Chapter 3

Organic Chemistry

Time Allocation

Teaching periods = 15
Assessment period = 03
Weightage = 15%

MAJOR CONCEPTS:

3.1 Organic Compounds
3.2 Sources of Organic Compounds
3.4 Uses of Organic Compounds
3.5 Alkanes and Alkyl Radicals
3.6 Nomenclature of simple Alakne, Alkenes and Alkynes
3.7 Introduction to Functional Groups

STUDENTS LEARNING OUT COMES (SLO'S)

- Recognize structural, condensed, and molecular formulas of the straight chain hydrocarbons up to ten carbon atoms. (Remembering)
- Identify some general characteristics of organic compounds. (Remembering)
- Explain the diversity and magnitude of organic compounds. (Understanding)
- List some sources of organic compounds (Remembering)
- List the uses of organic compounds (remembering)
- Recognize and identify a molecule's functional groups.(Remembering)
- Distinguish between saturated and unsaturated hydrocarbons. (Understanding)
- Name the alkanes up to decane, alkenes up to decene and alkynes up to decyne (Remembering)
- Modify alkanes into alkyl radicals. (Applying)
- Differentiate between alkanes and alkyl radicals. (Analyzing)
- Define functional group. (Remembering)
- Differentiate between different organic compounds on the basis of their functional groups. (Analyzing)
- Classify organic compounds into straight chain, branched chain and cyclic compounds. (Understanding)

Introduction

Mostly the products we use in our daily life such as computer, furniture, vehicles, food, cooking oil, soap, detergents, vinegar are made up of different organic compounds. Before 1828 it was believed that chemical compounds could be made only in the presence of vital force and that vital force theory was introduced by Berzelius in 1815. It states that "organic compounds can only be formed in the tissues of living organisms (plants and animals) and cannot be synthesized from inorganic substances in the laboratory".

In 1828 the German chemist Friedrich Wohler converted an inorganic compound ammonium cyanate into urea. Urea is an organic compound excreted in the urine of mammals. Wohler prepared urea in the absence of vital force.

$$\underset{\text{Ammonium cyanate}}{NH_4OCN} \xrightarrow{\text{heat}} \underset{\text{Urea}}{NH_2-\overset{\overset{\large O}{\|}}{C}-NH_2}$$

This was the first synthesis of an organic compound in the laboratory. This reaction gave a big blow to the vital force theory and propose a proper definition of organic chemistry that "Organic chemistry is branch of chemistry which deals with the study of compounds of carbon and hydrogen (hydrocarbons) and their derivatives".As all organic compound contain carbon as an essential element.

3.1 Organic Compound:

Organic compounds are those that include one or more carbon atoms that are covalently linked to atoms of other elements, such as hydrogen, oxygen, nitrogen etc.

For example: Ethane, Alcohol, Amine, Polystyrene, Chloroform.

General Characteristics of organic compounds

Some general characteristics of organic compounds are given below:

(i) Source

Organic compounds are obtained from living things (animals and plants) and minerals.

(ii) Composition

Carbon is the key element in all organic compounds. After carbon, most frequently used element is hydrogen. Organic compounds may also contain halogens, oxygen, sulphur, nitrogen and phosphorus elements. Organic compounds contain both types of covalent bonds-polar and non polar bonds.

(iii) **Solubility**

According to like dissolve like rule, organic compounds are insoluble in water but soluble in organic solvents. Non-polar organic compounds are soluble in benzene, carbon disulphide, ether etc and polar compounds are soluble in alcohols.

(iv) **Melting and boiling points**

As covalent bond is weaker than ionic bond, so organic compounds have lower melting and boiling points.

(v) **Rate of Reactivity**

The rate of reactivity of organic compound is very slow and need specific conditions.

(vi) **Electrical Conductivity**

Generally, organic compounds are non-conductors of electricity because they consist of covalent molecules.

(vii) **Combustion**

All organic compounds are more combustible and burn in air due to high percentage of carbon. The common product produced in all cases is carbon dioxide.

(viii) **Stability**

Organic compounds are less stable on a high temperature as compare to inorganic compounds.

Representation of organic compound

Though carbon oxides such as carbon monoxide and carbon dioxide, as well as carbonates, bicarbonates, and carbides, are carbon compounds, they are not classified as organic molecules since their characteristics are fundamentally different. The formula for each chemical compound is unique.Organic compounds have four different sorts of formulae:

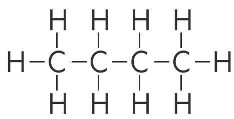
- Molecular formula
- Structural formula
- Condensed formula
- Dot and cross formula

Molecular Formula

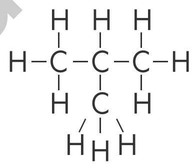
The molecular formula is the formula that indicates the exact number of atoms in one molecule of an organic compound; for example, the molecular formula of butane is C_4H_{10}. It demonstrates that butane is composed of carbon and hydrogen atoms. Butane has four carbon atoms and ten hydrogen atoms in each molecule.

Structural Formula

The exact arrangement of the individual atoms of various elements contained in a molecule of a substance is represented by the structural formula of a compound. Between the bonded atoms, a single bond is represented by a single line (-), a double bond by two lines (=), and a triple bond by three lines (≡). Organic compounds can have the same molecular formula but various structural formulas, such as butane C4H10, which has two the structural formulae:



n– Butane



isobutane

Condensed Formula

Condensed formula is the formula in which bond line to each carbon are omitted and each distinct structural unit is written with subscript numbers for multiple substituents including hydrogen.

$CH_3\,CH_2\,CH_2\,CH_3$

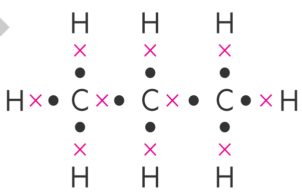
n– Butane

$CH_3\,CH(CH_3)\,CH_3$

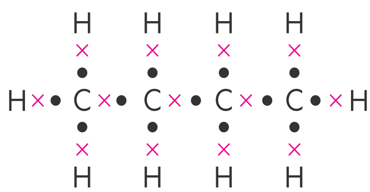
isobutane

Dot and Cross Formula (electronic)

The dot and cross formula, also known as the electronic formula, depicts the sharing of electrons between distinct atoms in a single molecule of an organic compound.

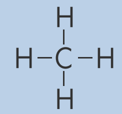
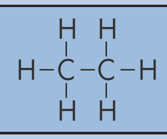
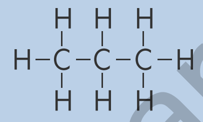
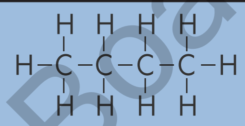
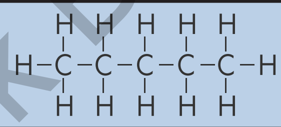
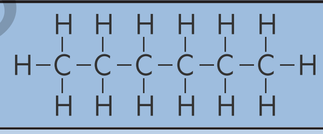
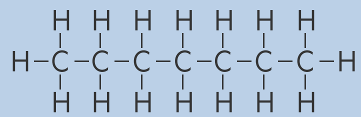
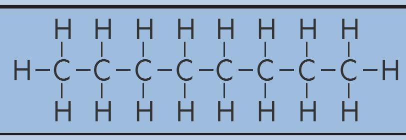
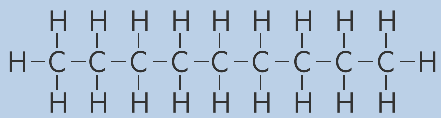
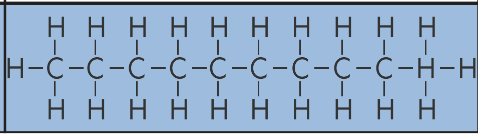


Propane



Butane

Table 3.1
Compound, Molecular, Structural and Condensed Formulae of first ten hydrocarbons

Compound	Molecular Formula	Structural Formula	Condensed form
Methane	CH_4		CH_4
Ethane	C_2H_6		H_3CCH_3
Propane	C_3H_8		$H_3CCH_2CH_3$
Butane	C_4H_{10}		$H_3C(CH_2)CH_3$
Pentane	C_5H_{12}		$H_3C(CH_2)_3CH_3$
Hexane	C_6H_{14}		$H_3C(CH_2)_4CH_3$
Heptane	C_7H_{16}		$H_3C(CH_2)_5CH_3$
Octane	C_8H_{18}		$H_3C(CH_2)_6CH_3$
Nonane	C_9H_{20}		$H_3C(CH_2)_7CH_3$
Decane	$C_{10}H_{22}$		$H_3C(CH_2)_8CH_3$

Classification of Organic compounds

Organic Compound

- **Open chain compounds**: The compound which contain atoms linked in open chain. *n*-pentane, isopentane
  - **Straight chain compounds**: The open chain compounds with substituents linked in the straight chain for example n-butane
  - **Branched chain compounds**: The open chain compound containbranches for example Isobutane
- **Cyclic compounds**: The organic compound having a basic non linear structure for example benzene and phenol cyclobutane
  - **Hetrocyclic compounds**: Organic compounds with a carbon ring structure that contains at least one other electronegative element, for example N, O, or S.
  - **Homocyclic compounds**: Cyclic compounds having atoms of the same elements in ring for example benzene, cyclobutane
    - **Alicyclic compounds**: The compounds which have no benzene ring for example cyclobutane
    - **Aromatic compounds**: The compounds which have benzene ring with six carbon atoms for example benzene naphthalene

Diversity and magnitude of organic compound

There are total of 118 elements that are currently known. More than 10 million organic compound (carbon compounds) exist. This amount is significantly more than the total number of compounds formed by the other elements. The following factors contribute to the existence of such a great number of organic compounds:

1. Catenation:

The ability of carbon atoms to join with another via covalent bonds to create long chains or rings of carbon atoms is the primary cause for the formation of a vast number of organic compounds. Straight or branched chains are possible. Catenation is the capacity of atoms to build long chains and huge rings by linking with other similar atoms.

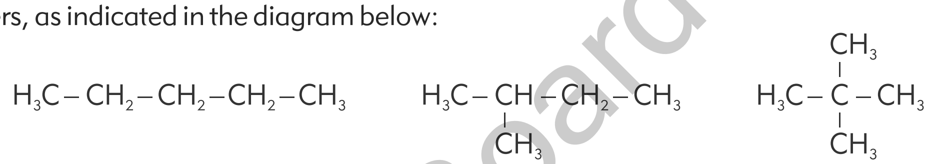
There are two main criteria for an element to show catenation:

1. The element should have a valency of two or more.

2. An element's bonds with its own atoms should be stronger than the element's bonds with other atoms, particularly oxygen.
Although both silicon and carbon have comparable electrical structures, carbon exhibits more catenation whereas silicon exhibits very less. The reason for this is that C-C bonds are substantially stronger (355 kJ mol^{-1}) than Si-Si bonds (200 kJ mol^{-1}). Si-O bonds, on the other hand, are more stronger (452 kJ mol^{-1}) than C-O bonds (351 kJ mol^{-1}). As a result, silicon is found in nature as silica and silicates.

2. Isomerism:

The phenomena of isomerism is another cause for the abundance of organic molecules. If two compounds have the same molecular formula but distinct atom arrangements in their molecules or different structural formulas, they are said to be isomers. Isomerism increases the number of structures that may be expressed; for example, the chemical formula of pentane (C_5H_{12}) can be represented by three distinct structures. As a result, C_5H_{12} has three isomers, as indicated in the diagram below:



n-pentane　　　iso-pentane　　　neopentane

The number of isomers increase as the number of carbon atoms in a chemical formula increases.

3. Carbon's covalent bond strength:

Because of its tiny size, carbon can make extremely strong covalent bonds with other carbon atoms, hydrogen, oxygen, nitrogen, and halogens. This allows it to make a vast number of different compounds.

4. Multiple bonding:

Carbon may form multiple bonds in order to meet its tetravalency (i.e., double and triple bonds). This increases the number of structures that can be built. A single covalent bond connects two carbons in ethane, a double covalent bond connects two carbons in ethylene, and a triple covalent bond connects two carbons in acetylene.

Test Yourself

1. Why number of compounds of Si are lesser than that of carbon compounds.
2. What is Rate of Reactivity of organic compound?

3.2 Source of organic compounds

There are two main sources of organic compounds namely living things and minerals. These sources are described as under.

- Sources of Organic Compounds
  - Living Things
    - Animals
      - Proteins → Eggs, Mutton, Chicken, Beef, Fish
      - Fats/Oils → Milk, Butter, Cheese
    - Plants
      - Carbohydrates → Wheat, Maize, Potatoes, Rice, Barley
      - Proteins → Pulses, Beans
      - Vitamins → Apple, Orange, Banana
      - Oils → Sunflower, Palm Oil, Olive oil, Soyabean, Peanut oil
  - Minerals → Coal, Petroleum, Gas

3.2.1 Coal:

Coal is made up of a variety of hydrocarbons. It is an important source of solid fossil fuels for us. It can be found at various depths beneath the Earth's surface. Coal is formed in a variety of ways.Coal is said to have developed in nature 500 million years ago from the remnants of trees buried deep inside the soil. It was turned to peat as a result of bacterial and chemical processes on the wood. Peat was then converted into coal as a result of high temperature and pressure within the Earth's crust. Natural carbonization is the process of converting wood into coal. Wood has a carbon content of 40%.Four varieties of coal are created depending on the degree of carbonization.

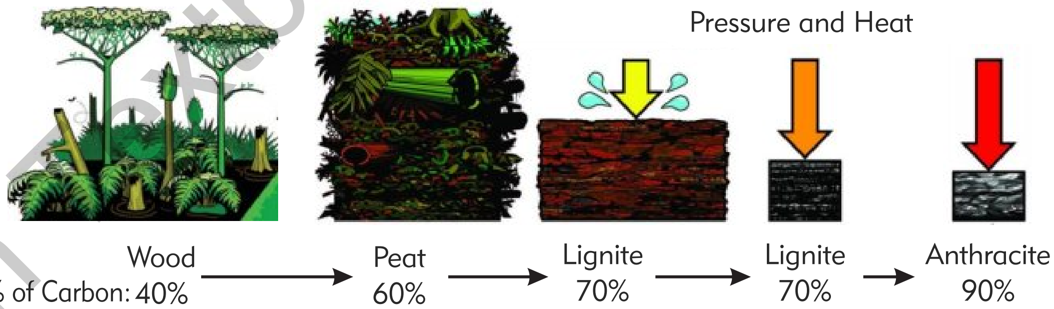


Figure 3.1 Formation of coal

China, the United States of America, Russia, the United Kingdom, Germany, Poland, Australia, and Pakistan are the world's top coal producers. In Sindh's Tharparkar area, Pakistan contains one of the world's biggest lignite deposits, estimated at more than 185 billion tonnes. Dighari-sor-Range, Kost-shahrig-Harnai (Balochistan), and Salt Range are the other active coal mines (Punjab).

3.2.2 Petroleum:

Petroleum is a thick dark brownish or greenish black liquid. It's a complicated combination of solid, liquid, and gaseous hydrocarbons, together with water, salts and earth particles.

Organic compounds are mostly derived from petroleum. It is made up of a variety of substances, the majority of which are hydrocarbons. Fractional distillation is used to separate these chemicals (separation of fractions or components from a liquid mixture depending upon their boiling point ranges is called fractional distillation). Each fraction contain single chemical compound, rather than multiple component.

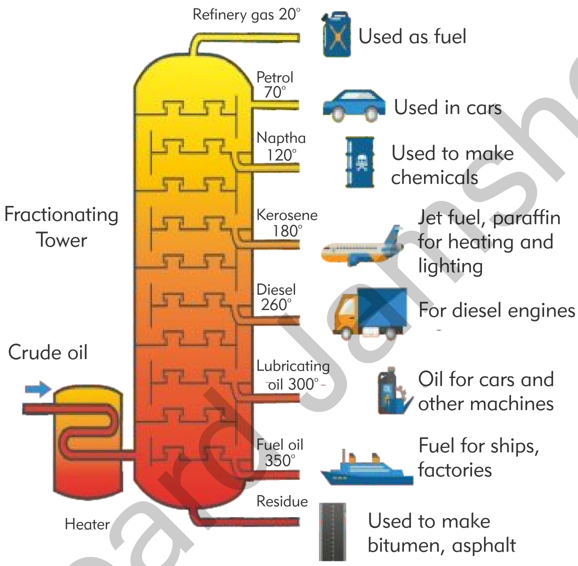


Figure 3.2 Fractional distillation

3.2.3 Natural Gas:

It's a mixture of hydrocarbons with low molecular weight. Methane, together with other gases such as ethane, propane, and butane, makes up around 85% of the mixture. It has a similar origin to coal and petroleum. As a result, it is discovered with their deposits. Natural gas is utilized as a fuel in both households and industries. Compressed natural gas (CNG) is utilized as a fuel in cars. Carbon black and fertilizers are also made from natural gas.

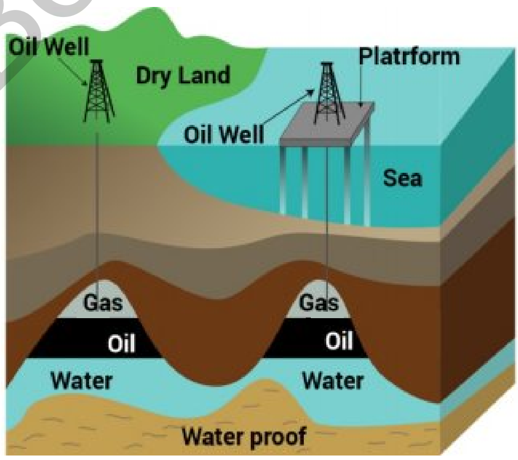


Figure 3.3 Drilling for Natural Gas

3.2.4 Plants:

Macromolecules, such as carbohydrates, proteins, lipids, and vitamins, are synthesized by living plants. Glucose is the fundamental unit of all carbohydrates, and it is produced by plants through photosynthesis. Starch, and cellulose are formed as glucose polymerizes further. Pulses and beans are high in protein. Proteins are made by nitrogen fixing bacteria that live on the roots of plants. Seeds from plants including sunflower, rapeseed, palm, coconut, and groundnut contain oils. Apples and citrus fruits are high in vitamins. Plants provide us with gums, rubber, medications, and other products in addition to these primary food staples.

3.2.5 Synthesis in Laboratory:

Only plants and animals, it was thought just over two centuries ago, could synthesize organic compounds because they possessed 'Vital Force,' which is required for organic compound synthesis. However, F.M. Wohler's laboratory synthesis of urea (NH_2CONH_2) in 1828 established the area of laboratory synthesis of organic molecules. More than 10 million organic molecules have been synthesized in laboratories till today. They range in complexity from simple to complicated.Drugs and medications, flavorings and scents, plastics and paints, synthetic fibers and rubber, cosmetics and toiletries, detergents, insecticides and pesticides, and other products include them.

Test Yourself

1. Name the Alkanes up to Decane?
2. Which type of bonding unsaturated Hydrocarbon possess?

3.3 Uses of organic compounds

Thousands of organic compounds are undoubtedly synthesized spontaneously by animals and plants, but scientists prepare millions of organic compounds in labs. These compounds are found in a wide range of products, from the food we consume to the many goods we use in our everyday lives to meet our requirements.

- Uses as Food: The foods we eat on a daily basis, such as milk, eggs, meat, vegetables, and so on, are all organic and contain carbohydrates, proteins, lipids, vitamins, and so on.
- Uses as Clothing: Natural (cotton, silk, wool, etc.) and synthetic (polyester, nylon, etc.) fibres are used in all forms of clothing (we wear, we use as bed sheets, etc). (nylon , dacron and acrylic, etc.) All of these substances are made up of organic components.
- Uses as a House: Wood is made mostly of cellulose (naturally synthesized organic compound). It's used to build anything from buildings to furnishings.
- Uses as Fuel: Coal, petroleum, and natural gas are the fuels we use in our cars and in our homes. These are referred to as fossil fuels. These are all organic compounds.
- Medical Applications: We employ a significant variety of organic compounds (naturally generated by plants) as medications. Antibiotics (which suppress or kill bacteria that cause infectious illnesses) and other life-saving medications and treatments are manufactured in laboratories.
- As a Raw Material: Organic compounds are used to make a wide range of products, including rubber, paper, ink, pharmaceuticals, dyes, paints, varnishes, insecticides, and more.

3.4 Alkanes and Alkyl Radicals

Saturated hydrocarbons or paraffins are alkanes (para means little, affin means affinity). C_nH_{2n+2} is their general formula, where 'n' is the number of carbon atoms. When it comes to alkanes, 'n' can range from 1 to 40. Alkanes are the most significant homologous sequence of compounds in this fashion.

Homologous Series

Organic substances are classified into classes based on their chemical characteristics. A homologous series is the name given to each group. Organic molecules belonging to the same homologous series have the following characteristics:

1. A general formula can be used to describe all members of a series. For example, the general formulas for alkanes, alkenes, and alkynes are C_nH_{2n+2} ,C_nH_{2n}, and C_nH_{2n-2}, respectively.
2. The relative molecular masses of successive members of the sequence differ by one unit of $^-CH_{2-}$ and 14 a.m.u.
3. They have chemical properties that are comparable (because they contain the same functional group).
4. Their physical properties evolve in a predictable pattern; melting and boiling points rise in lockstep with increasing molecule masses.
5. They can be prepared in a similar manner.

Hydrocarbons are organic substances that are considered to be the parents of other organic compounds. All other compounds are thought to be made by replacing one or more hydrogen atoms in a hydrocarbon with one or more reactive atoms or groups of atoms.

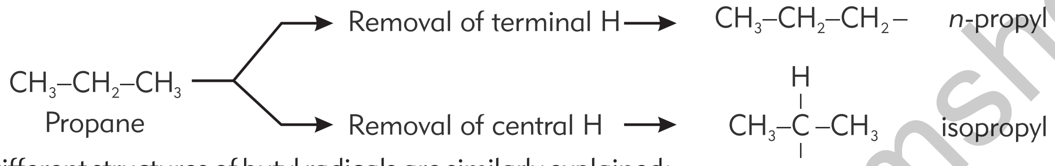
Formation of Alkyl Radical

Alkyl radicals are alkane derivatives. They are created by removing one of an alkane's hydrogen atoms and are symbolized by the letter 'R.' Their name is formed by substituting the letter "ane" in alkane with the letter "yl." The first 10 alkanes and their alkyl radicals are shown in Table. C_nH_{2n+1} is their general formula.

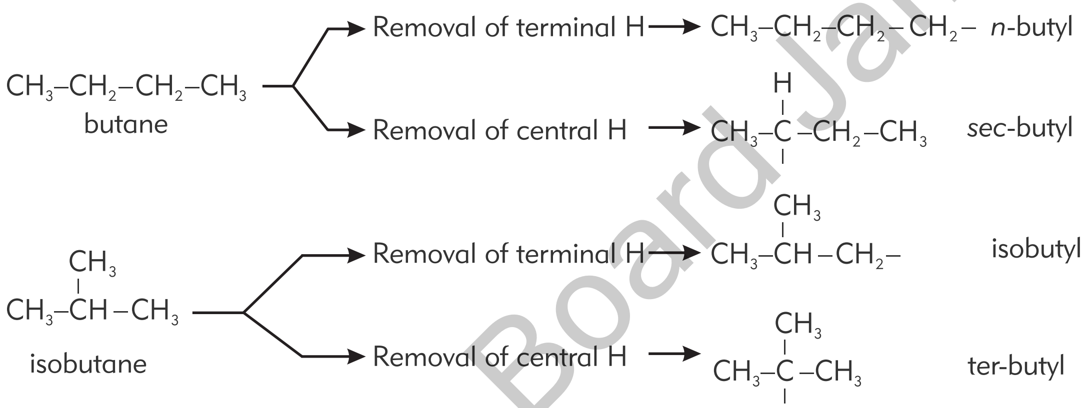
Table 3.2 Formation of Alkyl radical

Alkane	Molecular Formula	Alkyl radical	Name
Methane	CH_4	CH_3-	Methyl
Ethane	C_2H_6	C_2H_5-	Ethyl
Propane	C_3H_8	C_3H_7-	Propyl
Butane	C_4H_{10}	C_4H_9-	Butyl
Pentane	C_5H_{12}	$C_5H_{11}-$	Pentyl
Hexane	C_6H_{14}	$C_6H_{13}-$	Hexyl
Heptane	C_7H_{16}	$C_7H_{15}-$	Heptyl
Octane	C_8H_{18}	$C_8H_{17}-$	Octyl
Nonane	C_9H_{20}	$C_9H_{19}-$	Nonyl
Decane	$C_{10}H_{22}$	$C_{10}H_{21}-$	Decyl

It's easier to discuss the many types of propane and butane radicals. Propane has a chain structure that is straight. It's termed as n-propyl when terminal H is removed. Isopropyl is formed when hydrogen from the middle carbon is removed, as stated below:



Different structures of butyl radicals are similarly explained:



Differentiation between saturated and unsaturated hydrocarbons:

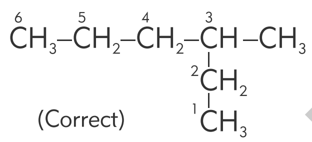
Saturated hydrocarbon:	Unsaturated hydrocarbon:
• Saturated hydrocarbons contain carbon carbon single bond.	• Unsaturated hydrocarbons contain carbon carbon double and tripple bonds.
• The valancies of all carbon atoms are fully satisfied through single bond.	• The valancies of all carbon atoms are fully satisfied through double and triple bond.
• Saturated hydrocarbons have a less amount of carbon and high amount of hydrogen.	• Unsaturated hydrocarbon have a less amount of hydrogen and high amount of carbon as compared to satured hydrocarbons.
• Saturated hydrocarbons are less reactive.	• Unsaturated hydrocarbons are more reactive.
• They burns with blue and non sooty flame in air.	• They burn with yellow and sooty flame in air.
• The compounds of saturated hydrocarbon are alkanes	• The compounds of unsaturated hydrocarbon are alkenes and alkynes.
• Alkanes are represented by general formula C_nH_{2n+2}.	• The general Formula of alkenes (C_nH_{2n}) and alkynes (C_nH_{2n-2}).
• Examples of alkanes are Ethane ($CH_3–CH_3$), Propane ($CH_3–CH_2–CH_3$).	• Examples of alkenes are Ethene (CH_3=CH_3), Propene ($CH_3–CH_2$=CH_3) and Example of alkynes, Ethyne (CH≡CH), Propyne (CH_3–C≡CH)

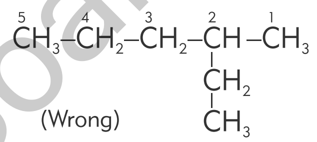
3.5 Nomenclature:

Organic compounds were once classified according to their sources. For example, methane as a marsh gas, methyl alcohol as a wood spirit, and acetic acid from vinegar (Latin: aceteum=vinegar) these are trivial names. Due to their fast rise, the number of organic compounds has increased, posing an issue in naming them. A symposium of top chemists was organized in Geneva to address the issue. In 1882, They developed a naming system known as the Geneva system. In Liege in 1930, the International Union of Chemistry (I.U.C.) changed this approach. The International Union of Pure and Applied Chemistry developed the I.U.C system even more. The I.U.P.A.C system of naming was created in 1960.even further. The I.U.P.A.C system of nomenclature was created in 1960.

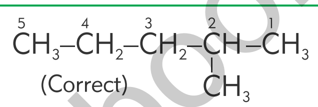
Rules for naming Alkanes:

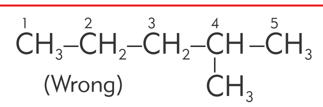
1. Consider the parent alkane and select the longest possible continuous chain of carbon atoms, whether straight or branched.


(Correct)

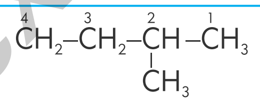

(Wrong)

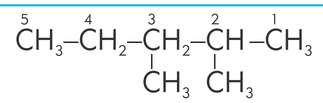
2. Assign numbering on c-atoms of chain from that end to which branch or radical is nearer.


(Correct)

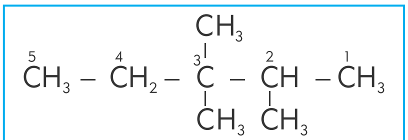

(Wrong)

3. Name the alkyl radical with its position.

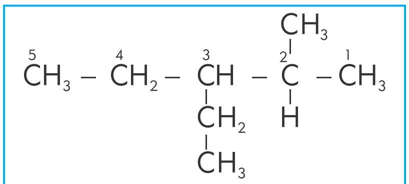

2- methyl butane


2,3- dimethyl pentane

4. If the same radical appears more than once in the chain, the number of alkyl radicals is expressed by prefixing the name of the alkyl radical with di, tri, tetra, penta, and so on.

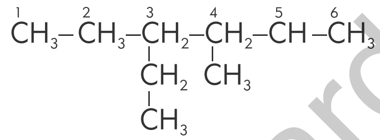

2,3,3- Trimethyl pentane

5. When there are two or more separate alkyl radicals in a chain, they are designated in alphabetical order, ethyl before methyl, methyl before propyl, and so on.



3–ethyl, 2–methyl pentane

6. When separate alkyl radicals occur at the same location on a carbon atom from either end of the chain, the carbon chain is numbered from that end to which larger radical is nearer.



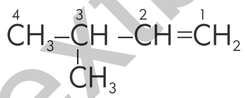
3–ethyl,4–methyl hexane

7. In the end name of parent chain is named as alkane w.r.t number of c-atoms.

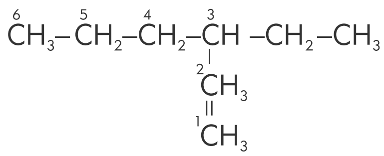
Rules for naming Alkenes:

1. Choose the longest continuous chain of carbon atoms, which must include both double-bonded carbon atoms.

2. Regardless of alkyl radicals, the longest chain is numbered from the end closest to the carbon-carbon double bond.



3– methyl, 1–butene

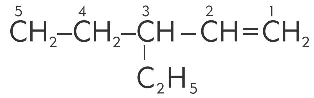


3–ethyl, 1–hexene

3. The presence of a double bond in a compound is indicated by replacing the suffix "ane" of the corresponding alkane with "ene," as well as the location of the double bond in the chain.

$$\overset{6}{C}H_3-\overset{5}{C}H_2-\overset{4}{C}H-\overset{3}{C}H=\overset{2}{C}H-\overset{1}{C}H_3$$

2–hexene



3–ethyl–1–pentene

4. If there are two or more double bonds in the chain, the prefixes di, tri, tera, and so on are added before the suffix "ene" with its position.

$$\overset{6}{C}H_3-\overset{5}{C}H=\overset{4}{C}H-\overset{3}{C}H_2=\overset{2}{C}H-\overset{1}{C}H_2$$

2,4–hexadiene

Rules for naming Alkynes:

1. Choose the longest continuous chain of carbon atoms, which must include both triple-bonded carbon atoms.
2. Regardless of alkyl radical, the longest chain of carbon atoms is numbered from the end closest to the carbon-carbon triple bond.

$$\overset{1}{C}H_3-\overset{2}{C}\equiv\overset{3}{C}-\underset{\underset{CH_3}{|}}{\overset{4}{C}H}-\overset{5}{C}H_3$$

4–methyl–2–pentyne

3. The number of the carbon atom with the lowest value indicates the position of the triple bond.
4. By changing the suffix "ane" of the matching alkane to "yne," the triple bond in the compound is indicated.

$$\overset{4}{C}H_3-\overset{3}{C}H_2-\overset{2}{C}\equiv\overset{1}{C}H_3$$

1–butyne

$$\overset{1}{C}H_3-\overset{2}{C}\equiv\overset{3}{C}-\overset{4}{C}H_2-\overset{5}{C}H_3$$

2–pentyne

5. When there are two or more triple bonds in the chain, the prefixes di, tri, and so on are added before the suffix-"yne" with its position.

$$\overset{5}{C}H_3-\overset{4}{C}\equiv\overset{3}{C}-\overset{2}{C}\equiv\overset{1}{C}H$$

1,3–pentadiyne

$$\overset{6}{C}H_3-\overset{5}{C}\equiv\overset{4}{C}-\underset{\underset{CH_3}{|}}{\overset{3}{C}H}-\overset{2}{C}\equiv\overset{1}{C}H$$

3–methyl–1, 4–hexadiyne

6. When both double and triple bonds are present at same locations in a chain of molecule, the double bond is given priority in numbering.

$$\overset{1}{C}H_2=\overset{4}{C}H-\overset{3}{C}H_2-\overset{4}{C}\equiv\overset{5}{C}H$$

1–penten–4–yne

$$\overset{1}{C}H_3-\overset{2}{C}H=\overset{3}{C}H-\overset{4}{C}H_2-\overset{5}{C}\equiv\overset{6}{C}-\overset{7}{C}H_3$$

2–hepten–5–yne

7. When there are both double and triple bonds at various places in a chain, the numbering begins at the end where the double or triple bond is closest.

$$\overset{6}{C}H_3-\overset{5}{C}H=\overset{4}{C}H-\overset{3}{C}H_2-\overset{2}{C}\equiv\overset{1}{C}H$$

4–hexen–1–yne

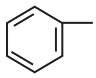
$$\overset{1}{C}H_2=\overset{2}{C}H-\overset{3}{C}H_2-\overset{4}{C}\equiv\overset{5}{C}-\overset{6}{C}H_3$$

1–hexen–4–yne

3.6 Functional groups:

The functional group, is an atom or group of atoms that is responsible for the features of organic molecules. Each functional group has its own distinct characteristics. As a result, a functional group is defined as an atom or group of atoms whose existence in an organic compound gives distinctive qualities to that compound. The structure of a certain family of organic molecules is also defined by the functional group. The functional group in alkyi halides (R–X) is the halogen atom (–X), while in alcohols (R–OH), the hydroxyl group (–OH) is the functional group. The functional group governs an organic compound's fundamental chemistry, whereas the alkyl group affects its physical properties. The polar hydroxyl group (–OH) in alcohols, for example, improves solubility. The non-polar alkyl group resists it in water. This opposing action is sufficiently higher for any alkyl groups larger than C4H9 (Butyl) to restrict a compound's solubility in water. Names of certain common functional groups, as well as the structures of organic compounds containing them, are listed in Table 3.3

Table 3.3 Functional Groups

S.#	Homologous Series	General Molecular Formula	Functional Group and its name
i.	Alkanes	C_nH_{2n+2} or R–H	———
ii.	Alkenes	C_nH_{2n}	>C=C< Double bond
iii.	Alkynes	C_nH_{2n-2}	–C≡C– Triple bond
iv.	Haloalkanes	R–X (where X=F, Cl, Br, I) or $C_nH_{2n+1}X$	–X (Halide group)
v.	Alcohols	R–OH or C_nH_{2n+1} OH	–OH (Hydroxyl group)
vi.	Phenols	 OH or C_6H_5OH	–OH (Hydroxyl group)
vii.	Ethers	R–O–R′ or $C_nH_{2n+2}O$	–OR′ (Alkoxy group)
viii.	Aldehydes	H, R >C=O	H >C=O (Carbonyl group) or –CHO (aldehyde group)
ix.	Ketones	R, R′ >C=O	>C=O (Carbonyl group) (kenotic group)

x.	Carboxylic Acids	R–C(=O)–OH or R–COOH	–C(=O)–OH (Carbonyl group) (Carboxylic group)
xi.	Esters	R–C(=O)–OR′	–C(=O)–OR′ (Alkoxy carbonyl group) or Ester group

3.6.1 Functional Groups Containing Carbon, Hydrogen and Oxygen

The organic compounds containing carbon, hydrogen and oxygen as functional groups are alcohols, ethers, aldehydes, ketones, carboxylic acids and esters. Their class name, functional group, class formula and examples are given in the Table 11.4.

(i) Alcoholic Group

The functional group of alcohol is -OH. Their general formula is ROH. Where R is any alkyl group.

$CH_3 - OH$	$CH_3 - CH_2 - OH$	$CH_3 - CH_2 - CH_2 - OH$
Methyl alcohol	Ethyl alcohol	n-Propyl alcohol

(ii) Ether Linkage

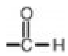
The functional group of ether is C - O - C. Their general formula is R - O - R\` where R and R' are alkyl groups.

R and R' may be same or different, such as:

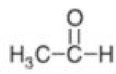
$H_3C - O - CH_3$ Dimethyl ether, $C_2H_5 - O - C_2H_5$, Diethyl ether $H_3C - O - C_2H_5$, Ethyl methyl ether

(iii) Aldehydic Group

Aldehyde family consists of carbonyl functional group. Their general formula is RCHO. Where R stands for H or some alkyl groups, such as:

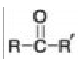



Formaldehyde

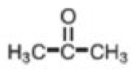

Acetaldehyde

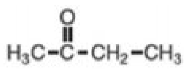
(iv) Ketonic Group

Compounds containing the functional group  are called ketones.

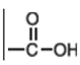
They have the general formula  where R and R' are alkyl groups.

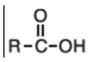
They may be same or different, such as:

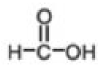

Acetone (Dimethyl ketone)

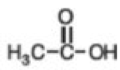

Ethyl methyl ketone

(v) Carboxyl Group

Compounds containing functional group  are called carboxylic acids.

Their general formula is  where R stands for — H or some alkyl groups. Such as:


Formic acid


Acetic acid

(vi) Ester Linkage

Organic compounds consisting of RCOOR' functional group are called esters.

Their general formula is where $R-\overset{O}{\overset{\|}{C}}-OR'$ R and R'are alkyl groups.

They may be same or different, such as: $H_3C-\overset{O}{\overset{\|}{C}}-OCH_3$ (Methyl acetate) $H_3C-\overset{O}{\overset{\|}{C}}-OC_2H_5$ (Ethyl acetate)

Table 3.4 Functional groups containing carbon, hydrogen and oxygen

Class Name	Functional Group	Class Formula	Examples
Alcohols			
Primary	$-CH_2-OH$	$R-CH_2-OH$	CH_3-CH_2-OH
Secondary	$>CH-OH$	R_2CH-OH	$(H_3C)_2CH-OH$
Tertiary	$-\overset{\vert}{\underset{\vert}{C}}-OH$	R_3C-OH	$(CH_3)_2(H_3C)C-OH$
Ethers	$-O-$	$R-O-R$	$H_3C-O-CH_3$
Aldehydes	$-\overset{O}{\overset{\|}{C}}-H$	$R-\overset{O}{\overset{\|}{C}}-H$	$H_3C-\overset{O}{\overset{\|}{C}}-H$
Ketones	$-\overset{O}{\overset{\|}{C}}-$	$R-\overset{O}{\overset{\|}{C}}-R$	$H_3C-\overset{O}{\overset{\|}{C}}-CH_3$
Carboxylic acids	$-\overset{O}{\overset{\|}{C}}-OH$	$R-\overset{O}{\overset{\|}{C}}-OH$	$H_3C-\overset{O}{\overset{\|}{C}}-OH$
Esters	$-\overset{O}{\overset{\|}{C}}-OR$	$R-\overset{O}{\overset{\|}{C}}-OR$	$H_3C-\overset{O}{\overset{\|}{C}}-OC_2H_5$

3.6.2 Functional Group Containing Carbon, Hydrogen and Nitrogen:

The organic compounds containing carbon, hydrogen and nitrogen as functional group are called as amines. Their functional group is $-NH_2$ and their general formula is $R-NH_2$. Examples of amines are:

$H_3C-\ddot{N}H_2$ Methylamine

$H_3C-\ddot{N}H-CH_3$ Dimethylamine

$H_3C-\ddot{N}(CH_3)-CH_3$ Trimethylamine

3.6.3 Functional Group Containing Carbon, Hydrogen and Halogens:

The organic compounds having functional group containing carbon, hydrogen and halogens are called alkyl halides. Their functional group is R-X. 'X' may be F, Cl, Br or I.

Table 3.5 Functional group containing carbon, hydrogen and halogens

Class Name	Functional Group	Class Formula	Examples
Alkyl Halides			
a. Primary	$-CH_2-X$	$R-CH_2-X$	H_3C-CH_2-X Ethyl halide
b. Secondary	$>CH-X$	R_2CH-X	$(H_3C)_2CH-X$ *sec*- Propyl halide
c. Tertiary	$-\overset{\vert}{\underset{\vert}{C}}-X$	R_3C-X	$H_3C-C(CH_3)_2-X$ *ter*- Butyl halide

3.6.4 Double and Triple Bond:

Hydrocarbon consisting of double bonds between two carbon atoms in their molecules are called as alkenes, such as:

$H_2C=CH_2$ — Ethene

$H_3C-HC=CH_2$ — Propene

Hydrocarbon consisting of triple bonds between two carbon atoms in their molecules are called as alkynes, such as:

$HC\equiv HC$ — Ethyne (Acetylene)

$H_3C-C\equiv CH$ — Propyne

Test Yourself

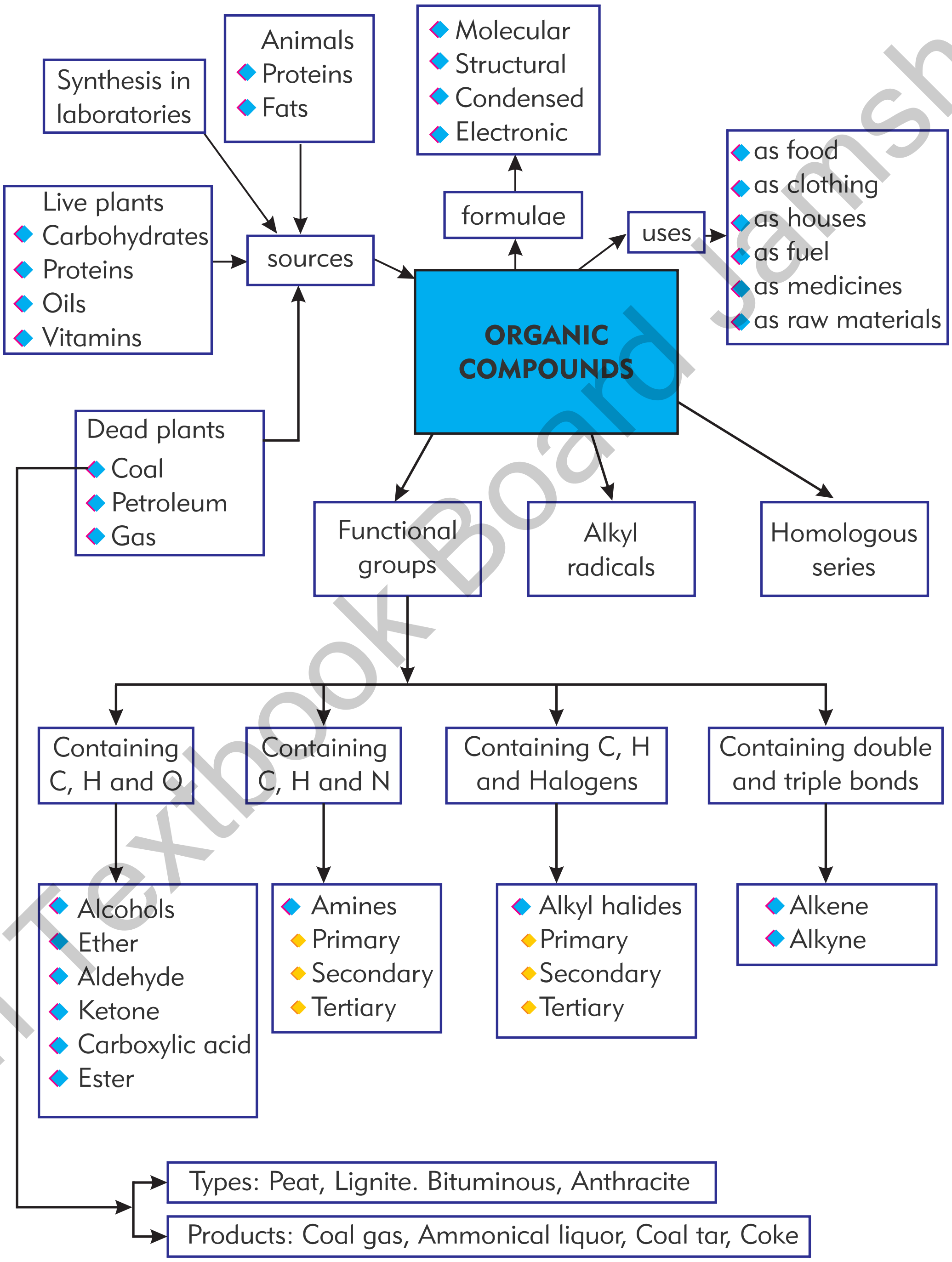
1. Identify functional group in the given compounds: CH_3CH_2OH, CH_3OCH_3, CH_3CHO
2. If we dip a blue litmus paper in a solution and it changes to red color which functional group does the solution have?

Society, Technology and Science

Role of pharmaceutical chemist in the synthesis of effective new drugs

The pharmaceutical chemist plays an important role in the pharmaceutical industry by laboratory analysis, quality assurance, quality control and production of new effective drugs. Pharmaceutical chemist prepare and select appropriate compounds for biological evolutions and decide its active implementation for diseases. The chemist plays the most critical role in the drug development process and serve as the backbone to framework for the drug discovery .

CONCEPT DIAGRAM



Summary

- First time Berzelius used the word organic compound for those compounds which were obtained from animals and plants.
- According to Vital Force Theory, organic compounds can only be prepared in living tissues by vital force.
- Urea is the first synthesized organic compound and it was prepared by Wohler in 1828.
- Carbon is an essential element in all natural and synthesized organic compounds.
- Hydrocarbons are composed of hydrogen and carbon atoms.
- The study of hydrocarbons and their derivatives is modern definition of organic chemistry.
- Self-linking property of carbon is called catenation.
- The compounds having same molecular formula but different structures are termed as isomers.
- Due to catenation and isomerization millions of organic compounds are existed in the universe.
- On the basis of chains organic compounds are divided into main two classes- open chain and closed chain (cyclic) compounds.
- Saturated hydrocarbons contain carbon-carbon single bonds. Alkanes are saturated hydrocarbons.
- Unsaturated hydrocarbons contain carbon-carbon double and triple bonds. Alkenes ($C=C$) and alkynes are ($C\equiv C$) unsaturated hydrocarbons.
- Organic compounds are soluble in organic solvents like benzene, carbon disulphide, ether alcohols etc.
- Organic compounds have weaker bonding than ionic compounds so they have lower melting and boiling points.
- Organic compounds have slow rate of reactions.
- On combustion, all organic compounds produce one of the common product carbon dioxide.
- The members of homologous series have same functional group.
- Coal is also called black gold.
- In Pakistan the name sui gas is used for natural gas.
- The name of organic compound is composed of two parts: Prefix + suffix. Prefix tells thenumber of carbon atoms and suffix functional group in each molecule.
- Alkyl radicals are formed by the removal of hydrogen from alkanes.
- A functional group is an atom or group of atoms that gives a molecule its characteristic properties.
- On the basis of functional groups organic compounds are divided into different families.
- Many organic compounds are used in perfumes, scents, paints, dyes and drugs.

Exercise

SECTION- A: MULTIPLE CHOICE QUESTIONS

1. Encircle the correct answer:

(i) The branch of chemistry which deals with the hydrocarbons and their derivatives is known as:

(a) Organic chemistry (b) Inorganic chemistry (c) Biochemistry (d) Physical chemistry

(ii) The general formula for alkanes is:

(a) C_nH_{2n} (b) C_nH_{2n+1} (c) C_nH_{2n+2} (d) C_nH_{2n-2}

(iii) Which of the following is an alcohol?

(a) CH_3CHO (b) CH_3-CH_2-O-CH_3 (c) CH_3-OH (d) HCOOH

(iv) Which of the following is saturated hydrocarbon?

(a) $CH_3CH=CH_2$ (b) CH_3-CH_2-CH_3 (c) CH_3-C≡CH (d) CH_2=CH-C≡CH

(v) The prefix 'hept' stands for the .... carbon atoms.

(a) 2 (b) 5 (c) 7 (d) 9

(vi) The functional group –COOH is used for:

(a) Alkynes (b) alcohols (c) Phenols (d) Carboxylic acids

(vii) Polyethene is:

(a) oil (b) paper (c) plastic (d) wood

(viii) Acetic acid is obtained from:

(a) Banana (b) Dates (c) Garlic (d) Vinegar

(ix) Alkenes:

(a) show same general formula as alkynes.
(b) have carbon carbon triple bond.
(c) have carbon carbon double bond.
(d) are saturated hydrocarbons.

(x) CH_3-CH_2- is … radical.

(a) Methyl (b) Ethyl (c) n-propyl (d) Isopropyl

SECTION- B: SHORT QUESTIONS:

(i) Define Vital Force Theory.

(ii) Explain how petroleum is source of organic compounds?

(iii) Define the functional group. Write the functional groups which contain carbon, hydrogen and oxygen.

(iv) Define the alkyl radicals with suitable examples.

(v) What is homologous series? Name the some common homologous series.

(vi) Identify the functional groups in the following compounds.

(a) CH_3-CHO (b) CH_3-CH_2-CH_2-OH (c) CH_3-CO-CH_3

(d) CH_3-COOH (e) CH_2=CH-CH_3

(vii) Write the condensed and structural formulae of the pentane and octane.

(viii) What is catenation? Give any two examples of catenation of carbon atoms.

SECTION- C: DETAILED QUESTIONS:

(i) Give the important characteristics of organic compounds.

(ii) Differentiate between saturated and unsaturated hydrocarbons.

(iii) What are the main sources of organic compound? mention with special reference of coal, petroleum and natural gas.

(iv) Describe the uses of organic compound.

(iv) Name the alkenes and alkynes having the following formula.

(i)	C_2H_4	(ii)	C_3H_4	(iii)	C_3H_6	(iv)	C_6H_{12}
(v)	C_5H_8	(vi)	C_8H_{16}	(vii)	C_7H_{12}	(viii)	C_6H_{10}

(v) Define nomenclature and describe the I.U.P.A.C nomenclature rules for alkynes.

(vi) What do you mean by diversity and magnitude of organic compounds?