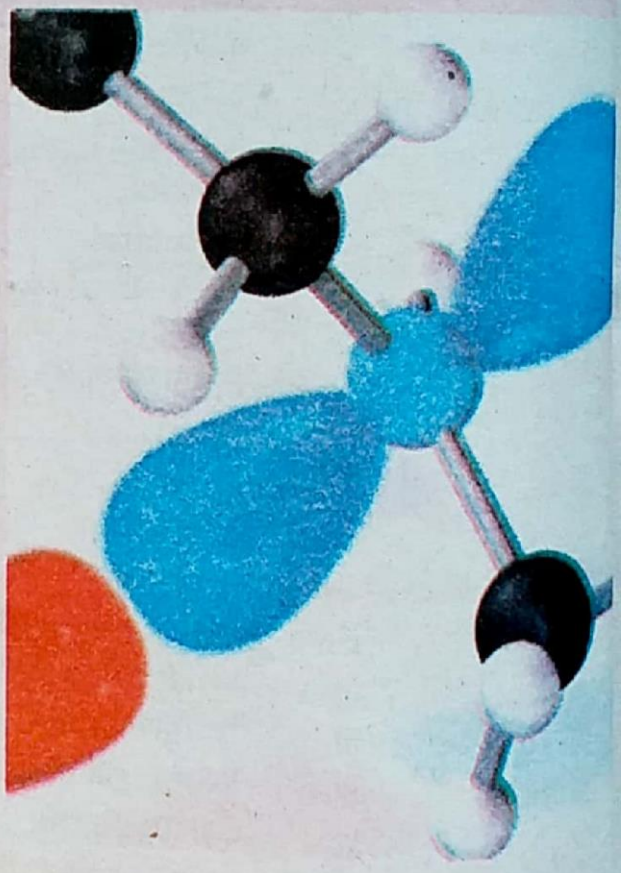
Chapter

11

Organic Chemistry



After careful study and working on the exercise of this chapter the students will be able to:

- Recognize structural, condensed and molecular formulae of the straight chain hydrocarbons up to ten carbon atoms.
- Identify some general characteristics of organic compounds.
- Explain the diversity and magnitude of organic compounds.
- List some sources of organic compound.
- List the uses of organic compounds.
- Recognize and identify a molecule's functional groups.
- Distinguish between saturated and unsaturated hydrocarbons.
- Name the alkanes upto decane.
- Convert alkanes into alkyl radicals.
- Differentiate between alkanes and alkyl radicals.
- Define functional group.
- Differentiate between different organic compounds on the basis of their functional groups.
- Classify organic compounds into straight chain, branched chain and cyclic compounds.

Introduction

Nearly two centuries ago all substances then known were classified on the basis of source from which they were derived into two main classes, inorganic and organic. The compounds derived from earth crust were named as inorganic and those obtained from vegetable and animals or in other words from living organisms as organic. For example, table salt (NaCl), marble ($CaCO_3$) and carbon dioxide (CO_2) were inorganic, whereas, urea (from urine), tartaric acid (from grapes), Citric acid (from lemons) and sucrose (from cane sugar) were organic.

Since Organic compounds have common features and exist in large number, they are studied in separate branch of chemistry called organic chemistry. *"The branch of chemistry which deals with the study of organic compounds is called organic chemistry"*.

11.1 Organic Compounds

It has become evident that all organic compounds whether natural or synthetic, essentially contain carbon and hydrogen and occasionally a few other elements such as oxygen, nitrogen, sulphur, phosphorus and halogens.

Organic compounds can now be defined as the compounds of carbon except the oxides of carbon, carbonates, bicarbonates and some metal carbides. Further, organic compounds made up of only carbon and hydrogen are called hydrocarbons. All other organic compounds may be regarded to have been derived from them. Therefore, organic chemistry may be defined as *the chemistry of hydrocarbons and their derivatives*.

Characteristics of Organic Compounds

Organic compounds have many common characteristics which are entirely different from inorganic compounds. Some of their general characteristics are described below.

1. **Composition**:
Carbon is the essential constituent of all organic compounds.

2. **Low melting and boiling points**:
Organic compounds have generally low melting and boiling points and are volatile in nature.

3. **Thermal Instability**:
Many organic compounds are thermally unstable. Since organic compounds have low melting and boiling points, they generally decompose at high temperature into simple substances.

4. **Inflammability**:
Most of the organic compounds are inflammable and burn in air to give carbon dioxide water and heat energy. Thus most fuels such as natural gas, petrol and coal are organic and their combustion or burning is our main source of heat energy.

5. **Bonding**:
Organic compounds are generally covalent in nature.

6. **Solubility**:
Most of the organic compounds are non-polar in nature so they are soluble in non-polar solvents such as acetone, ether and benzene etc. They are less or insoluble in water, which is polar.

7. **Electrical conductivity**:
Because of non-polar covalent bonds present in most of the organic compounds, they are poor conductor of electricity both in fused state and in solution form.

8. **Reactivity**:
Reactions involving organic compounds are much slower than the reactions which involve inorganic substances.

Society, Technology and Science

It was assumed that the organic compounds could only be produced by living organisms under the influence of a super natural force called *Vital Force*. In 1828, Friedrich Wohler, a German chemist, synthesized the organic substance urea in the laboratory from inorganic substance ammonium cyanate. Ammonium cyanate is obtained by heating solid ammonium chloride with solid potassium cyanate.

$$NH_4Cl_{(s)} + KCNO_{(s)} \xrightarrow{\text{heat}} NH_4CNO_{(s)} + KCl_{(s)}$$

$$\underset{\text{Ammonium Cyanate}}{NH_4CNO_{(s)}} \xrightarrow{\text{heat}} \underset{\text{Urea}}{NH_2CONH_{2\,(s)}}$$

The synthesis of urea proved that the formation of organic compound is no more dependent on the vital force and that the influence of living organism was not necessary for the production of the organic compounds.

11.2 Sources of Organic Compounds

All organic compounds, long before, were obtained from plants and animals. Many of the organic compounds are still derived directly or indirectly from these sources. Coal, petroleum and natural gas are the major sources of a large variety of organic compounds. They are called fossil fuels and are formed over a long period of time, from the decay of plants and animals.

Coal

Coal is a major source of organic compounds. It is used as a solid fuel. It yields coke and coal tar on heating at a high temperature in the absence of air. More than two hundred important organic compounds have been isolated from coal tar.

Petroleum

It is an important source of organic compounds. It is generally dark brown coloured and unpleasant smelling liquid containing a mixture of hydrocarbons. Majority of these are open chain and cyclic alkanes. After refining, it is used as a fuel. It is also used for the production of useful products such as synthetic rubber, explosives and plastics etc.

Natural gas

Natural gas is a mixture of the gaseous hydrocarbons. It consists of 85% methane and 15% ethane, propane butane. It is used as a fuel for domestic as well as for industrial purposes. It is also used for the production of many organic compounds. It is a chief source of power generation in Pakistan.

Plants

Plants are the main source of organic compounds. Most of the organic compounds are obtained directly from plants e.g Sugar, while some other are obtained indirectly from their decay and death, e.g Coal.

Synthesis in Laboratory

The synthesis of organic compound in Laboratory started a new era of organic compound. The synthesis of NH_4CNO (Ammonium Cyanate), caused the end of vital force theory.

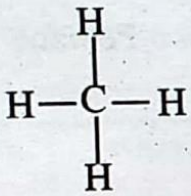
11.3 Uses of organic compounds

Organic compounds are very important. 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 are all organic compounds. Similarly the petroleum we use in our vehicle, the ink and paper that we use for writing and the drugs and medicines that we use are also organic compounds.

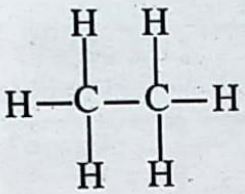
11.4 Alkanes and Alkyl Radicals

11.4.1 Alkanes:

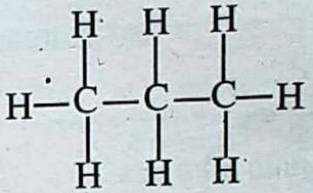
Alkanes are saturated hydrocarbons in which all carbon-carbon bonds are single covalent bonds. They have the general formula C_nH_{2n+2}, where n represents the number of carbon atoms. The first three members of this class can be represented as CH_4, C_2H_6 and C_3H_8. Their structural formulae are given below.



Methane



Ethane



Propane

11.4.1.1 Classification of Alkanes

On the basis of the structure of chain, alkanes are classified into two types.

1) Open chain alkanes
2) Cyclic alkanes

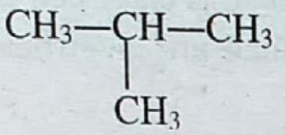
1) **Open chain alkanes:**
Compounds which consist of open chain of carbon atoms are called aliphatic compounds. They are further classified into

i) *Straight chain alkanes*: These alkanes contain straight chain of carbon atoms in their molecules. A carbon atom in straight chain alkanes is not linked to more than two other carbon atoms. They are commonly named as n-alkanes. For example n-Butane and n-pentane are given below.

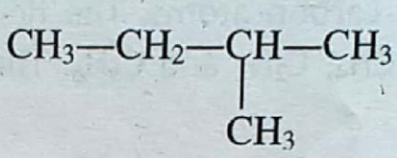
$CH_3—CH_2—CH_2—CH_3$
n-Butane

$CH_3—CH_2—CH_2—CH_2—CH_3$
n-Pentane

ii) *Branched chain alkanes*: 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 to more than two other carbon atoms in their molecules. Their common names have a prefix iso- with the corresponding alkanes. For example iso-Butane and iso-pentane are given below.



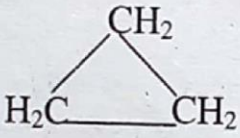
iso-Butane



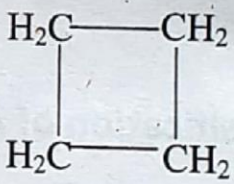
iso-Pentane

2) Cyclic alkanes:

When carbon atoms are linked in cyclic form they are called cyclic compounds. Examples are as follows.



Cyclopropane



Cyclobutane

11.4.1.2 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.

The names of first ten alkanes are as follows; Methane, (CH_4), Ethane, (C_2H_6), Propane, (C_3H_8), Butane, (C_4H_{10}), Pentane, (C_5H_{12}), Hexane (C_6H_{14}), Heptane (C_7H_{16}), Octane (C_8H_{18}), Nonane (C_9H_{20}), Decane ($C_{10}H_{22}$).

11.4.2 Alkyl Radicals

The radicals or groups derived from alkanes by removal of one H-atom are called alkyl radicals or alkyl groups. They are denoted by a general symbol –R. Hence, the formula of alkyl group is C_nH_{2n+1}, where n is the number of carbon atoms = 1,2,3....The name of an alkyl group is derived from the name of corresponding alkane by replacing the –ane by –yl

Table 11.1 shows first ten members of alkanes and their corresponding alkyl radicals.

Table 11.1

C-atoms	Name of Alkane	Formula C_nH_{2n+2}	Name of Alkyl Radicals	Formula C_nH_{2n+1}
1	Methane	CH_4	Methyl	$-CH_3$
2	Ethane	C_2H_6	Ethyl	$-C_2H_5$
3	Propane	C_3H_8	Propyl	$-C_3H_7$
4	Butane	C_4H_{10}	Butyl	$-C_4H_9$
5	Pentane	C_5H_{12}	Pentyl	$-C_5H_{11}$
6	Hexane	C_6H_{14}	Hexyl	$-C_6H_{13}$
7	Heptane	C_7H_{16}	Heptyl	$-C_7H_{15}$
8	Octane	C_8H_{18}	Octyl	$-C_8H_{17}$
9	Nonane	C_9H_{20}	Nonyl	$-C_9H_{19}$
10	Decane	$C_{10}H_{22}$	Decyl	$-C_{10}H_{21}$

Activity 11.1: Name the following alkyl groups.

Activity 1

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

An atom or group of atoms which replaces the hydrogen atom in alkane and gives the molecule its characteristic chemical properties is called functional group. The most common functional groups are –OH, –CHO, –COOH, $-NH_2$ and –X (halogens) etc. Organic compounds are composed of two parts

(i) The hydrocarbon part which is alkyl group i.e. –R.(ii) Functional group part For example in methanol, CH_3OH, $-CH_3$ is R and –OH is the functional group.

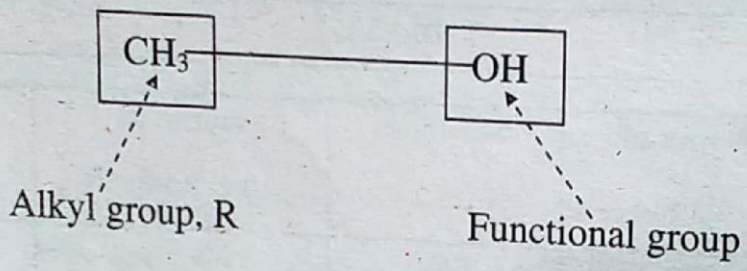


Table 11.2 represents the organic compounds containing methyl radical attached to different functional groups.

Table 11.2

Functional Group	Name of the class	Example	Name of the Compound
–OH	Alcohols	CH_3–OH	Methanol
–CHO	Aldehydes	CH_3–CHO	Ethanal
–CO–	Ketones	CH_3–CO–CH_3	Propanone
–COOH	Carboxylic acids	CH_3–COOH	Ethanoic acid
$-NH_2$	Amines	CH_3–NH_2	Methyl amine
–X	Alkyl halides	CH_3–Cl	Methyl chloride

11.5.1

Functional groups containing carbon, hydrogen and oxygen. Alcohols, Aldehydes, Ketones and Carboxylic acids are its examples.

11.5.2

Functional groups containing carbon, hydrogen and nitrogen. Amines come in this category, e.g., Methyl amine, $CH_3–NH_2$.

11.5.3

Functional groups containing carbon, hydrogen and halogen. Alkyl halides are the examples , e.g. $CH_3 – Cl$ (methyl chloride)

Activity 2

Name the class of the compounds to which each of the following belongs.

i) $CH_3CH_2CH_3$ ii) CH_3CH_2Br iii) CH_3COOH

iv) C_2H_5CHO v) CH_3CH_2OH

11.6 Homologous Series

There are millions of organic compounds and several thousand new compounds are synthesized each year. In order to study such a large number of organic compounds they are classified into various groups or series. The classification is based on the fact that all the members in a particular series possess the same functional group and have the same chemical properties. There are seven homologous series of the organic compounds. They are hydrocarbons, alcohols, carboxylic acids, carbonyl compounds, alkyl halides, amines and ethers. Table 11.1 shows a homologous series of alkanes which is the simplest of organic compounds. It is clear from table-11.1 that each member differs from its adjacent member by one CH_2 (Methylene) group. A homologous series may be defined as *a series of compounds in which adjacent members differ by a CH_2 unit.* The individual member is called *homologue.*

Activity 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) $C_3H_7NH_2$

KEY POINTS

- The branch of chemistry which deals with the study of hydrocarbons and their derivatives is called organic chemistry.
- The compounds which contain carbon and hydrogen as essential elements and occasionally a few other elements such as oxygen, nitrogen, sulphur, phosphorus and the halogens are called organic compounds.
- Hydrocarbons are the simplest organic compounds which contain carbon and hydrogen only, for example, methane (CH_4), ethane (C_2H_6) etc.
- A hydrocarbon is said to be saturated if it contains only single covalent bonds.
- Alkanes are saturated hydrocarbons for example, methane (CH_4), ethane (C_2H_6) etc. Their general formula is C_nH_{2n+2}.
- Alkyl Radicals are groups derived from alkanes by removing one H-atom. Their general formula is C_nH_{2n+1}.
- Functional Group is an atom or group of atoms which replaces the hydrogen atom in alkanes and gives its characteristic properties to the molecule. For example, when a hydrogen atom from methane (CH_4) is replaced by –OH, methyl alcohol (CH_3OH) is formed, which has its own characteristic properties. So –OH is a functional group which gives characteristic properties to the molecule.
- Homologous Series is a set of organic compounds containing the same elements with the same general formula and have the same chemical properties.
- Each member of the homologous series is termed as homologue.

EXERCISE

Q.1 Choose the correct answer.

i. Which of the following is organic compound.

A) CO B) CO_2

C) $NaHCO_3$ D) C_2H_2

ii. Which one of the following is the general formula of alkanes.

A) C_nH_{2n+2} B) C_nH_{2n+1}

C) C_nH_{2n-1} D) C_nH_{2n-2}

iii. The homologues have the same:

A) State B) Colour

C) Density D) Chemical properties

iv. Carbon atom usually:

A) Forms four covalent bonds B) Gains four electrons

C) Loses four electrons D) Ionizes

v. Organic radical with general formula C_nH_{2n+1} is:

A) Phenyl B) Benzyl

C) Alkyl D) Allyl

vi. The next homologue of C_8H_{18} is:

A) C_8H_{16} B) C_9H_{20}

C) C_9H_{18} D) C_7H_{14}

vii. Methane is the first member of:

A) Alkane series B) Alkene series

C) Alcohol series D) Carboxylic acids series

viii. The compound C_3H_8 must have :

A) All single bonds B) At least one double bond

C) At least one triple bond D) An ionic bond

ix. Organic compounds are originated from.

A) Air B) Rock

C) Sun D) Living organisms

x. The name of C_6H_{14} is:

A) Propane B) Heptane

C) Hexane D) Decane

xi. Which one of the following organic compounds has different chemical properties:

A) CH_3OH B) C_2H_5COOH

C) C_2H_5OH D) $C_5H_{11}OH$

xii. Which of the following is inorganic:

A) CH_4 B) CH_3OH

C) NaCN D) CH_3Cl

Q. 2 Write answers for the given questions.

i. Why organic compounds are volatile in nature?

ii. Organic compounds are insoluble in water but soluble in organic solvents?

iii. Functional group is a group of atoms but not a molecule explain.

iv. Organic substances can be made from inorganic substances.

v. Why the vital force theory was discarded?

vi. Why are hydrocarbons combustible?

vii. The chemical properties of a homologous series are always the same?

Q.3 Write long answers of the given questions.

i What is a homologous series? Give the names of alkane homologous series up to ten C-atoms.

ii. What are alkyl groups? Name and derive the alkyl groups from the first five members of alkane series.

iii. Give characteristic properties of organic compounds. Why organic compounds are placed in a separate branch of chemistry?

iv. What is organic chemistry? Briefly discuss how organic and inorganic compound differ.