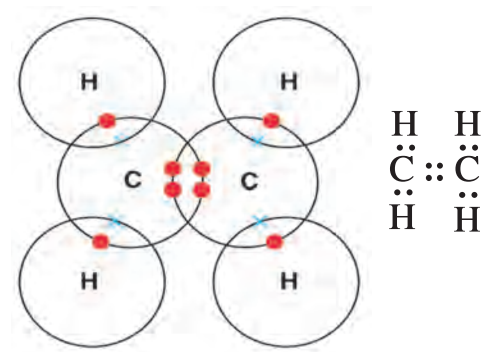


It appears that one valency of each of the two carbon atoms is not satisfied.

Step 3: Satisfy the tetravalency of the two carbon atoms by drawing a double bond in place of the single bond between them.



9.10 Line structure/ structural formula



9.11 Electron-dot structures of ethane

Use your brain power !

1. The molecular formula ethyne is C_2H_2. From this draw its structural formula and electron - dot structure.
2. How many bonds have to be there in between the two carbon atoms in ethyne so as to satisfy their tetravalency?

The carbon compounds having a double bond or triple bond between two carbon atoms are called unsaturated compounds. Ethene and ethyne are unsaturated hydrocarbons. The unsaturated hydrocarbons containing a carbon-carbon double bond are called 'Alkenes'. The unsaturated hydrocarbons whose structures contain a carbon-carbon triple bond are called 'Alkynes'. Generally the unsaturated compounds are more reactive than the saturated compounds.

Straight chains, Branched chains and Rings of Carbon atoms

Let us compare the structural formulae of methane, ethane and propane. From these structural formulae it is seen that the carbon atom (single or more carbon atoms bonded to each other) lie in the core of the molecule, while the hydrogen atoms bonded to each of the carbon atoms are on the periphery of the molecule. The mutually bonded carbon atoms in the core are like the skeleton of the molecule. The carbon skeleton determines the shape of the molecule of a carbon compound.

A straight chain of carbon atoms is formed by joining the carbon atoms are next to the other. The first column of the table 9.12 shows straight chains of carbon atoms. Write the structural formulae of the corresponding straight chain hydrocarbons in the second column satisfying the tetravalency of the carbon atom by joining them to hydrogen atoms. Work out the molecular formula from this and write it down in the third column. The name of the hydrocarbon is given in the fourth column.

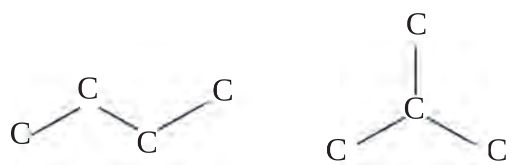
Straight chain of carbon atoms	Structural formula	Molecular formula	Name
C	H H–C–H H	CH_4	Methane
C-C			Ethane
C-C-C			Propane
C-C-C-C			Butane
C-C-C-C-C			Pentane
C-C-C-C-C-C			Hexane
C-C-C-C-C-C-C			Heptane
C-C-C-C-C-C-C-C			Octane
C-C-C-C-C-C-C-C-C			Nonane
C-C-C-C-C-C-C-C-C-C			Decane

9.12 Straight chain hydrocarbon

Do you know ?

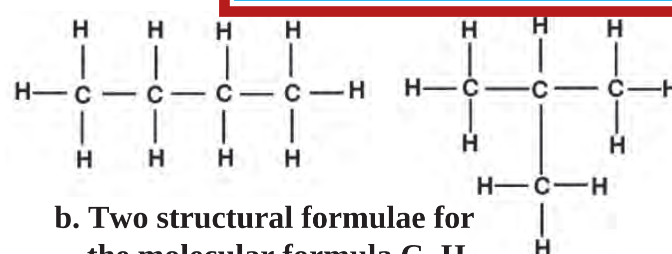
In the course of millions of years the reserves of crude oil were formed from the dead organisms buried under the sea floor. This crude oil and natural gas are now recovered from the oil wells. The natural gas is mainly methane . The crude oil is a complex mixture of thousands of different compounds. It mainly contains various hydrocarbons. Various useful components such as CNG, LPG, petrol (gasoline), kerosene, diesel, engine oil, lubricant, etc. are obtained by separation crude oil using fractional distillation.

Now let us pay more attention to the carbon chain in butane. The four carbon atoms can be joined to form a carbon chain in yet another way. (See fig 9.13 a)



(i) (ii)

a. Two possible carbon chains



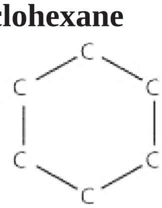
b. Two structural formulae for the molecular formula C_4H_{10}

9.13 Two isomeric compounds with molecular formula C_4H_{10}

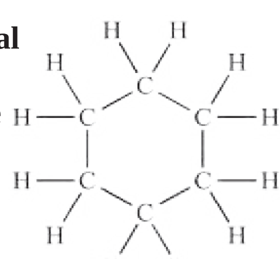
Two different structural formulae are obtained on joining hydrogen atoms to these two chains so as to satisfy the tetravalency of the carbon atoms. The molecular formula of both these structural formulae is the same which is C_4H_{10}. These are two different compounds as their structural formulae are different. The phenomenon in which compounds having different structural formulae have the same molecular formula is called 'structural isomerism'. The number of carbon compounds increases further due to the isomerism observed in carbon compounds. The carbon chain (i) in the figure 9.13 (a) is a straight chain of carbon atoms, whereas the carbon chain (ii) is a branched chain of carbon atoms.

Apart from the straight chains and branched chains, closed chains of carbon atoms are present in some carbon compounds. Where in rings of carbon atoms form. For example, the molecular formula of cyclohexane is C_6H_{12} and its structural formula contains a ring of six carbon atoms. (See fig 9.14)

a. the carbon ring in cyclohexane



b. Structural formula of cyclohexene

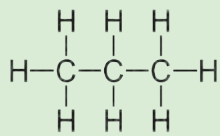
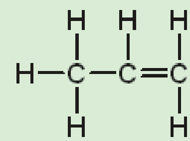
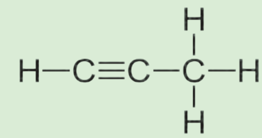
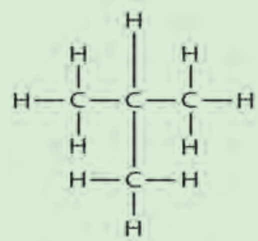
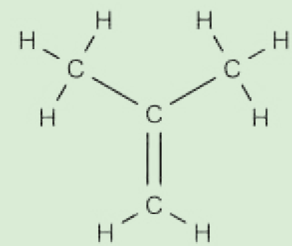
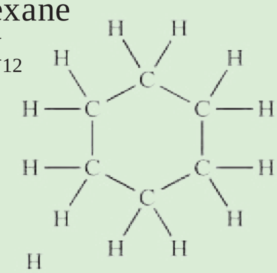
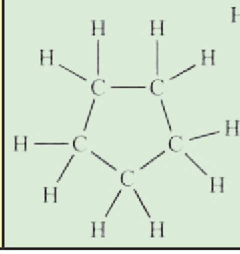
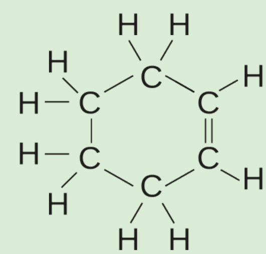
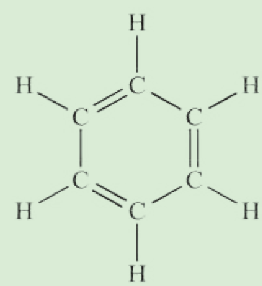


9.14 Ring Structure of Cyclohexane

Use your brain power !

Draw electron-dot structure of cyclohexane.

All types of carbon compounds whether straight chain, branched chain or cyclic, can be saturated or unsaturated. This is explained by the various examples of hydrocarbons in table 9.15

	Saturated hydrocarbons	Unsaturated hydrocarbons
Straight chain hydrocarbons	Propane C_3H_8 	 Propene C_3H_6  Propyne C_3H_4
Branched chain hydrocarbons	isobutane C_4H_{10} 	isobutylene C_4H_8 
Cyclic hydrocarbons	Cyclohexane C_6H_{12}   Cyclopentane C_5H_{10}	Cyclohexene C_6H_{10}   Benzene C_6H_6

9.15 Various Types of Hydrocarbons

It is learnt from the structural formula of benzene that it is a cyclic unsaturated hydrocarbon. There are three alternate double bonds in the six membered ring structure of benzene. The compounds having this characteristic unit in their structure are called aromatic compounds.

Functional Groups in Carbon Compounds

Till now you have learnt about the hydrocarbon compounds formed by combination of the elements carbon and hydrogen. Many more types of carbon compounds are formed by formation of bonds of carbon with other elements such as halogens, oxygen, nitrogen, sulphur. The atoms of these elements substitute one or more hydrogen atoms in the hydrocarbon chain and thereby the tetravalency of carbon is satisfied. The atom of the element which is substitute for hydrogen is referred to as a hetero atom. Sometimes hetero atoms are not alone but exist in the form of certain groups of atoms. (See the table 9.16).

The compound acquire specific chemical properties due to these hetero atoms or the groups of atoms that contain heteroatoms, irrespective of the length and nature of the carbon chain in that compound. Therefore these hetero atoms or the groups of atoms containing hetero atoms are called functional groups. The table 9.16 shows a few functional groups that occurs in carbon compounds.

Here the free valency of the functional group is indicated by a short line. The functional group taking place of a hydrogen is joined to the carbon chain with this valency. The **carbon- carbon double and triple bonds** are also recognised as functional groups as the respective compounds get specific chemical properties due to them.

Hetero Atom	Functional Group		
	Name	Structural formula	Condensed Structural formula
Halogen (chlorine, bromine, iodine)	Halo (chromo/ bromo / iodo)	-X (-C1, -Br, -I)	- X (-C1, -Br, -I)
Oxygen	1. Alcohol	- O - H	-OH
	2. Aldehyde	O ‖ - C - H	-CHO
	3. Ketone	O ‖ - C -	-CO-
	4. Carboxylic Acid	O ‖ - C - O - H	-COOH
	5. Ether	- O -	-O-
	6. Ester	O ‖ - C - O -	-COO-
Nitrogen	Amines	- N - H | H	- NH_2

9.16 Some functional groups in carbon compounds

Homologous series

You have seen that chains of different length are formed by joining the carbon atoms to each other. Moreover you have also seen that a functional group can take place of a hydrogen atom on these chains. As a result of this, large number of compounds are formed having the same functional groups but different length of carbon chain. For example, there are many compounds such as CH_3-OH, CH_3-CH_2-OH, CH_3-CH_2-CH_2-OH, CH_3-CH_2-CH_2-CH_2-OH which contain alcohol as the functional group. Though the length of the carbon chains in them is different, their chemical properties are very much similar due to the presence of the same functional group in them. The series of compounds formed by joining the same functional group in the place of a particular hydrogen atom on the chains having sequentially increasing length is called homologous series. There are different homologous series in accordance with the functional group. For example, homologous series of alcohols, homologous series of carboxylic acids, homologous series of aldehydes, etc. All the members of the homologous series are homologues of each other. Earlier you filled the structural formulae and molecular formulae in the table 9.12. From that the initial part of the homologous series of alkanes was formed.

Let us understand the characteristics of homologous series by considering initial parts of homologous series of alkanes, alkenes and alcohols. (See table No. 9.17.)

Complete the table

Fill in the gaps in the table 9.17 a, b and c of homologous series.

a. Homologous Series of Alkanes

Name	Molecular formula	Condensed Structural formula	Number of carbon atoms	Number of $-CH_2-$ units	Boiling point ^0C
Methane	CH_4	CH_4	1	1	- 162
Ethane	C_2H_6	CH_3-CH_3	2	2	- 88.5
Propane	C_3H_8	$CH_3-CH_2-CH_3$	3	3	- 42
Butane	C_4H_{10}	$CH_3-CH_2-CH_2-CH_3$	...	...	0
Pentane	C_5H_{12}	$CH_3-CH_2-CH_2-CH_2-CH_3$	...	...	36
Hexane	C_6H_{14}	$CH_3-CH_2-CH_2-CH_2-CH_2-CH_3$	...	...	69

b. Homologous Series of Alcohols

Name	Molecular formula	Condensed Structural formula	Number of carbon atoms	Number of $-CH_2-$ units	Boiling point ^0C
Methanol	CH_4O	CH_3-OH	1	1	63
Ethanol	C_2H_6O	CH_3-CH_2-OH	2	2	78
Propanol	C_3H_8O	$CH_3-CH_2-CH_2-OH$	...	...	97
Butanol	$C_4H_{10}O$	$CH_3-CH_2-CH_2-CH_2-OH$	...	...	118

c. Homologous Series of Alkenes

Name	Molecular formula	Condensed Structural formula	Number of carbon atoms	Number of $-CH_2-$ units	Boiling point ^0C
Ethene	C_2H_4	$CH_2= CH_2$	2	0	- 102
Propene	C_3H_6	$CH_3-CH=CH_2$	3	1	- 48
1-Butene	C_4H_8	$CH_3-CH_2-CH=CH_2$	...	...	- 6.5
1-Pentene	C_5H_{10}	$CH_3-CH_2-CH_2-CH=CH_2$	...	...	30

9.17 Some Homologous Series

Use your brain power !

1. By how many $-CH_2-$ (methylene) units do the formulae of the first two members of homologous series of alkanes, methane (CH_4) and ethane (C_2H_6) differ? Similarly, by how many $-CH_2-$ units do the neighbouring members ethane (C_2H_6) and propane (C_3H_8) differ from each other?
2. How many methylene units are extra in the formula of the fourth member than the third member of the homologous series of alcohols?
3. How many methylene units are less in the formula of the second member than the third member of the homologous series of alkenes?

You have found that in any homologous series while going in an increasing order of the length of the carbon chain, every time one methylene unit ($-CH_2-$) goes on increasing. Therefore, while going in an increasing order of the length there is a rise in the molecular mass of the members by 14 u.

Inspection of the table 9.17 (a), (b) and (c) will reveal one more point to you, and that is gradation in the boiling points. Boiling point is a physical property of a compound. Generally it is found that, while going in an increasing order in any homologous series the physical properties show variation in one direction, that is, a gradation is observed in the physical properties.

Use your brain power !

1. The table 9.17 (c) shows the homologous series of alkenes. Inspect the molecular formulae of the members of this series. Do you find any relationship, in the number of carbon atoms and the number of hydrogen atoms in the molecular formulae?
2. If the number of carbon atoms in the molecular formulae of alkenes is denoted by 'n' , what will be the number of hydrogen atoms?

The molecular formulae of the members of the homologous series of alkenes can be represented by a general formula C_nH_{2n}. When the value of 'n' is '2'. We get the molecular formula of the first member of this series as $C_2\,H_{2x2}$, that is, C_2H_4. When the value of 'n' is '3', the molecular formula of the second member of the alkene series is obtained as $C_3H_{2x3,}$ that is, $C_3H_{6.}$

1. What would be the general formula for the molecular formulae of the members of the homologous series of alkanes? What would be the value of 'n' for the first member of this series?

2. The general molecular formula for the homologous series of alkynes is C_nH_{2n-2} .Write down the individual molecular formulae of the first, second and third members by substituting the values 2,3 and 4 respectively for 'n' in this formula. From the above examples we come to know the following characteristics of the homologous series.

(i) While going from one member to the next in a homologous series.

(a) One methylene ($-CH_2-$) unit gets added. (b) molecular mass increases by 14 u.

(c) number of carbon atoms increases by one.

(ii) Chemical properties of members of a homologous series show similarity.

(iii) All the members of a homologous series can be represented by The same a general molecular formula.

Use your brain power !

1. Write down structural formulae of the first four members of the various homologous series formed by making use of the functional groups in the table 9.16
2. General formula of the homologous series of alkanes is C_nH_{2n+2}. Write down the molecular formula of the 8^{th} and 12^{th} member using this.

Nomenclature systems of carbon compounds

a. System of common names : We have seen that today millions of carbon compounds are known. Initially when the number of known carbon compounds was small, scientists named them in a variety of ways. Now those names are called common names. For example, the sources of the names of the first four alkanes, namely methane, ethane, propane and butane are different. The names of the alkanes thereafter were given from number of carbon atoms in them. Two isomeric compounds having a straight chain or branched chain in their structural formulae are possible for the molecular formula C_4H_{10}. the difference and interrelationship in them was indicated by naming them as n-butane (normal-butane) and i- butane (iso-butane).

Use your brain power !

1. Draw three structural formulae having molecular formula C_5H_{12}.
2. Give the names n-pentane, 1(i-pentane) and neo-pentane to the above three structural formulae. (Use the same logic as used in the names of the isomeric butanes for this purpose.)
3. Draw all the possible structural formulae having molecular formula C_6H_{14}. Give names to all the isomers. Which difficulties were faced by you while naming?

As the time progressed, the carbon compounds became very large in number and their common names caused confusion. A need was felt to have a logical system acceptable to all for naming the carbon compounds.

IUPAC nomenclature system

International Union for Pure and Applied Chemistry (IUPAC) put forth a nomenclature system based on the structure of the compounds, and it was accepted all over the world. There is a provision in this system for giving a unique name to all the carbon compounds. Let us see how some straight chain compounds containing one functional group are given IUPAC names and let us also see their common names.

There are three units in the IUPAC name of any carbon compound : parent, suffix and prefix. These are arranged in the name as follows

prefix - parent - suffix

An IUPAC name is given to a compound on the basis of the name of its parent alkane. The name of the compound in constructed by attaching appropriate suffix and prefix to the name of the parent alkane. The steps in the IUPAC nomenclature of straight chain compounds are as follows.

Step 1 : Draw the structural formula of the straight chain compound and count the number of carbon atoms in it. The alkane with the same number of carbon atoms is the parent alkane of the concerned compound. Write the name of this alkane. In case the carbon chain of the concerned compound contains a double bond, change the ending of the parent name from 'ane' to 'ene'. If the carbon chain in the concerned compound contains a triple bond, change the ending of the parent name from 'ane' to 'yne'. (See the table 9.18)

Sr.No.	Structural formula	Straight chain	Parent name
1	CH_3-CH_2-CH_3	C-C-C	propane
2	CH_3-CH_2-OH	C-C	ethane
3	CH_3-CH_2-COOH	C-C-C	propane
4	CH_3-CH_2-CH_2- CHO	C-C-C-C	butane
5	CH_3-CH=CH_2	C-C=C	propene
6	CH_3-C ≡ CH	C-C≡C	propyne

9.18 IUPAC Nomenclature of straight chain compounds: step 1

Step 2: If the structural formula contains a functional group replace the last letter 'e' from the parent name by the condensed name of the functional group as the suffix. (Exception : The condensed name of the functional group 'halogen' is always attached as the prefix.) (see the table 9.19)

Step 3: Number the carbon atoms in the carbon chain from one end to the other. Assign the number '1' to carbon in the functional group -CHO or -COOH, if present, Otherwise, the chain can be numbered in two directions. Accept that numbering which gives smaller number to the carbon carrying the functional group. In the final name a digit (number) and a character (letter) should be separated by a small horizontal line (See the table 9.20) (Usually numbering is not required if the carbon chain contain only two carbon atoms)

Sr. No	Structural formula	Functional group (Condensed name)	Parent name	parent-suffix	prefix-parent
1	CH_2-CH_2-OH	- OH (ol)	ethane	ethanol	-
2	CH_3-CH_2-Cl	- C1 (chloro)	ethane	-	chloroethane
3	Br-CH_2-CH_3	-Br (bromo)	ethane	-	bromoethane
4	CH_3-CH_2-CHO	- CHO (al)	propane	propanal	-
5	CH_3-COOH	- COOH (oic acid)	ethane	ethanoic acid	-
6	CH_3-NH_2	- NH_2 (amine)	methane	methanamine	-
7	CH_3 - CO - CH_3	- CO- (one)	propane	propanone	-

9.19 IUPAC Nomenclature : Step- 2

Sr. No	Structural formula	Two numberings of the carbon chain	Acceptable numbering	IUPAC name of the compound
1.	$CH_3-\underset{\underset{\displaystyle OH}{\vert}}{CH}-CH_3$	$C^1-\underset{\underset{\displaystyle OH}{\vert}}{C^2}-C^3$ $C^3-\underset{\underset{\displaystyle OH}{\vert}}{C^2}-C^1$	Both the numberings equivalent	propan-2-ol
2.	$CH_3-CH_2-CH_2-\underset{\underset{\displaystyle Cl}{\vert}}{CH}-CH_3$	$C^1-C^2-C^3\ \underset{\underset{\displaystyle Cl}{\vert}}{C^4}-C^5$ $C^5-C^4-C^3-\underset{\underset{\displaystyle Cl}{\vert}}{C^2}-C^1$	$C^5-C^4-\underset{\underset{\displaystyle Cl}{\vert}}{C^3}-C^2-C^1$	2 - chloropentane
3.	$CH_3-\overset{\overset{\displaystyle O}{\vert\vert}}{C}-CH_2-CH_2-CH_3$	$C_1-\overset{\overset{\displaystyle O}{\vert\vert}}{C_2}-C_3-C_4-C_5$ $C_5-\overset{\overset{\displaystyle O}{\vert\vert}}{C_4}-C_3-C_2-C_1$	$C_1-\overset{\overset{\displaystyle O}{\vert\vert}}{C_2}-C_3-C_4-C_5$	pentan-2-one

9.20 IUPAC Nomenclature : Step- 3

Some more steps are required for writing IUPAC names of compounds having more complex structural units such as branched chains, carbon rings, heterocycles, etc. Study of these will be included in the further standards. At the same time, also keep in mind that there is a practice of using common names of the carbon compounds which are frequently use in the laboratory.

Complete the table

The table 9.19 shows common names and structural formulae of a few carbon compounds. Complete the table by writing their IUPAC names in the third column.

Sr. No.	Common name	Structural formula	IUPAC Name
1	ethylene	$CH_2=CH_2$	
2	acetylene	$HC \equiv CH$	
3	acetic acid	CH_3-COOH	
4	methyl alcohol	CH_3-OH	
5	ethyl alcohol	CH_3-CH_2-OH	
6	acetaldehyde	CH_3-CHO	
7	acetone	CH_3-CO-CH_3	
8	ethyl methyl ketone	CH_3-CO-CH_2- CH_3	
9	ethyl amine	CH_3-CH_2-NH_2	
10	n-propyl chloride	CH_3- CH-CH_2-Cl	

9.21 Common and IUPAC names of some carbon compounds

Chemical Properties of Carbon Compounds

Can you recall?

1. Which is the component of biogas that makes it useful as fuel?
2. Which product is formed by the combustion of elemental carbon?
3. Is the biogas combustion reaction endothermic or exothermic?

1. Combustion : Let us first look at combustion as a chemical property of carbon compounds. We have seen in the previous standard that, carbon in the form of various allotropes on ignition in presence of oxygen undergoes combustion to emit heat and light, and forms carbon dioxide. Hydrocarbons as well as most of the carbon compounds under goes combustion in presence of oxygen to emit heat and light and form carbon dioxide and water as the common products. Some of the combustion reactions are as follows.

(i) $C + O_2 \rightarrow CO_2$ + heat + light
(Carbon)

(ii) $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ + heat + light
(methane)

(iii) CH_3- CH_2- OH + $3O_2 \rightarrow 2CO_2 + 3H_2O$ + heat + light
(Ethanol)

Use your brain power !

Propane (C_3H_8) is one of the combustible component of L.P.G. Write down the reaction for Propane (C_3H_8)

Try this.

Apparatus : Bunsen burner, copper gauze, metal plate, etc.

Chemicals : Ethanol, acetic acid, naphthalene

Procedure : Place one of the above chemicals (3-4 drops or a pinch) on a clean copper gauze at room temperature, hold it on a blue flame of the Bunsen burner and observe. Is smoke/ soot seen to form due to combustion? Hold the metal plate on the flame when the substance is undergoing combustion. Does any deposit get collected on the plate? Which colour? Repeat the same procedure using other chemicals from the above list.

In the above activity ethanol is a saturated carbon compound, while naphthalene is an unsaturated compound. Generally saturated carbon compounds burn with a clean blue flame while unsaturated carbon compounds burn with a yellow flame and release black smoke. It is this black smoke due to which a deposit of black soot got collected on the metal plate.

Comparison of the molecular formulae indicates that the proportion of carbon is larger in unsaturated compounds than in saturated compounds. As a result, some unburnt carbon particles are also formed during combustion of unsaturated compounds. While in the flame, these hot carbon particles emit yellow light and therefore the flame appears yellow. However, if oxygen supply is limited a yellow flame is obtained by combustion of saturated compounds as well.

Compare

The proportion of carbon atoms in ethanol (C_2H_5OH) and naphthalene ($C_{10}H_8$)

Try this.

Light a Bunsen burner. Open and close the air hole at the bottom of the burner by means of the movable ring around it. When do you get yellow sooty flame? When do you get blue flame?

2. Oxidation

You have seen that carbon compounds start burning by combining easily with oxygen in the air when ignited in air. In this process of combustion all the chemical bonds in the molecule of the carbon compound break and CO_2 and H_2O are formed as the products. In other words the carbon compounds is completely oxidised during combustion. Chemical compounds can also be used as source of oxygen. Substances that can give oxygen to other substances are called oxidants or oxidizing agents. Potassium permanganate or potassium dichromate are commonly used as oxidizing agents. An oxidising agents affects on certain functional groups in present carbon compounds.

Always remember

There are inlets for air in the gas or kerosene stove at home. It is because of these air inlets that the gaseous fuel is mixed with sufficient oxygen and a clean blue flame is obtained. In case there is deposition of black soot on the bottom of cooking vessels it is an indication of choking of the air inlets and thereby the wastage of fuel. In such case the air inlets of the stove should be got cleaned.

Try this.

Apparatus : Test tube, Bunsen burner, measuring cylinder, dropper, etc.

Chemicals : Ethanol, dilute solution of sodium carbonate, dilute solution of potassium permanganate.

Procedure : Take 2-3 ml ethanol in a test tube, add 5 ml sodium carbonate solution to it and warm the mixture by holding the test tube on the burner for a while. Do dropwise addition of a dilute solution of potassium permanganate to this warm mixture with stirring. Does the typical pink colour of potassium permanganate stay as it is on addition ? Does the pink colour stop vanishing and stays on after some time of the addition process?

In the above activity ethanol gets oxidised by alkaline potassium permanganate to form ethanoic acid. Only certain bonds in the vicinity of the functional group take part in this reaction. The following equation will explain this.

$$\underset{\text{(ethanol)}}{CH_3 - CH_2 - OH} \xrightarrow[\text{alkaline } KMnO_4]{(O)} \underset{\text{(ethanoic acid)}}{CH_3 - \overset{\overset{\displaystyle O}{||}}{C} - OH}$$

Compare

How is the transformation of ethanol into ethanoic acid an oxidation reaction?

On adding the pink coloured solution of potassium permanganate to ethanol, the pink colour disappears in the beginning. This is because potassium permanganate is used up in the oxidation reaction. At a certain point of the addition, oxidation of all the quantity of ethanol in the test tube is complete. If the addition of potassium permangnate is continued beyond this point, it is not used up and becomes excess. The pink colour of this excess potassium permangnate does not vanish but stays as it is.

3. Addition Reaction

Try this.

Apparatus : Test tubes, droppers, etc.

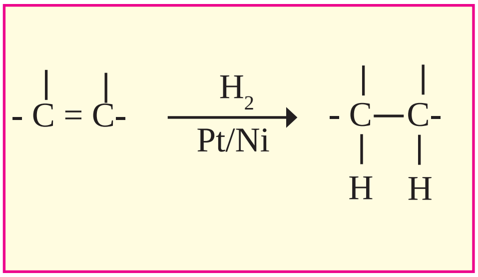
Chemicals : Tincture iodine, bromine water, liquefied Vanaspati ghee, various vegetable oils (peanut, safflower, sunflower, olive, etc.)

Procedure : Take 4 ml oil in a test tube and add 4 drops of tincture iodine or bromine water in it. Shake the test tube. Find out whether the original colour of bromine or iodine disappears or not. Repeat the same procedure using other oils and Vanaspati ghee.

In the above activity, the observation of the disappearing /diminishing colour of bromine / iodine indicates that bromine / iodine is used up. This means that bromine/ iodine has undergone a reaction with the concerned substance. This reaction is an 'addition reaction'. When a carbon compound combines with another compound to form a product that contain all the atoms in both the reactants, it is called an addition reaction. Unsaturated compounds contains a multiple bond as their functional group. They undergo addition reaction to form a saturated compound as the product. The addition reaction of an unsaturated compound with iodine or bromine takes place instantaneously at room temperature. Moreover the colour change can be felt by eyes. therefore this reaction is used as a test for detection of a multiple bond in a carbon compound. In the above activity, the colour of iodine / bromine disappears in the reaction between an oil and iodine, however, there is no colour change with Vanaspati ghee. What inference will you draw from this? Which of the substances do contain a multiple bond?

Name	Molecular Formula	Number of C=C double bonds	Will it decolourize I_2?
Stearic acid	$C_{17}H_{35}COOH$	....	yes / no
Oleic acid	$C_{17}H_{33}COOH$	....	yes / no
Palmitic acid	$C_{15}H_{31}COOH$	....	yes / no
Linoleic acid	$C_{17}H_{31}COOH$	....	yes / no

The unsaturated compound can also undergo addition reaction with hydrogen to form a saturated compound. However, it is necessary to use a catalyst like platinum or nickel for this reaction. We have already seen that catalyst is such a substance due to presence of which rate of reaction changes without causing any disturbance to it.



This reaction is used for hydrogenation of vegetable oils in presence of nickel catalyst. You have seen in the above activity that iodine test indicates presence of multiple bonds (double bond in particular) in the molecules of oils while Vanaspati ghee is found to be saturated. The molecules of vegetable oil contain long and unsaturated carbon chains. Hydrogenation transforms them into saturated chains and thereby Vanaspati ghee is formed.

Unsaturated fats containing double bonds are healthy while saturated fats are harmful to health.

4. Substitution reaction

As the single bonds C-H and C-C are very strong, the saturated hydrocarbons are not reactive, and therefore they remain inert in presence of most reagents. However, saturated hydrocarbons, in presence of sunlight react rapidly with chlorine. In this reaction chlorine atoms replace, one by one, all the hydrogen atoms in the saturated hydrocarbon. The reaction in which the place of one type of atom / group in a reactant is taken by another atom / group of atoms, is called substitution reaction. Chlorination of methane, is a substitution reaction which gives four products.

$$CH_4 + Cl_2 \xrightarrow{\text{Sunlight}} CH_3\text{-}Cl + HCl$$

$$CH_3Cl + Cl_2 \xrightarrow{\text{Sunlight}} CH_2Cl_2 + HCl$$

$$CH_2Cl_2 + Cl_2 \xrightarrow{\text{Sunlight}} CHCl_3 + HCl$$

$$CHCl_3 + Cl_2 \xrightarrow{\text{Sunlight}} CCl_4 + HCl$$

Still larger number of products are formed in chlorination reaction of higher homologues of alkanes.

Use your brain power !

In the chlorination, substitution reaction of propane two isomeric products containing one chlorine atom are obtained. Draw their structural formulae and give their IUPAC names.

You have learnt about four types of common reactions in the previous chapter. In which of these four types the addition and substitution reaction of carbon compounds can be included? What are the additional details and difference in the addition and substitution reaction?

Important carbon compounds : Ethanol and Ethanoic Acid

Ethanol and ethanoic acid are two of the commercially important carbon compounds. Let us now learn more about them.

At room temperature colourless ethanol is a liquid and its boiling point is 78 ^{0}C. Generally ethanol is called alcohol or spirit. Ethanol is soluble in water in all proportions. When aqueous solution of ethanol is tested with litmus paper it is found to be neutral. Consumption of small quantity of dilute ethanol shows its effect, even though is condemned still it has remained socially widespread practice. Consumption of alcohol harms health in a number of ways. It adversely affects the physiological processes and the central nervous system. Consumption of even a small quantity of pure ethanol (called absolute alcohol) can be lethal. Ethanol being good solvent, it is used in medicines such as tincture iodine (solution of iodine and ethanol), cough mixture and also in many tonics.

Do you know ?

Methanol (CH_3OH), the lower homologue of ethanol, is poisonous, and intake of its small quantity can affect vision and at times can be lethal. To prevent the misuse of the important commercial solvent ethanol, it is mixed with the poisonous methanol. Such ethanol is called denatured spirit. A blue dye is also added to it, so that it is easily recognised.

Chemical properties of ethanol

You have learnt about the oxidation reaction of ethanol in a previous unit of this chapter. Two more reactions of ethanol are as follows. The functional group -OH plays an important role in the reactions of ethanol.

(i) Reaction with sodium

$$2Na + 2\ CH_3\text{-}CH_2\text{-}\ OH \longrightarrow 2\ CH_3\text{-}CH_2\text{-}ONa + H_2\uparrow$$

(Sodium ethoxide)

All the alcohols react with sodium metal to liberate hydrogen gas and form sodium alkoxide salts. In the reaction of ethanol with sodium metal, hydrogen gas and sodium ethoxide are formed as products.

Try this. **Note : This activity should be demonstrated by the teacher.**

Apparatus : Big test tube, delivery tube fitted in a rubber cork, knife, candle, etc.

Chemicals : Sodium metal, ethanol, magnesium ribbon, etc.

Procedure : Take 10 ml ethanol in a big test tube. Cut sodium metal into 2-3 pieces of a cereal grain size. Put the sodium pieces into the ethanol in the test tube and fix the gas delivery tube to the test tube. Take a burning candle near the outlet of the gas delivery tube and observe.

1. Which is the combustible gas coming out of the gas delivery tube?
2. Why do the sodium pieces appear to dance on the surface of ethanol?
3. Repeat the above procedure using magnesium ribbon instead of sodium.
4. Do you see gas bubble released from the piece of magnesium ribbon?
5. Does magnesium metal react with ethanol?

In previous standard you have learnt that a moderately reactive metal such as magnesium reacts with strong acid to liberate hydrogen gas. Though ethanol is neutral, it reacts with sodium metal and liberates hydrogen gas. Sodium being highly reactive metal, it reacts with the neutral functional group -OH of ethanol.

(ii) Dehydration reaction : When ethanol is heated at the temperature 170 ^{0}C with excess amount of concentrated sulphuric acid, one molecule of water is removed from its molecule to form ethene, an unsaturated compound.

$$CH_3\text{-}CH_2\text{-}OH \xrightarrow[\text{conc. } H_2SO_4]{170^0C} CH_2{=}CH_2 + H_2O$$

Here, concentrated sulphuric acid acts as a dehydrating agent.

Use your brain power !

1. Explain by writing a reaction, what will happen when pieces of sodium metal are put in n- propyl alcohol.
2. Explain by writing a reaction, which product will be formed on heating n - butyl alcohol with concentrated sulphuric acid.

Science : Alcohol : A fuel

The sugarcane plant transforms solar energy into chemical energy very efficiently. When molasses, obtained during production of sugar from sugarcane, is subjected to fermentation, alcohol (ethanol) is obtained. On combustion in sufficient air ethanol gives carbon dioxide and water as the only products. In this way, ethanol is a clean fuel. Therefore in some countries it is used as an additive to increase the efficiency of petrol. Such a fuel is called gasohol.

Ethanoic acid: Ethanoic acid is a colourless liquid with boiling point118^{0}C. Ethanoic acid is commonly known as acetic acid. Its aqueous solution is acidic and turns blue litmus red. Vinegar, which is used as preservative in pickles, is a 5-8 % aqueous solution of acetic acid. The melting point of pure ethanoic acid is 17^{0}C . Therefore during winter in cold countries ethanoic acid freezes at room temperature itself and looks like ice. Therefore it is named 'glacial acetic acid'.

Try this.

Apparatus: Glazed tile, glass rods, pH paper, blue litmus paper.
Chemicals : Dilute ethanoic acid, dilute hydrochloric acid

Procedure: Place two strips of blue litmus paper on a glazed tile. Put one drop of dilute hydrochloric acid on one strip with the help of a glass rod. Put one drop dilute ethanoic acid with the help of another glass rod on the other strip. Note the colour change taken place in the litmus strip. Repeat the same procedure using strips of pH paper. Note all the observation in the following table.

Substance	Colour change in blue litmus paper	Corresponding pH (Scratch the unwanted)	Colour change seen on the pH paper	Corresponding pH
Ethanoic acid		< 7 / 7 / > 7		
Hydrochloric acid		< 7 / 7 / > 7		

9.23 Testing ethanoic acid & Hydrochloric acid

Use your brain power !

1. Which one of ethanoic acid and hydrochloric acid is stronger?
2. Which indicator paper out of blue litmus paper and pH paper is useful to distinguish between ethanoic acid and hydrochloric acid?

Chemical Properties of ethanoic Acid

Ethanoic acid contain carboxylic acid as its functional group. The chemical reaction of ethanoic acid are mainly due to this functional group.

i. Reaction with base

a. A reaction with strong base

Ethanoic acid gives neutralization reaction with a strong base sodium hydroxide to form a salt and water.

$$\underset{\text{(Acid)}}{CH_3\text{-}COOH} + \underset{\text{(Base)}}{NaOH} \rightarrow \underset{\text{(Salt)}}{CH_3\text{-}COO\,Na} + \underset{\text{(Water)}}{H_2O}$$

The IUPAC name of the salt formed here is sodium ethanoate while its common name is sodium acetate. You have learnt in the previous standard that acetic acid is a weak acid. Will the salt sodium acetate be neutral?

b. Reaction with carbonate and bicarbonate

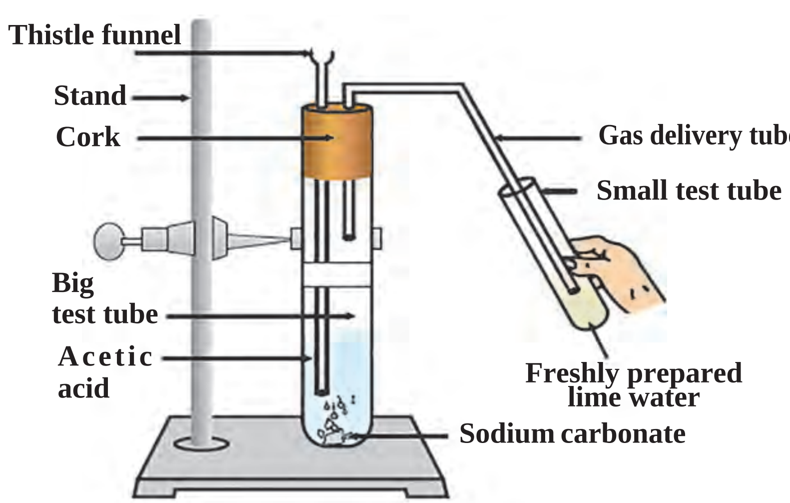
Try this.

Apparatus : Big test tube, small test tube, bent gas delivery tube, rubber cork, thistle funnel, stand, etc.

Chemicals : Acetic acid , sodium carbonate powder, freshly prepared lime water.

Procedure : Arrange the apparatus as shown in figure. Place sodium carbonate powder in the big test tube. Pour 10 ml acetic acid through the thistle funnel. Observe the changes taking place in the two test tubes.

1. Which gas does come out as effervescence in the big test tube?
2. Why are bubbles seen in the small test tube ?
3. What is the colour change in the lime water? Write the related equation.



9.24 Reaction of acetic acid and sodium carbonate

In this activity ethanoic acid reacts with the basic salt, namely, sodium carbonate, to form a salt , named sodium ethanoate, water and carbon dioxide gas.

$$2CH_3COOH\ (aq) + Na_2CO_3\ (g) \rightarrow CH_3COONa\ (aq) + H_2O\ (l) + CO_2\ (g)$$

The CO_2 gas of the effervescence passes through the gas delivery tube and reacts with the lime water in the small test tube. 'Lime water turning milky' is the test of carbon dioxide gas. If sodium bicarbonate is used instead of sodium carbonate in the above activity, similar observation are obtained.

$$CH_3COOH + NaHCO_3 \rightarrow CH_3COONa + H_2O + CO_2$$

Use your brain power !

1. Explain with reaction why does the lime water turn milky in the above activity.
2. Explain the reaction that would take place when a piece of sodium metal is dropped in ethanoic acid.
3. Two test tubes contain two colourless liquids ethanol and ethanoic acid. Explain by writing reaction which chemical test you would perform to tell which substance is present in which test tube.

ii. Esterification Reaction : Substances having ester as the functional group are formed by reaction between a carboxylic acid and an alcohol.

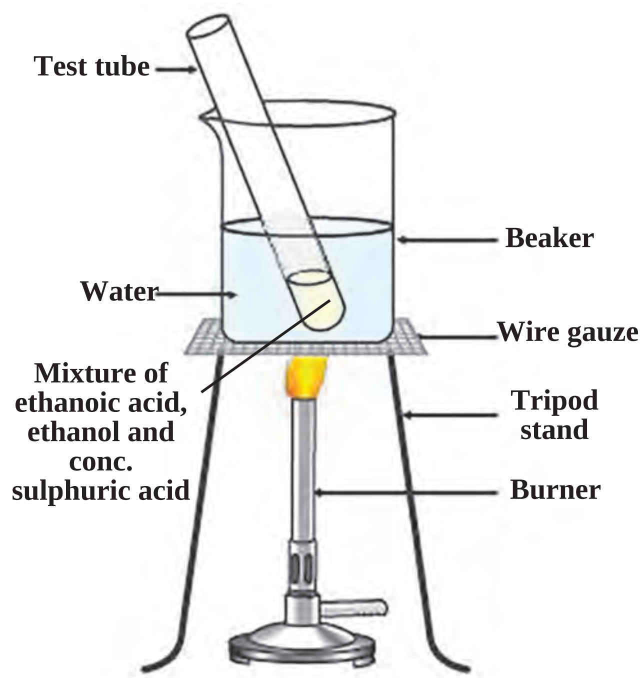
Try this.

Apparatus : Test tube, beakers, burner etc.

Chemicals : Glacial ethanoic acid, ethanol concentrated sulphuric acid etc.

Procedure : Take 1 ml ethanol and 1 ml glacial ethanoic acid in a test tube. Add a few drops of concentrated sulphuric acid in it. Keep this test tube in the beaker containing hot water (hot water bath) for five minutes. Then take 20-30 ml water in another beaker and pour the above reaction mixture in it and smell it.

Ethanoic acid reacts with ethanol in presence of an acid catalyst and ester, ethyl ethanoate is formed.



9.25 Esterification Reaction

$$\underset{\text{(Ethanoic acid)}}{CH_3\text{-}COOH} + \underset{\text{(Ethanol)}}{CH_3\text{-}CH_2\text{-}OH} \xrightarrow[\text{Catalyst}]{\text{Acid}} \underset{\text{(Ethyl Ethanoate)}}{CH_3\text{-}COO\text{-}CH_2\text{-}CH_3} + \underset{\text{(Water)}}{H_2O}$$

Esters have sweet odour. Majority of fruits owe their odour to a particular ester present in them. Esters are used for making fragrances and flavouring agents. When an ester is reacted with the alkali sodium hydroxide, the corresponding alcohol and carboxyclic acid (in the form of its sodium salt) are obtained back. This reaction is called saponification reaction, as it is used for preparation of soap from fats.

Ester + Sodium hydroxide $\longrightarrow$ Sodium Carboxylate + Alcohol

Use your brain power !

When fat is heated with sodium hydroxide solution, soap and glycerin are formed. Which functional groups might be present in fat and glycerin? What do you think?

Macro molecules and Polymers

Can you tell?

1. What are the chemical names of the nutrients that we get from the food stuff, namely, serials, pulses and meat?
2. What are the chemical substances that make cloth, furniture and elastic objects?

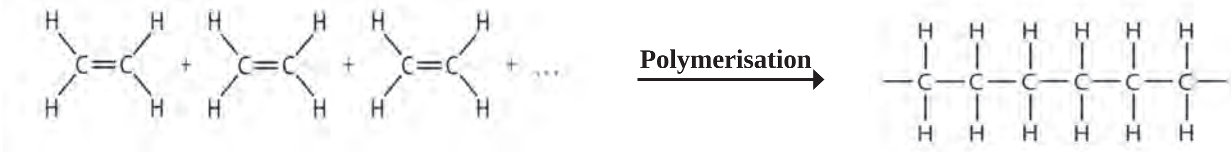
Macromolecules : We have seen in the beginning of this chapter that the number of the known carbon compounds is as large as about 10 million, and the range of their molecular masses is as large as 10^1- 10^{12}. The number of constituent atoms is very large for the molecules with high molecular mass. The giant carbon molecules formed from hundreds of thousands of atoms are called macromolecules. They are from the type of compounds called polymers.

Natural macromolecules : The natural macromolecules namely, polysaccharides, proteins and nucleic acids are the supporting pillars of the living world. We get food, clothing and shelter from polysaccharides, namely, starch and cellulose. Proteins constitute a large part of the bodies of animals and also are responsible for their movement and various physiological processes. Nucleic acids control the heredity at molecular level. Rubber is another type of natural macromolecule.

Manmade macromolecules : Macromolecules were produced for the first time in the laboratory and factory with an intention to invent an alternative for rubber and silk. Today manmade macromolecules are in use in every walk of life. Manmade fibres which have strength along the length similar to natural fibres cotton, wool and silk; elastomers which have the elastic property of rubber; plastics from which innumerable types of articles, sheets, pipes and surface coatings are made are all examples of manmade macromolecules. The structure of natural and manmade macromolecules is formed by joining several small units in a regular manner. As a result the macromolecules are polymeric in nature.

Polymers : A macromolecule formed by regular repetition of a small unit is called polymer. The small unit that repeats regularly to form a polymer is called monomer. The reaction by which monomer molecules are converted into a polymer is called polymerization.

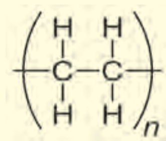
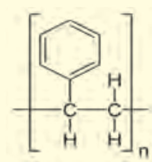
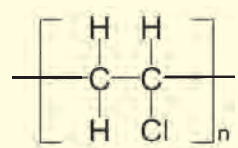
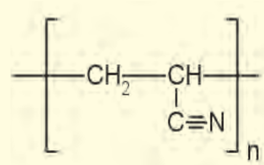
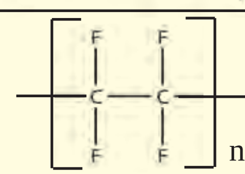
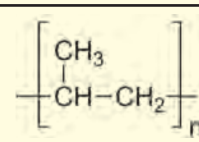
One important method of polymerization is to make a polymer by joining alkene type monomers. For example, synthesis of polyethylene is as shown further (see 9.26). Also, the table 9.27 shows the polymers used in large scale.



ethylene monomer

Polyethylene

9.24 Synthesis of polyethylene

Name of polymer	Constituent monomer	Structural formula of the polymer	Uses
Polyethylene	Ethylene $CH_2 = CH_2$		Carry bags, sports wear
Polystyrene	Styrene $C_6H_5 - CH = CH_2$		Thermocol articles
Polyvinyl chloride (PVC)	Vinyl chloride $Cl - CH = CH_2$		P.V.C. pipes, door mats, tubes and bags in hospital kits.
Polyacrylo nitrile	Acrylo nitrile $CH_2 = CH - C \equiv N$		Winter clothing, blankets
Teflon	Tetrafluro ethylene $CF_2 = CF_2$		Nonstick cookware
Polypropylene	Polypropylene $CH_3 - CH = CH_2$		Injection syringe, Furniture

9.27 Various polymers and their uses

The polymers in the above examples are formed by repetition of single monomer. These are called homopolymers. The other type of polymers are formed from two or more monomers. They are called copolymers. For example, PET is poly ethylene terephthalate. The structures of polymers are linear as in the above examples or they are branched and cross linked as well. Polymers acquire various properties as per the nature of the monomers and the type of structure.

The composition and structure of natural polymers were understood after carrying out their decomposition. The composition of the main natural polymers in given in the Table 9.28.

Polymer	Name of the monomer	Occurrence
Polysaccharide	Glucose	Starch
Cellulose	Glucose	Wood (cell walls of plant cells)
Proteins	α amino acids	Muscles, hair, enzymes, skin, egg
D.N.A.	Nucleotide (deoxyribose-phosphate)	Chromosomes of organisms
R.N.A.	Nucleotide (ribose-phosphate)	Nucleus and cytoplasm of cell
Rubber	Isoprene $CH_2= C\text{-}CH=CH_2$ $\quad\;\; \vert$ $\quad\; CH_3$	Latex of rubber tree

9.28 Some natural polymers and their occurrence

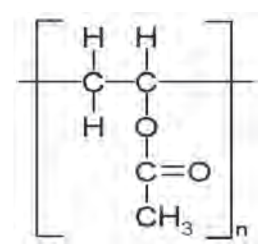
Use your brain power !

1. Structural formulae of some monomers are given below. Write the structural formula of the homopolymer formed from them.

a.
$$\begin{array}{c} \qquad\;\; CH_3 \\ \qquad\;\; \vert \\ CH_2= C \\ \qquad\;\; \vert \\ \qquad\;\; CH_3 \end{array}$$

b.
$$\begin{array}{c} \qquad\;\; CH_3 \\ \qquad\;\; \vert \\ CH_2= C \\ \qquad\;\; \vert \\ \qquad\;\; CN \end{array}$$

2. From the given structural formula of polyvinyl acetate, that is used in paints and glues, deduce the name and structural formula of the corresponding monomer.



Exercise

1. **Match the pairs.**

Group 'A'	Group 'B'
a. C_2H_6	1. Unsaturated hydrocarbon
b. C_2H_2	2. Molecular formula of an alcohol
c. CH_4O	3. Saturated hydrocarbon
d. C_3H_6	4. Triple bond

2. **Draw an electron dot structure of the following molecules. (Without showing the circles)**

   a. Methane b. Ethene

   c. Methanol d. Water

3. **Draw all possible structural formulae of compounds from their molecular formula given below.**

   a. C_3H_8 b. C_4H_{10} c . C_3H_4

4. **Explain the following terms with example.**

   a. Structural isomerism
   b. Covalent bond
   c. Hetero atom in a carbon compound
   d. Functional group
   e. Alkane
   f. Unsaturated hydrocarbon
   g. Homopolymer
   h. Monomer
   i. Reduction
   j. Oxidant

5. **Write the IUPAC names of the following structural formulae.**

a. CH_3-CH_2-CH_2-CH_3

b. CH_3-CHOH-CH_3

c. CH_3-CH_2-COOH

d. CH_3-CH_2-NH_2

e. CH_3-CHO

f. CH_3-CO-CH_2-CH_3

6. **Identify the type of the following reaction of carbon compounds.**

a. $CH_3-CH_2-CH_2-OH \longrightarrow CH_3-CH_2-COOH$

b. $CH_3-CH_2-CH_3 \longrightarrow 3\ CO_2 + 4\ H_2O$

c. $CH_3-CH= CH-CH_3 + Br_2 \longrightarrow CH_3-CHBr - CHBr-CH_3$

d. $CH_3-CH_3 + Cl_2 \longrightarrow CH_3-CH_2-Cl + HCl$

e. $CH_3-CH_2-CH_2-CH_2-OH \longrightarrow CH_3-CH_2-CH=CH_2 + H_2O$

f. $CH_3-CH_2-COOH + NaOH \longrightarrow CH_3-CH_2-COO^-Na^+ + H_2O$

g. $CH_3-COOH + CH_3-OH \longrightarrow CH_3-COO-CH_3 + H_2O$

7. **Write structural formulae for the following IUPAC names.**

a. pentan -2-one

b. 2- chlorobutane

c. propan - 2- ol

d. methanal

e. butanoic acid

f. 1- bromopropane

g. ethanamine

h. butanone

8. **Write answers as directed.**

a. What causes the existance of very large number of carbon compound ?

b. Saturated hydrocarbons are classified into three types. Write these names giving one example each.

c. Give any four functional groups containing oxygen as the heteroatom in it. Write name and structural formula of one example each.

d. Give names of three functional groups containing three different hetero atoms. Write name and structural formula of one example each.

e. Give names of three natural polymers. Write the place of their occurrance and names of monomers from which they are formed.

f. What is meant by vinegar and gasohol? What are their uses ?

g. What is a catalyst ? Write any one reaction which is brought about by use of catalyst ?

Project

Prepare a chart giving detailed information of carbon compounds in everyday use. Display it in the class and discuss.

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