Unit		Teaching (Periods)	Assessment (Periods)	Weightage %
11	Organic Chemistry	10	3	10

Introduction

Early scientists defined organic compounds as compounds that were derived from living things i.e. plants and animals. A Swedish Chemist, Berzellius in 1815 put forward a theory called **Vital Force Theory**. According to this theory, vital forces are necessary for the synthesis of organic compounds.

Organic compounds are very important as they are extensively used in our daily life e.g the food that we eat, the clothes that we wear, the natural gas that we burn for cooking and in industry, all are organic compounds.

In this unit, you will study the organic compounds, their sources, their structural, condensed and molecular formulae, the characteristic of organic compounds and the functional groups of organic compounds.

11.1 Organic Compounds

Organic compounds exist in large number and they are studied in a separate branch of chemistry called organic chemistry.

Organic chemistry is the study of Carbon containing compounds, except Oxides of Carbon (Carbon monoxide and Carbon dioxide), Carbonates, Bicarbonates and some metal Carbides. In other words we can say that, it is the study of hydrocarbons and their derivatives.

There are several million organic compounds known today and thousands of organic compounds are prepared every year. A detailed study of carbon showed that carbon is an element, but still its compounds are in millions. Therefore, the Organic compounds are now defined as hydrocarbons and their derivatives. Organic compounds that contain only hydrogen and carbon are called hydrocarbons. Organic compounds may also contain other elements such as oxygen, chlorine, sulphur and nitrogen. Organic compounds may be classified into two groups depending upon their origin.

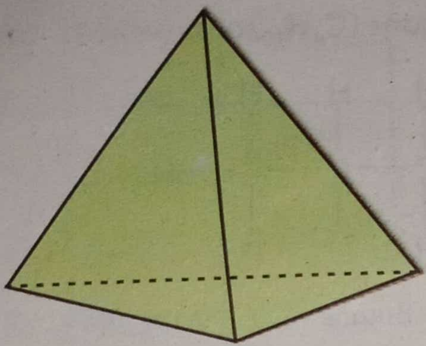
Organic Compounds

- Naturally Occurring e.g Coal, Food we eat etc
- Synthetic (Man-made) e.g. Plastic, Detergents, Medicines etc

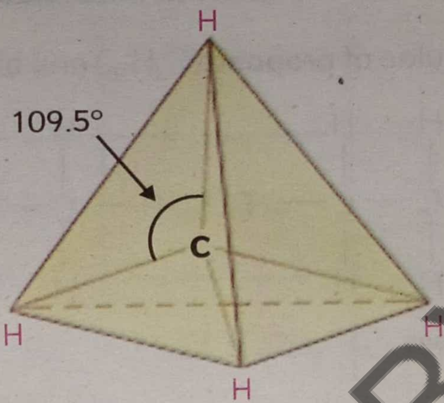
Tidbit

Tetrahedron

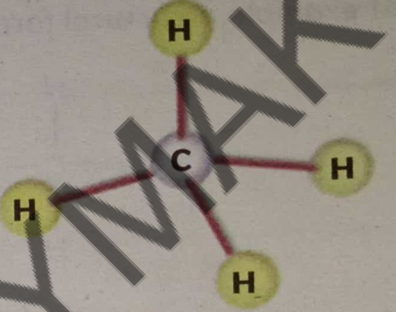
The carbon atom has a valency of four and forms covalent bonds. It is in the middle of the tetrahedron with hydrogen atoms at each of its corners in the hydrocarbons. Tetrahedron is a 3 –Dimensional (3-D) solid figure with four faces.



A tetrahedron



Three- dimensional structure of a methane molecule



A model of methane molecule

Reading Check

Define organic chemistry and organic compounds.

Each of these organic compound can be represented by,

1. Molecular formula,
2. Structural formula,
3. Condensed formula and
4. Dot and cross formula.

1. Molecular formula

The formula which represents the actual number of atoms in one molecule of organic compound is called the molecular formula. For example, the molecular formula of propane is C_3H_8, and butane is C_4H_{10}, etc. It shows that,

i. Propane consists of three carbon atoms and eight hydrogen atoms.

ii. Butane consists of four carbon atoms and ten hydrogen atoms.

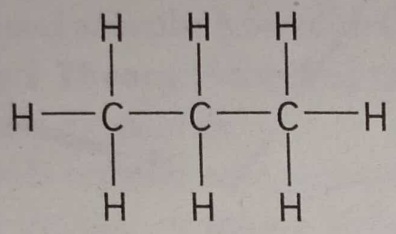
2. Structural formula

Structural formula of a compound is the arrangement of different atoms of various elements around the carbon atoms present in a molecule of a compound.

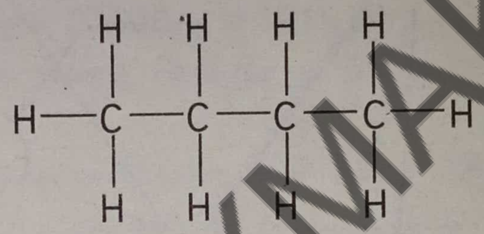
A structural formula shows the number and types of atoms present in a molecule and also shows the bonding arrangement of the atoms.

In structural formula, all the bonds are shown with their exact number. Single bonds are represented by a single line (—), double bonds are represented by double lines (=), and triple bond are represented by three lines (≡) between the bonded atoms.

For example, structural formulae of propane (C_3H_{10}) and butane (C_4H_{10}) are,



Propane



n- Butane

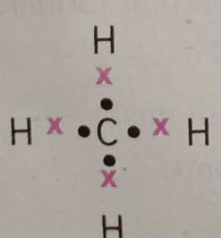
3. Condensed formula

The condensed formula of a molecule is the formula where the groups of atoms are shown in order as they appear in the structural formula with no bonds or dashes.

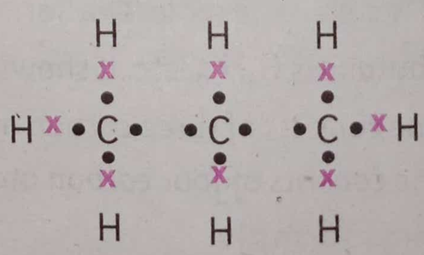
A true condensed formula can be written on a single line without any branching above or below it. For example, Hexane has six carbon and fourteen hydrogen atoms with molecular formula of C_6H_{14}. The condensed formula of hexane is $CH_3(CH_2)_4CH_3$ and condensed formula of heptane is $CH_3(CH_2)_5CH_3$.

4. Dot and Cross Formula

A structural formula in which electrons are shown as dots and cross between various atoms in one molecule of a compound are called dot and cross formula or electronic formula. The shared pair of electron between two atoms represents a covalent bond. For example, in methane molecule, the four electrons of the carbon are represented by dots (•) and cross (×) is used to represent the electrons of four hydrogen atoms. The molecules of methane and propane are shown below.

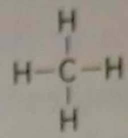
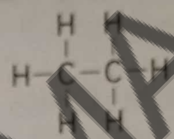
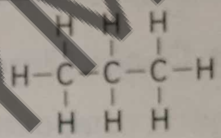
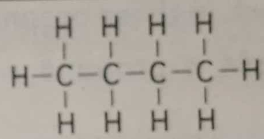
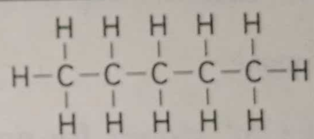
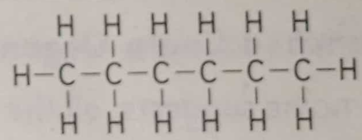
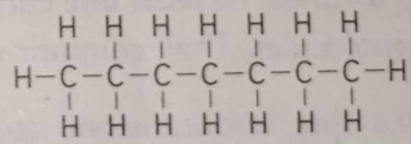
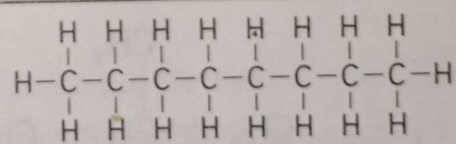
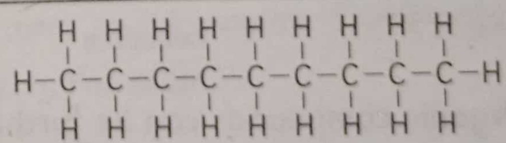
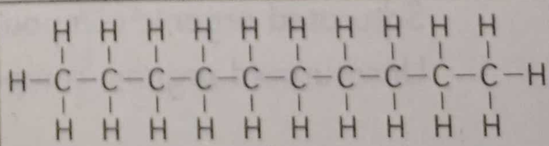


Dot - Cross Formula of Methane



Dot - Cross Formula of Propane

Table11.1 Names, Molecular Formula, Condensed Formula and Structural Formula of First Ten Hydrocarbons

Carbon atom	Name	General Formula C_nH_{2n+2}	Molecular formula	Condensed formula	Structural formula
1	Methane	C_1H_{2x1+2}	CH_4	CH_4	
2	Ethane	C_2H_{2x2+2}	C_2H_6	H_3CCH_3	
3	Propane	C_3H_{2x3+2}	C_3H_8	$H_3CCH_2CH_3$	
4	Butane	C_4H_{2x4+2}	C_4H_{10}	$H_3C(CH_2)_2CH_3$	
5	Pentane	C_5H_{2x5+2}	C_5H_{12}	$H_3C(CH_2)_3CH_3$	
6	Hexane	C_6H_{2x6+2}	C_6H_{14}	$H_3C(CH_2)_4CH_3$	
7	Heptane	C_7H_{2x7+2}	C_7H_{16}	$H_3C(CH_2)_5CH_3$	
8	Octane	C_8H_{2x8+2}	C_8H_{18}	$H_3C(CH_2)_6CH_3$	
9	Nonane	C_9H_{2x9+2}	C_9H_{20}	$H_3C(CH_2)_7CH_3$	
10	Decane	$C_{10}H_{2x10+2}$	$C_{10}H_{22}$	$H_3C(CH_2)_8CH_3$	

Classification of Organic Compounds

Organic compounds are mainly classified into two types on the bases of their carbon skeleton.

1. Open chain or acyclic organic compounds
2. Close chain or cyclic organic compounds

1. Open chain or Acyclic organic compounds

These are organic compounds in which carbon atoms are in open chain skeleton (structure). They can form long possible chains. Open chain organic compounds are further classified into,

i. Straight Chain organic compounds
ii. Branched Chain organic compounds

i. Straight Chain Organic Compounds

In these organic compounds carbon atoms link with each other to form straight chains. There is no branch in these organic compounds.

For example, n- propane, n- Butane, – pentane etc.

$CH_3-CH_2-CH_3$ Propane

$CH_3-CH_2-CH_2-CH_3$ n– Butane

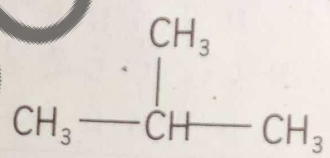
$CH_3-CH_2-CH_2-CH_2-CH_3$ n– Pentane

The Prefix "n" stands for normal and is used for straight chain organic compounds

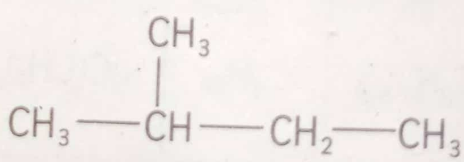
ii. Branched Chain Organic Compounds

As the name suggests, all the carbon atoms are not present in a linear sequence in branched chain alkanes. At least one carbon atom is linked with more than two other carbon atoms in their molecules. Their common names have a prefix iso— with the corresponding alkanes.

For example, Isobutane and isopentane etc.



Isobutane



Isopentane

Organic compounds can be further classified into,

i. Saturated organic compounds
ii. Unsaturated organic compounds

i. Saturated Organic Compounds

Organic compounds in which each carbon atom in the molecule forms four single covalent bonds with other atoms are called saturated organic compounds. Examples of saturated hydrocarbons are **alkanes**.

Hydrocarbons that contain only single bond are called **alkanes**, Such as Methane (CH_4), Ethane (C_2H_6) and Propane (C_3H_8) etc.

ii. Unsaturated Organic Compounds

Organic Compounds in which at least one double or triple covalent bond is present between carbon–carbon are called unsaturated organic compounds. It can be further divided into alkenes and alkynes.

Alkenes: Hydrocarbons that contain at least one double covalent bond between two carbon atoms.

Alkynes: Hydrocarbons with at least one triple covalent bond between two carbon atoms.

2. Close Chain or Cyclic Organic Compounds

Close chain or cyclic organic compounds are those organic compounds in which carbon atoms are linked together to form a close chain structure or ring.

The close chain or cyclic organic compounds are further divided into two groups. These are,

i. Homocyclic or Carbocyclic Organic Compounds

ii. Hetrocyclic Organic Compounds

i. Homocyclic or Carbocyclic Organic Compounds

Organic compounds which are in close chain or ring structure are called Homocyclic compounds. The ring is composed of only carbon atoms.

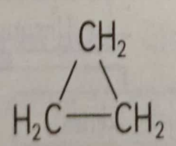
These organic compounds are further divided into two types.

a. Ali-cyclic organic compound

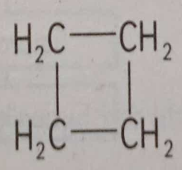
b. Aromatic organic compound

a. Ali-cyclic Organic Compound

These are the organic compounds which are in close chain structure forming a ring. The ring is composed of only carbon atoms. These organic compounds resemble in properties to the open chain organic compounds but differ in their structures and formulae. These organic compounds differ from open chain organic compounds by H_2. For example,



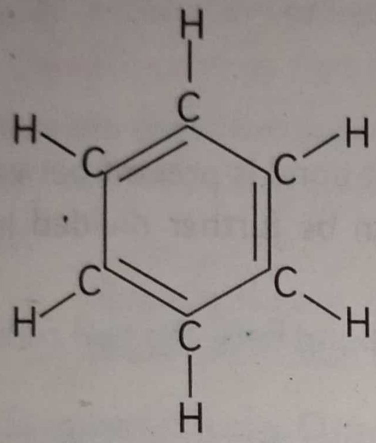
Cyclopropane



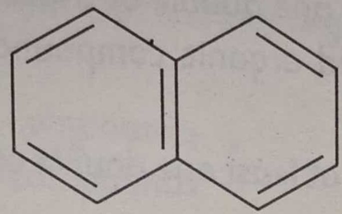
Cyclobutane

b. Aromatic Organic Compound

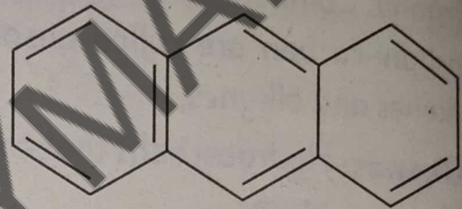
The cyclic organic compounds having alternate single and double bonds in its structure/carbon ring are known as aromatic organic compounds The important member of this class is benzene and other compounds that are derived from benzene. These compounds are called the derivatives of benzene. For example, Naphthalene, Anthracene etc.



Benzene



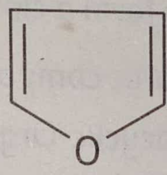
Naphthalene



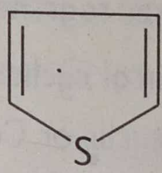
Anthracene

ii. Hetrocyclic Organic Compounds

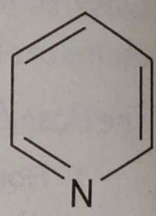
These are the organic compounds which contain one or more atoms other than carbon such as sulphur, oxygen or nitrogen in the ring or cycle are called hetrocyclic organic compounds. Examples are Furane, Thiophene and Pyridine etc.



Furane



Thiophene



Pyridine

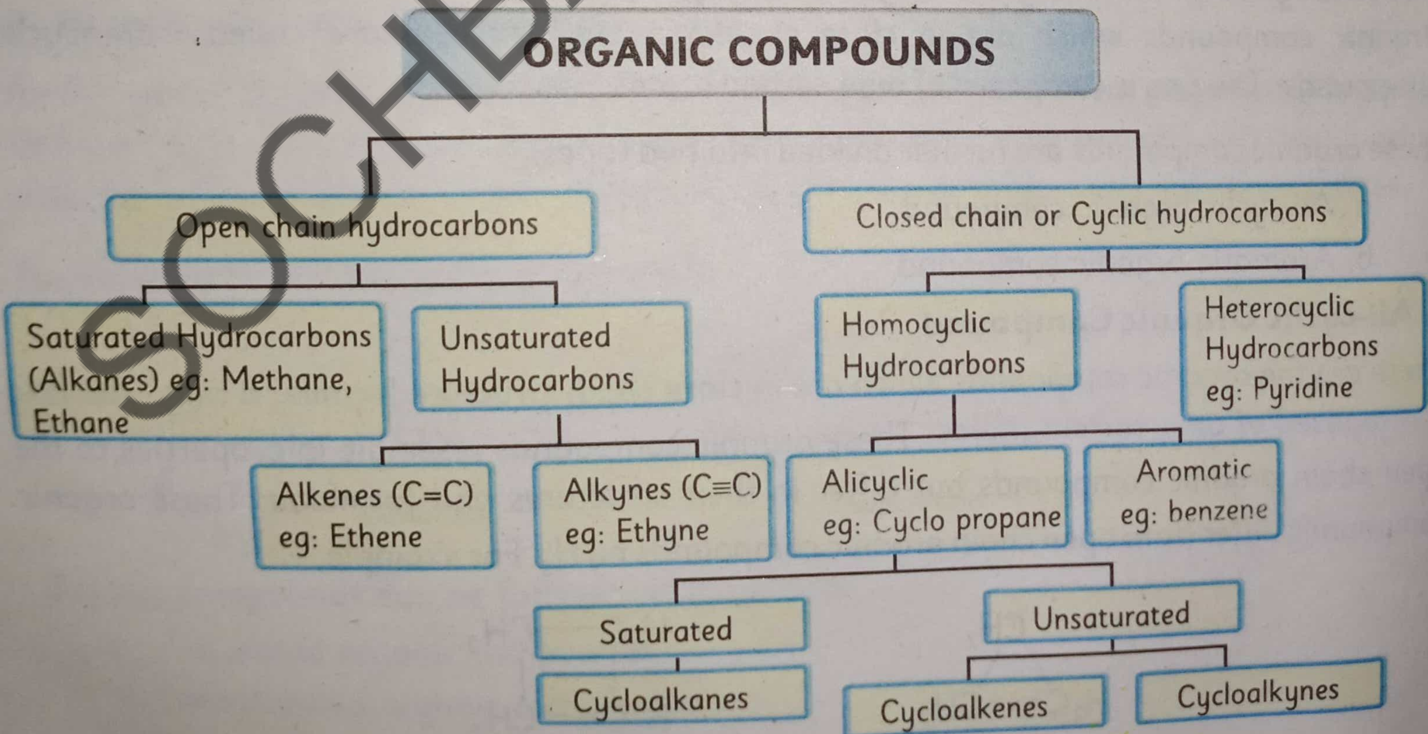


Fig.11.1 Organic Compounds

Diversity and Magnitude of Organic Compounds

The diversity and magnitude of organic compounds is due to the uniqueness of carbon's bonding and its structure. Carbon's unique bonding properties allow the formation of a variety of structures, including chains and rings of many shapes and sizes. Carbon can make bond with many other types of atoms such as hydrogen, oxygen, nitrogen etc. As carbon is an element but still its compounds are in millions due to the following reasons:

1. Tetra-valent

Carbon is a tetra-valent atom. Carbon atom can form a total of four covalent bonds.

2. Mode of Bonding

The carbon atom can form a single, double or triple bond in their compounds.

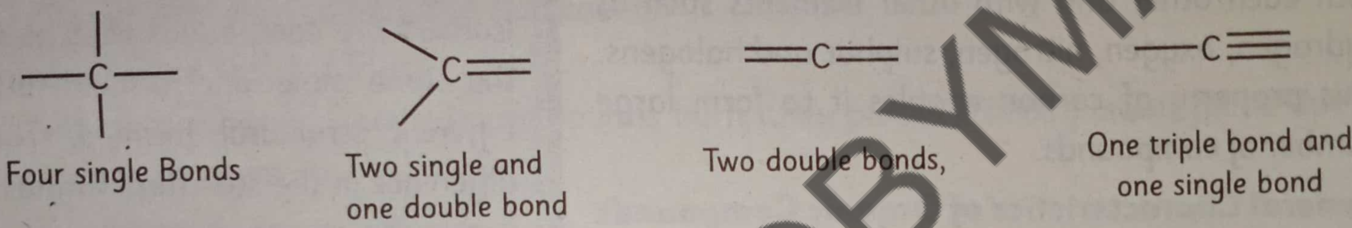
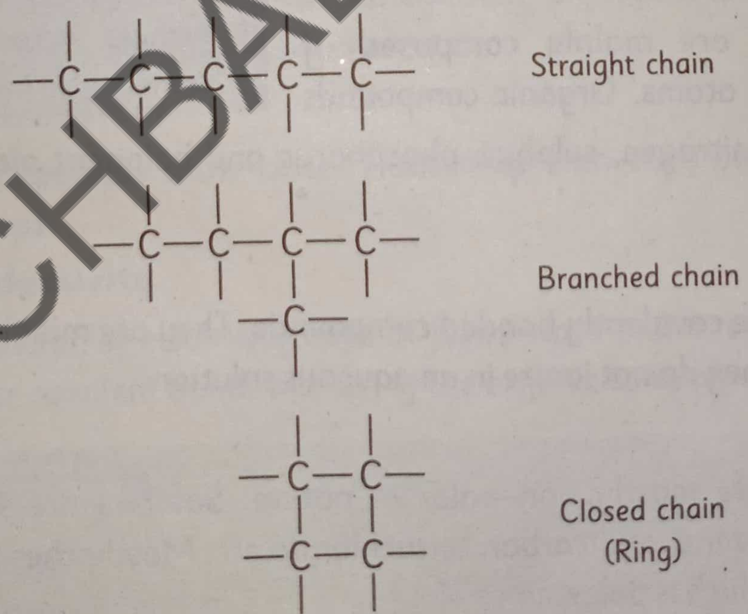


Fig.11.2 Different modes of Bond Formation in Carbon

3. Carbon-Carbon Bonding

Carbon atoms have the ability to covalently bond with other carbon atoms to form straight chains, branched chains and rings. This self linking ability of carbon is called **catenation**.



4. Carbon Bonding to other Elements

Besides Catenation, carbon atoms can bind easily with other atoms/ elements like O_2, N_2, S, and the halogens etc.

5. Arrangement of Atoms

The different bonding ability of carbon also allows for different arrangements of carbon atoms. This means that some organic compounds may contain the same atoms but have different properties because the atoms are arranged differently. For example, the molecular formula C_2H_6O represents both ethanol and dimethyl ether.

$$CH_3—O—CH_3$$

Ether

$$CH_3—CH_2—OH$$

Alcohol

6. Strength of Covalent Bonds of Carbon Atoms

The size of the carbon atom is very small. Due to which the carbon atoms form strong covalent bonds with each other and with other elements such as hydrogen, oxygen, nitrogen, sulphur and halogens. This property of carbon enables it to form large number of compounds.

Tidbit

Isomers

Isomers are compounds that have the same molecular formula, but different structural formula. The difference in the structural formula is due the arrangement of carbon atoms. The atoms in the compound are arranged differently. Two isomers will therefore have different properties. As the number of carbon atoms in a molecular formula increases, the number of isomers also increases.

General Characteristics of Organic Compounds

Organic compounds have many common characteristics due to their molecular structure. Some of the important characteristics are given below.

1. Composition

Organic compounds are mainly composed of carbon and hydrogen atoms. Organic compounds may contain oxygen, nitrogen, sulphur, phosphorus and halogens along with carbon and hydrogen atoms.

2. Covalent Nature

Organic compounds are covalently bonded compounds. They are mainly non-polar in nature with few exceptions. They do not ionize in an aqueous solution.

3. Solubility

Organic compounds are mostly non–polar in nature. So they are soluble in non–polar solvents like ether, benzene, and carbon tetrachloride etc. Mostly these compounds are less or insoluble in water, which is polar.

4. Low Melting and Boiling Points

Organic compounds have generally low melting and boiling points. This is due to the reason that organic compounds are held together by weak intermolecular forces. They can be easily broken down and are volatile in nature. Therefore, their melting and boiling points are low.

5. Thermal Instability

Organic compounds are usually thermally unstable. They decompose into smaller molecules on heating. This property is of great commercial importance e.g. as in the cracking of petroleum.

6. Inflammability

Organic compounds are inflammable. They burn in the presence of air and produce carbon dioxide and water with huge amount of heat. That is why fuels are organic compounds (wood, Coal, Oil, Natural gas) and their combustion produce a large amount of heat.

7. Reactivity

Reactions involving organic compounds are much slower than reactions which involve inorganic substances, that is why organic reaction requires heating, thorough mixing and the use of proper catalyst to speed up the reaction.

8. Burn with Smoky Flame

When higher molecular organic compounds burn, they produce smoky (soot) flame due to incomplete combustion.

9. Isomerism

Organic compounds show isomerism. Isomerism is the phenomenon in which two or more compounds having the same molecular formula but different structural formula.

10. Non – Ionic Character

They do not furnish ions. They show molecular reactions. Organic compounds have covalent bond between C – C and C – H. The electronegativity difference is very small, so they are non– polar in nature and show non – ionic character.

11. Similarity in Behaviour

Different organic compounds show close relationship with each other due to presence of same functional groups.

12. Electrical conductivity

They are poor conductor of electricity both in fused state and in solution form due to the presence of non-polar covalent bonds in most of the organic compounds.

Self Assessment

1. Define condensed formula.
2. What are the major characteristics of organic compounds?
3. Explain magnitude and diversity of organic compounds.
4. Differentiate between cyclic and acyclic organic compounds.
5. What are the branched chain organic compounds? Give your answer with examples.
6. Define aromatic compounds.

11.2 Sources of Organic Compounds

Natural organic compounds are prepared by living things such as plants and animals. Some organic compounds such as proteins are obtained from animals in the form of meat, mutton, chicken, egg etc. and fats are obtained in the form of animal fat, milk, butter etc.

Plants are also a rich source of organic compounds. Plants prepare a large number of organic compounds such as carbohydrates, proteins, fats (oil), vitamins etc.

Tidbit

Fossil fuel is formed due to the anaerobic decomposition of plants and animals under high temperature and pressure under the surface of earth in millions of years. Coal, petroleum, natural gas are collectively called fossil fuels.

Beside this, when plants and animals are dead, they are buried underneath the earth surface. Under high temperature and pressure, in millions of years these are converted into fossil fuels. These fossil fuels are the main source of organic compounds. The main sources of organic compounds are discussed in detail below.

11.2.1 Coal

It is a brown black solid mass and a major source of organic compounds. It is believed that coal is formed from the remains of plants. It is formed under high temperature and pressure, below the earth surface. In millions of years, under the bacterial and chemical action on the remains of trees and plants, it is converted into peat. The peat under high temperature and pressure is converted into coal.

Fig.11.2 Stages of formation of coal

Coal as a Source of Organic Compounds

Coal is a rich source of organic compounds. These organic compounds are obtained by the process of destructive distillation.

Carbonization or Destructive Distillation

When coal is strongly heated in the absence of air, this process is called carbonization or destructive distillation of coal. During this process, the coal is converted into coal gas, coke and coal tar and ammonical liquor, which are the sources of other organic compounds.

11.2.2 Petroleum

The word petroleum is a combination of two Latin words Petra means Rock and Oleum means Oil. The petroleum is also called Mineral Oil, Crude Oil or Liquid Gold. It occurs under the ground at different depths. It is a complex mixture of solids, liquids or gaseous hydrocarbons, water, salts and in addition to that mixed with earth particles. It is generally dark brown coloured and an unpleasant smelling liquid containing mixture of hydrocarbons. These hydrocarbons are alkanes, cyclo-alkanes, and aromatic compounds. After refining, it is used as a fuel. It is also used for the production of useful products such as synthetic rubber, explosives and plastic etc.

11.2.3 Natural gas

The natural gas is a mixture of low molecular mass gaseous hydrocarbons. It is mainly composed of low boiling point hydrocarbons. These hydrocarbons are methane, ethane, propane and traces of butane etc. Methane is the main component 85 – 95 percent of natural gas. In Pakistan, the natural gas is called Sui Gas.

The origin of natural gas is the same as that of coal and petroleum. It is found in combination with petroleum reservoirs or it can also be found without petroleum. It is mainly used as fuel in homes as well as in industries. It is used as fuel in automobiles as compressed natural gas (CNG). It is used for the preparation of carbon black and also as a basic raw material in the preparation of fertilizers.

11.2.4 Plants

Plants are a rich source of organic compounds. These compounds are mainly proteins, carbohydrates, fats, oils, vitamins etc. These compounds are obtained from plants in the form of leaves, stems, fruits, flowers, seeds and roots etc. These compounds are called **natural products**. Most natural products are extracted from plants and are used as medicines.

11.2.5 Animals

Reading Check

What are natural products?

Animals are also a good source of organic compounds. Most organic compounds such as proteins, carbohydrates, fats, vitamins, etc are obtained from animals in form of milk, meat, butter and egg etc.

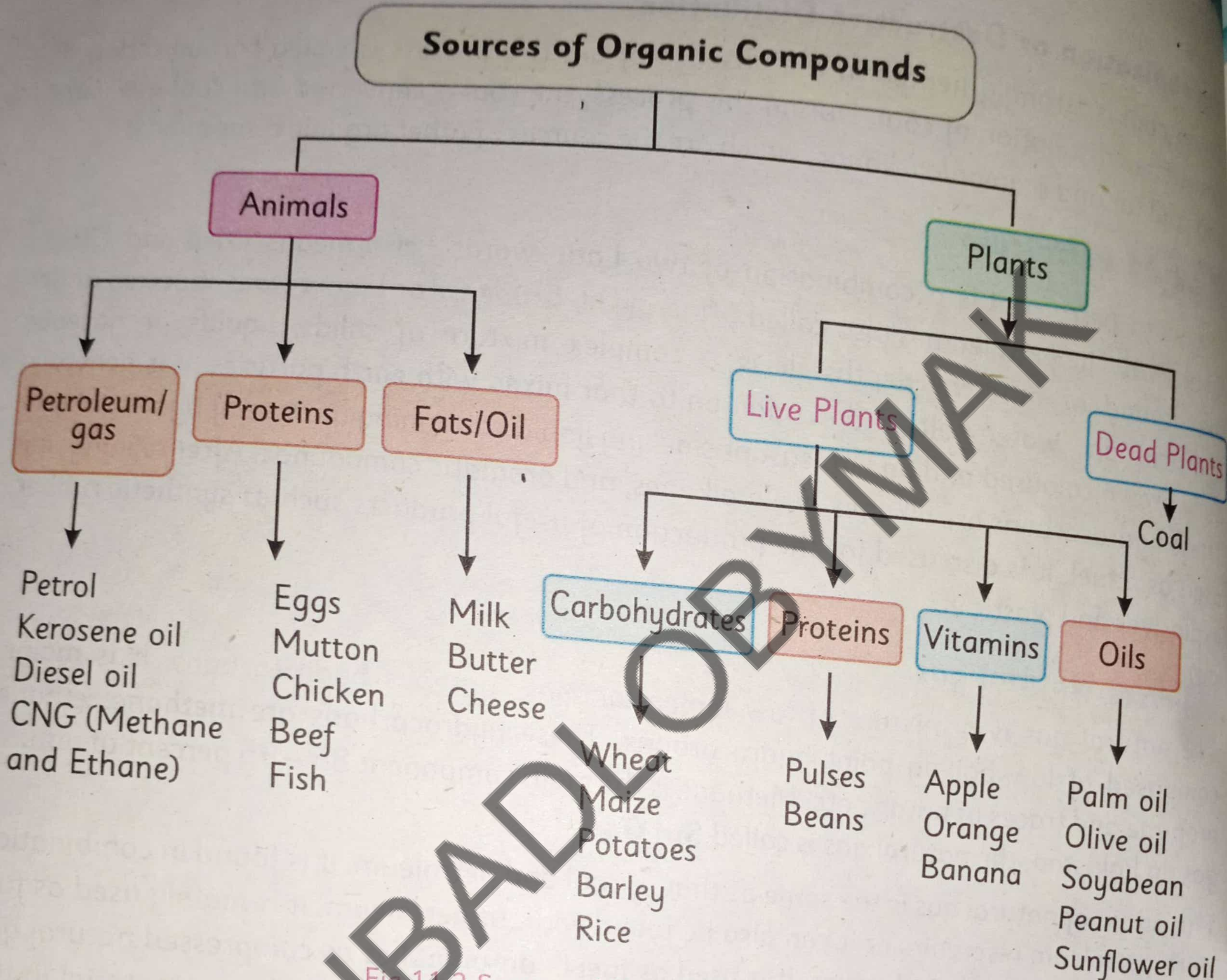


Fig 11.3 Sources of Organic Compounds

11.2.6 Synthesis of organic Compounds in the Laboratory

Upto the beginning of 19th century it was believed that living things i.e. plants and animals can only prepare the organic compounds due to vital force. The vital force theory was proved wrong, when the German chemist Friedrich Wohler prepared an organic compound called urea, $CO(NH_2)_2$, from inorganic compounds such as Potassium Cyanate and Ammonium Chloride on heating. The synthesis of organic compound in laboratory started a new era of organic compounds.

Friedrich Wohler

$$K\boxed{CNO + NH_4}Cl \xrightarrow{\text{Heat}} NH_4CNO + KCl$$

$$\underset{\text{Ammonium Cyanate}}{NH_4CNO_{(aq)}} \longrightarrow \underset{\text{Urea}}{H_2N-\overset{\overset{\displaystyle O}{\|}}{C}-NH_2}$$

Millions of compounds have been prepared in the laboratory, and every day a large number of compounds are being synthesized in the laboratories. These compounds range from simple to complex. Today, hundreds of compounds are synthesized in the laboratories such as drugs, medicines, flavours, fragrances, fertilizers, plastics, paints, synthetic fibres, cosmetics, detergents, pesticides, insecticides and herbicides etc. All these things have changed our lives.

11.3 Uses of Organic Compounds

The things we use in our daily life are mostly organic compounds such as the food we eat, the clothes we wear etc. Our dependence on organic compounds is increasing day by day. It has changed our life style.

i. Uses as food

The food we eat in our daily life such as milk, meat, egg, vegetables, etc. consists of carbohydrates, proteins, vitamins, fats etc. which are all organic compounds.

ii. Uses as clothing

The clothes we wear are made up of fibres. These fibres are either natural such as cotton, silk, wool etc or synthetic fibres such as nylon, polyester and acrylic etc. all these are organic compounds.

iii. Uses as medicine

Most of the medicines that we use are organic compounds. These are naturally synthesized from plants and are used as medicines. Most of the life saving drugs such as antibiotics, anti-inflammatory, anti-malarial etc. are synthesized in the laboratory.

iv. Uses as fuel

The fuels which we use, such as petrol, diesel oil, compressed natural gas (CNG), coal and natural gas are organic compounds.

v. Uses as chemical materials

The chemicals that we use such as rubber, paper, ink, plastics, fibres, fertilizers, pesticides, insecticides, cosmetics, paints, detergents etc. are all organic compounds.

vi. Uses as life molecules

Thousands of organic molecules are taking part in our body functions. There are four ma groups of organic molecules that are carbohydrates, proteins, lipids and nucleic acids th combine to build cells and their parts. These molecules are called life molecules.

Fig.11.4 Different Organic Compounds

Activity 11.1

Uses of Organic Compounds

Objective: In this activity you will be able to recognize the uses of common organic compounds.

Materials: paper and pen, labels or pictures of the following: gasoline, Alcohol (methylated Sprit), acetone, cooking oil, kerosene, acetic acid, soap.

Procedure: Complete the table about the uses of the compounds. Using a check mark (✓) to indicate the uses of the compounds.

		Organic compounds						
		Gasoline	Alcohol (Methylated Spirit)	Soap	Acetone	Cooking oil	Kerosene	Acetic acid
Uses	Solvent							
	Food							
	Antiseptic							
	Fuel							
	cleaner							

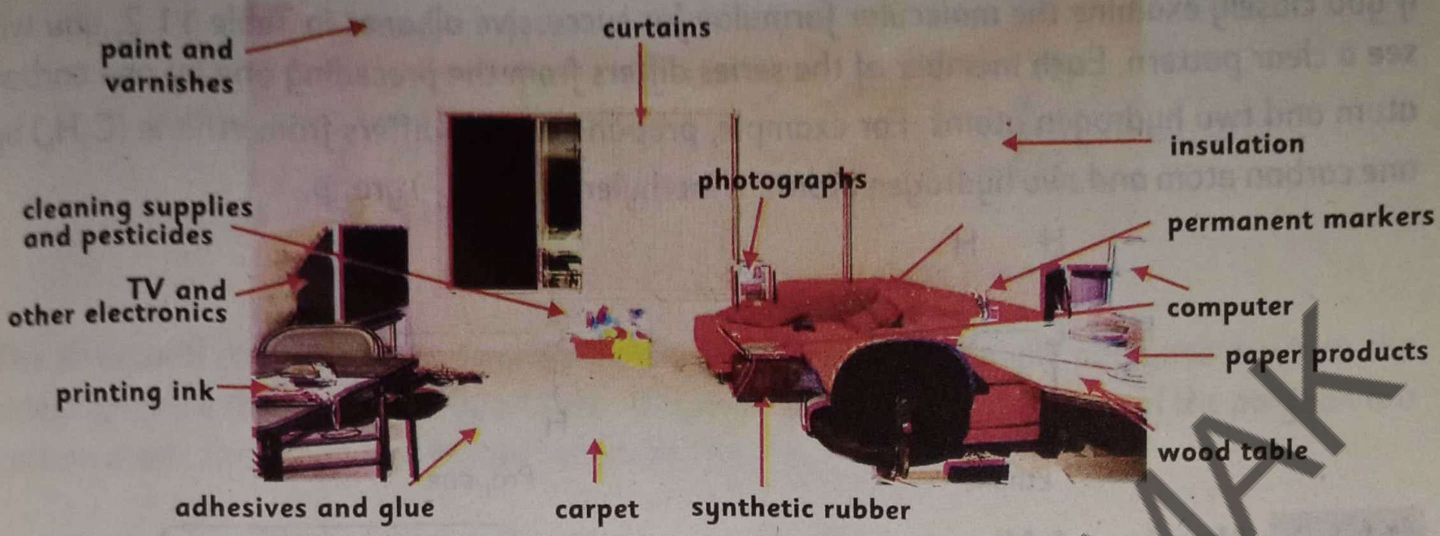


Fig. 11. 5 Some Uses of Organic Compounds in a single room

11.4 Alkanes and Alkyl Radicals

11.4.1 Alkanes

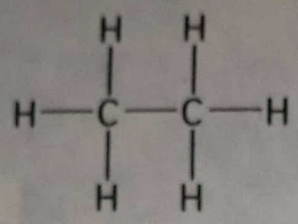
Hydrocarbons that contain only single covalent bond between carbon atoms are called alkanes. Alkanes are saturated hydrocarbons. These hydrocarbons are also called paraffins, which is a latin word meaning "little affinity". These hydrocarbons are less reactive due to their saturated nature.

This group of compounds comprises a homologus series with a general molecular formula of C_nH_{2n+2}, where 'n' stands for number of carbon atoms in the alkane.

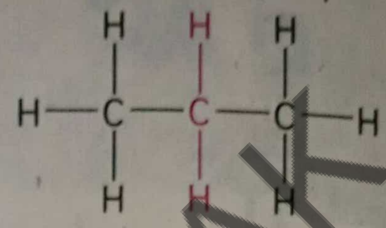
Table 11.2 First Ten Alkanes General Formulae and their names

'n' no of carbon atoms	General formula C_nH_{2n+2}	Formula	Name
1	$C_1H_{2\times1+2}$	CH_4	Methane
2	$C_2H_{2\times2+2}$	C_2H_6	Ethane
3	$C_3H_{2\times3+2}$	C_3H_8	Propane
4	$C_4H_{2\times4+2}$	C_4H_{10}	Butane
5	$C_5H_{2\times5+2}$	C_5H_{12}	Pentane
6	$C_6H_{2\times6+2}$	C_6H_{14}	Hexane
7	$C_7H_{2\times7+2}$	C_7H_{16}	Heptane
8	$C_8H_{2\times8+2}$	C_8H_{18}	Octane
9	$C_9H_{2\times9+2}$	C_9H_{20}	Nonane
10	$C_{10}H_{2\times10+2}$	$C_{10}H_{22}$	Decane

If you closely examine the molecular formulae for successive alkanes in Table 11.2, you see a clear pattern. Each member of the series differs from the preceding one by one carbon atom and two hydrogen atoms. For example, propane (C_3H_8), differs from ethane (C_2H_6) by one carbon atom and two hydrogen atoms, a methylene ($-CH_2-$) group.



Ethane



Propane

11.4.2 Naming of Alkanes

Simple straight chain alkanes can be named by the following rules.

1. Count the number of carbon atoms in a formula of an alkane.
2. The first four alkanes are named methane, ethane, propane and butane. For higher alkanes write the prefixes of Greek numerals, pent, hex, hept etc for 5, 6, 7 and so on.
3. End the name by writing – ane to the Greek numerals.

Reading Check

What are paraffins?

11.4.3 Homologous Series

A series of organic compounds that have similar structural features but differ from adjacent members by a ($-CH_2-$) group is referred as homologous series. Each member of homologous series is called homologue. A general molecular formula can be used to determine the formulae of the whole series.

Tidbit

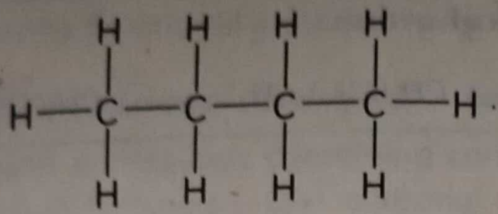
Organic compounds composed of carbon and Hydrogen are called hydrocarbons.

Characteristics of homologous series

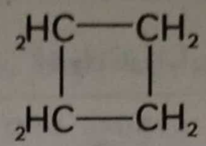
- They have a same general formula.
- They have similar chemical properties because they have the same functional group.
- Each member differs from the previous one by a methylene ($-CH_2-$) group.
- They have similar methods of preparation.

11.4.4 Cycloalkanes

Cycloalkanes are alkanes, in which the carbon atom are arranged in a ring or cyclic structure. In cycloalkanes, there are no free end carbons (no primary carbons). In the open chain alkanes, the free end carbon atoms are attached to three hydrogen atoms. Cycloalkanes have two less hydrogen atoms than in corresponding straight chain alkanes. For example cyclic butane C_4H_8 has two less hydrogen atoms than non cyclic butane C_4H_{10}.

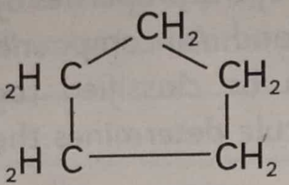


Butane



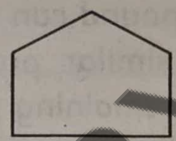
Cyclo butane

The structural formulas for cycloalkanes are often drawn in a simple polygons in which the sides represent the carbon-carbon bonds. It is understood that each corner of the polygon is a carbon atom bonded to two hydrogen atoms.



Cyclopentane

or



Cyclopentane

11.4.5 Alkyl Radicals

Alkyl radicals are groups of atoms that are formed when one hydrogen atom is removed from an alkane molecule. When one hydrogen atom is removed from any alkane, it becomes an alkyl radical. Alkyl radical is represented generally by a letter 'R'. The name of the alkyl radical is derived from the name of the corresponding alkane, in which the last **'ane'** of alkane is replaced by **'yl'**. The general formula of alkyl radical is, C_nH_{2n+1}, where 'n' stands for the number of carbon atoms in the alkyl radical.

$$\text{Alkane} \xrightarrow[+yl]{-ane} \text{Alkyl}$$

Table 11.3 Names and Molecular Formulae of Alkanes and their Respective Alkyl Radicals

Carbon atoms	Name of Alkane	C_nH_{2n+2}		Alkyl radical	Name
1	Methane	CH_4	$\xrightarrow{-H}$	CH_3—	Methyl
2	Ethane	C_2H_6	$\xrightarrow{-H}$	C_2H_5—	Ethyl
3	Propane	C_3H_8	$\xrightarrow{-H}$	C_3H_7—	Propyl
5	Butane	C_4H_{10}	$\xrightarrow{-H}$	C_4H_9—	Butyl
4	Pentane	C_5H_{12}	$\xrightarrow{-H}$	C_5H_{11}—	Pentyl

Activity 11.2 **Name the following alkyl groups**

i). $CH_3CH_2CH_2-$ ii). CH_3CH_2- iii). CH_3- iv). $CH_3(CH_2)_2CH_2-$ v). $CH_3(CH_2)_4CH_2-$

11.5 Functional Groups

A functional group is an atom or a group of atoms attached with R that is responsible for the specific properties of an organic compound. In other words, we can say that the reactive portion of the molecule, containing other element(s), is called the functional group. The bonds within functional groups are usually the site of chemical reactions. Once the functional group of an organic compound is identified then most of the properties of that compound and preparation of that compound can easily be understood. All compounds that contain same functional group have similar properties and can be classified together in the same homologous series. The remaining part of the molecule determines the physical properties such as melting point, boiling point, density etc.

Organic compounds are composed of two parts.

i. The hydrocarbon part which is alkyl group i.e. —R, and

ii. Functional group part.

For example, in methanol, CH_3OH, $—CH_3$ is the alkyl group and —OH is the functional group of alcohol.

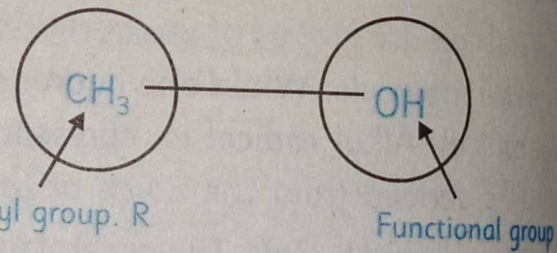


Table 11.4 Represents the organic compounds containing methyl radical attached to different functional groups.

Table 11.4 Functional Groups and Example of their Compounds

functional group	General formula	Name of the class	Example	Name of the compound
—OH	R —OH	Alcohol	$CH_3—OH$	Methanol
—CHO	R—CHO	Aldehyde	$CH_3—CHO$	Ethanal
—CO—	R—CO—R	Ketone	$CH_3—CO—CH_3$	Propanone
—COOH	R—COOH	Carboxylic acid	$CH_3—COOH$	Ethanoic acid
$—NH_2$	$R—NH_2$	Amines	$CH_3—NH_2$	Methyl amine
—X	R—X	Alkyl halides	$CH_3—Cl$	Methylchloride

Based on the functional groups the organic compounds are divided into the following groups.

11.5.1 Functional Groups Containing Carbon, Hydrogen and Oxygen

The organic compounds containing carbon, hydrogen and oxygen as functional group are alcohols (–OH), ethers (–O–), carbonyl compounds ($>C=O$) or groups (aldehydes, ketones) carboxylic acids (–COOH), and their derivatives such as esters, acid halide and acid amides.

i. Alcoholic Functional Group

The functional group of alcohol is —OH. The general formula of alcohol is 'R—OH', where letter 'R' represent the alkyl group in the organic compounds and 'OH' is the functional group of alcohols.

Reading Check

What is a functional group?

Alkyl group 'R'	Alcohol	Name
CH_3—	CH_3—OH	Methyl alcohol
C_2H_5—	C_2H_5—OH or CH_3—CH_2—OH	Ethyl alcohol

ii. Ether Functional Group

The functional group of ether is '—O—'. The general formula of ether is R—O—R, where letters 'R' represents the alkyl groups in the organic compounds and '—O—' is the functional group of ether.

General formulae	Ether	Name
R—O—R	H_3C—O—CH_3	Dimethyl ether
R—O—R	C_2H_5—O—CH_3	Ethyl methyl ether

Fig.11.6 Ether is Used as a Solvent in Paints and Liquors

Tidbit

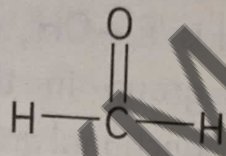
S.No	Functional Group	Identification Test
1	Aldehyde	Fehling's and Tollen's tests
2	Ketone	2,4-Dinitrophenylhydrazine
3	Carboxylic acids	litmus solution
4	Phenols	$FeCl_3$ solution
5	Amines	Dil. HCl and Sodium Nitrite

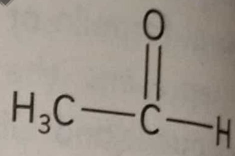
iii. Carbonyl Compounds or group ($>C=O$)

A carbonyl group is a functional group composed of a carbon atom double bonded to an oxygen atom, $C=O$. A compound containing a carbonyl group is often referred to as a carbonyl compound. The general formula of carbonyl compounds is '$\begin{smallmatrix}R\\R\end{smallmatrix}\!\!>C=O$'. These compounds are further divided into aldehydes and ketones.

> **Tidbit**
>
> There are seven homologous series of the organic compounds. These are hydrocarbons, alcohols, carboxylic acids, carbonyl compounds, alkyl halides, amines and esters.

a. Aldehyde: The functional group for these organic compounds is the carbonyl carbon. In these organic compounds the functional group is bonded with hydrogen on one side and Carbon on the other side. For example,


Formaldehyde


Acetaldehyde

b. Ketone: The functional group for these organic compounds is the carbonyl carbon. In these organic compounds the functional group is bonded with carbon atoms on both sides. For example,

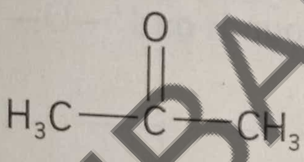
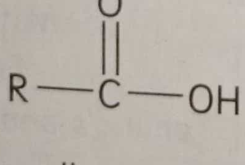

Ketone(Acetone)

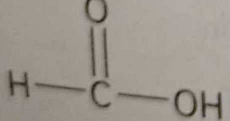

Fig.11.7 Propanone (Acetone) used in nail polish

iv. Carboxylic Acids

The functional group for these organic compounds is the carboxyl carbon (COOH). Their general formula is



where 'R' stands for alky group. For example,


Formic acid

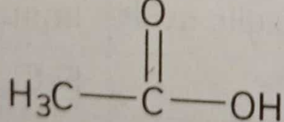

Acetic acid


Fig.10.8 Many salad dressings contain vinegar (Acetic acid)

11.5.2 Functional Groups Containing Carbon, Hydrogen and Nitrogen

Organic compounds composed of carbon, hydrogen and nitrogen as functional group are called amines. The functional group for these organic compounds is NH_2 group. The general formula is 'R—NH_2' where 'R' stands for alky group.

$$H_3C—NH_2$$

Methylamine

11.5.3 Functional Groups Containing Carbon, Hydrogen and Halogens

Organic compounds composed of carbon, hydrogen and halogens as functional group are called alkyl halides. Their functional group is halogen, represented by 'X'. Their general formula is 'R—X', where letter 'R' is an alkyl group and 'X' may be F, Cl, Br, or I. For example,

R—X	$H_3C—Cl$
Alkyl Halide	Methylchloride

11.5.4 Double and Triple Bonds

a. Double Bonds Hydrocarbons

Hydrocarbons which consist of double bonds between any two carbon atoms are called alkenes. For example,

$H_2C=CH_2$	$H_3C—CH=CH_2$	$H_3C—CH_2—CH=CH_2$
Ethene	Propene	1–Butene

b. Triple Bonds Hydrocarbons

Hydrocarbons which consist of triple bonds between any two carbon atoms are called alkynes. For example,

$HC\equiv CH$	$H_3C—C\equiv CH$	$H_3C—CH_2—C\equiv CH$
Ethyne	Propyne	1–Butyne

Activity 11.3 **What is the next homologue of each of the following compound?**

(i). C_3H_8 (ii). CH_3OH (iii). CH_3COOH (iv). CH_4 (v). C_2H_5Br (vi). $C_3H_7NH_2$

Self Assessment

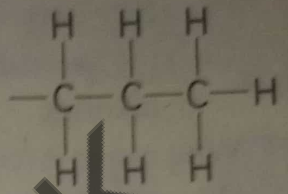
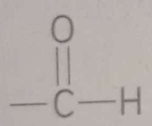
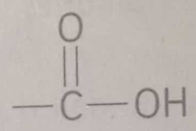
1. Explain the different sources of organic compounds.
2. What is alkyl radical? Enlist alkyl radical up to five carbon atoms.
3. Define functional groups. Also give some examples of functional groups.
4. What is homologous series?

Key Points

- According to the vital force theory plants and animals are formed due to a super natural force.
- Organic chemistry is the chemistry of Hydrocarbons and their derivatives.
- Organic compounds are those compounds that are based on carbon.
- Organic compounds that contain only hydrogen and carbon are called hydrocarbons.
- The formula which represents the actual number of atoms in one molecule of an organic compound is called the molecular formula.
- Structural formula of a compound is the arrangement of different atoms of various elements around the carbon atom present in a molecule of a compound.
- Organic compounds having the same molecular formula but different structural formulae are called isomers of each other.
- Saturated hydrocarbons are hydrocarbons in which each carbon atom in the molecule forms four single covalent bonds with other atoms.
- Unsaturated hydrocarbons are hydrocarbons in which carbon have atleast one multiple bond.
- Close chain or cyclic organic compounds are those organic compounds in which carbon atoms are linked together and form a close chain structure or ring.
- Homocyclic or carbocyclic organic compounds are those organic compounds which are in a close chain or ring structure. The ring is composed of only carbon atoms.
- The organic compounds which contain one or more atoms other than carbon such as sulphur, oxygen or nitrogen in the ring or cycle are called hetrocyclic organic compounds. Examples are Furane, Thiophene and Pyridine etc.
- Homologous series is a series of organic compounds that have similar structural features but differ from adjacent members by $(-CH_2-)$ group.
- Alkyl radicals are groups of atoms that are formed when one hydrogen atom is removed from an alkane molecule.
- A functional group is an atom or group of atoms that is responsible for the specific properties of an organic compound. In another words, we can say that the reactive portion of the molecule, containing the other element(s), is called the functional group.

Exercise

A. Choose the Correct Option.

1. The condensed structural formula of butane is,
   a. $CH_3—CH_2—CH_2—CH_3$ b. $CH_3(CH)_2CH_3$ c. C_4H_{10} d. 
2. The compounds C_6H_{12} must have
   a. All single bonds b. At least one double bond
   c. At least one triple bond d. All double bonds
3. Which of the following is an inorganic compound?
   a. CH_4 b. CH_3OH c. NaCN d. CH_3Cl
4. Alkyl halid is composed of carbon, hydrogen and
   a. Oxygen b. Nitrogen c. Halogen d. Sulphur
5. Which of the following is an alcohol?
   a. $CH_3—O—CH_3$ b. $CH_3—CH_2—OH$ c. CH_3COOH d. $CH_3—COH$
6. Unsaturated hydrocarbon is
   a. C_3H_8 b. C_2H_6 c. C_3H_6 d. CH_4
7. The functional group of ketone is
   a.  b.  c.  d. —C—O—C—
8. Natural gas is mainly composed of
   a. CH_4 b. C_2H_8 c. C_2H_6 d. C_2H_2
9. Catenation is the linkage of carbon with other
   a. Oxygen atoms b. Carbon atoms c. Nitrogen atoms d. Halogens
10. Oxygen is attached on both sides to carbon atom in
   a. Alcohol b. Ketone c. Aldehyde d. Ether

B. Short questions

1. Define the functional group. Give some example of functional groups containing oxygen.
2. How can we obtain the organic compounds from natural sources?
3. What are cycloalkanes?

4. Write down examples of three unsaturated hydrocarbons with structural and condensed formulae.
5. Define hydrocarbons, and briefly discuss their importance?
6. How alkyl radicals are formed. Discuss it with examples.
7. List some uses of organic compounds.
8. Give the general molecular formulae of the following homologus series:
   a. alkanes   b. alkenes   c. alkynes
9. Why organic compounds are volatile in nature?
10. Why are the chemical properties of a homologous series always same?

C. Long Questions

1. a. List the different characteristics of organic compounds.
   b. Which of these is not an unsaturated molecule?
   (i). C_4H_6 (ii). C_6H_6 (iii). C_8H_{18} (iv). C_3H_6
   c. Define destructive distillation of coal. Name the different types of products obtained by the destructive distillation of coal.
2. a. What is catenation?
   b. How does catenation contribute to the diversity of organic compounds?
3. a. What information about a compound is provided by a structural formula?
   b. How are structural formulae used in organic chemistry?
4. a. What do the terms saturated and unsaturated mean when applied to hydrocarbons?
   b. What other meanings do these terms have in chemistry?
   c. Classify alkenes, alkanes, alkynes and aromatic hydrocarbons as either saturated or unsaturated.
5. a. Can you explain the term homologous series?
   b. How the straight-chain hydrocarbons are named?
   c. Name the straight-chain alkane with the molecular formula C_8H_{18}.

Project

a. Make models of any five alkanes and display it in the classroom.
b. Prepare a list of organic compounds and their uses in your daily life and share with your classmates.
c. Class discussion on topic "Importance of organic compounds".