



11

ORGANIC CHEMISTRY



After completing this lesson, you will be able to:

**This is 13 days lesson
(period including homework)**

- Recognize structural, condensed and molecular formulas 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 compounds.
- List the uses of organic compounds.
- Recognize and identify molecule's functional groups.
- Distinguish between saturated and unsaturated hydrocarbons.
- Name the alkanes up to decane.
- Convert alkanes into alkyl radicals.
- Differentiate between alkane and alkyl radicals.
- Define functional group.
- Differentiate between organic compounds on the basis of their functional groups.
- Classify organic compounds into straight chain, branched chain and cyclic compounds.
- Identify carboxylic acids, phenols, amines, aldehydes and ketones in terms of functional groups in the lab.
- Distinguish between saturated and unsaturated compounds using iodine, bromine and potassium permanganate solutions.
- Show how pharmaceutical chemists work towards the partial and total synthesis of effective new drugs.
- Explain how substances produced by plants and animals can also be produced in the lab.



Reading

INTRODUCTION:

The Study of Carbon containing compounds and their properties is called organic chemistry. However, few compounds of carbon such as carbon dioxide, carbon monoxide, carbonates and carbides are considered to be inorganic substances. This is



because they have totally different properties than organic compounds. Organic compounds play a vital role in the bodies of living things. Products of industrial organic chemistry such as plastics, rubber, synthetic fibers, paints, glues, varnishes, artificial sweeteners and flavors, drugs, dyes, soaps and detergents etc. are important part of modern life. In addition, the energy on which we rely heavily is based mostly on organic materials found in coal, petroleum and natural gas.

11.1. ORGANIC COMPOUNDS

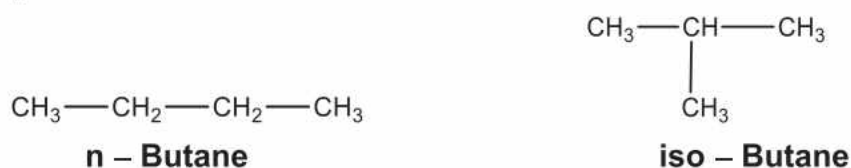
The Chemistry of carbon compounds pervades every aspect of our lives. We use thousands of carbon compounds every day. They are carrying out important chemical reactions within our bodies. Many of them are so vital that we cannot live without them. A detailed study of organic compounds confirms that carbon is their essential constituent in combination with H, O, N, S, P and halogens. They may also (rarely) contain metal atoms. **Organic compounds are defined as the hydrocarbons and their derivatives.** (see section 11.4 and Chapter 12)

11.1.1 Chemical Diversity and Magnitude of Organic Compounds

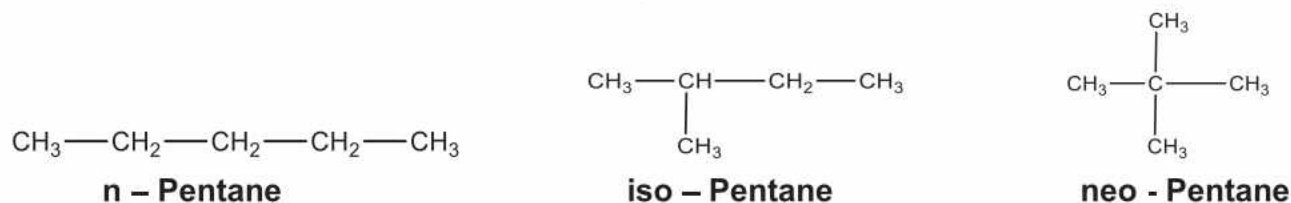
Carbon has four bonding electrons in its valence shell. Carbon therefore forms four bonds with other atoms.

The Chemical diversity of organic compounds arises from carbon's ability to bond to each other to form long chains, branched chains and rings. This self-linking ability of carbon is called **catenation**. There appears to be almost no limit to the number of different structures that carbon can form. (See 11.1.6). No other element can compete with carbon in this regard. Silicon and few other elements can form chains, but only short one. Carbon chains may contain thousands of carbon atoms. For these reasons carbon forms almost infinite number of molecules of various sizes, shapes and structures. Another reason for the large number of organic compounds is the phenomenon of **isomerism**.

The compounds that have same molecular formula but different arrangement of atoms in their molecules are called isomers. This phenomenon is called isomerism. For example two compounds have molecular formula C_4H_{10}



What is the molecular formula of the following compounds?



Teacher's Point

A teacher may give examples of petrol, kerosene, diesel, mobile oil as hydrocarbons.



This means three compounds have molecular formula C_5H_{12} . As the number of carbon atoms in an organic compound increases, the number of possible isomers also increase. What is the number of isomers in pentane? Hexane has five isomers.

Carbon can also form stable single and multiple bonds with other atoms like oxygen, nitrogen and sulphur.

Carbon can also make **multiple bonds** to itself i.e. $C=C$, $C\equiv C$, $C=O$, $C\equiv N$ etc. This further increase the number of organic compounds. In fact, many common groups of atoms can occur within organic molecules. These groups are called functional group. (See 11.4). That is why of more than 20 million known chemical compounds; over 95% are compounds of carbon. Millions of organic compounds are already known and new ones are being discovered every day.

In fact many common groups of atoms can occur within organic molecules. These groups are called functional groups. (See 11.5).

11.1.2 General Characteristics of Organic Compounds

(i) Occurrence:

Most of them come from living things or from the things that were once living.

(ii) Covalent nature:

Organic compounds are generally covalent in nature. They may have polar or non-polar bonds.

(ii) Composition:

Carbon is the main constituent of organic compounds. Hydrogen is also frequently present in organic compounds. Other elements like oxygen, nitrogen, sulphur, phosphorous and halogens are present in many organic compounds.

(iv) Melting and boiling point:

Generally organic compounds are volatile. So they have low melting and boiling points.

(v) Solubility:

Organic compounds are mostly non-polar in nature therefore they are soluble in organic solvents such as ether, benzene, carbon disulphide etc. Polar Organic Compounds are soluble in alcohols such as methyl alcohol and ethyl alcohol.

(vi) Similarity in behaviors (Homology):

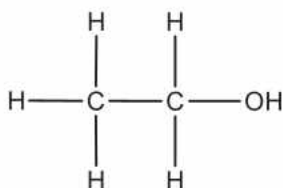
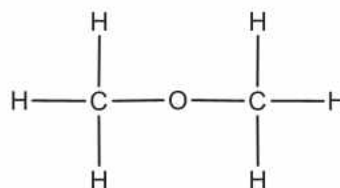
There exists a close relationship between different organic compounds. This similarity in behavior has made the study of millions of organic compounds easier. They can be classified into few families. A series of related compounds in which any two adjacent molecules differ by $-CH_2-$ group is called homologous series.

**(vii) Reaction rates:**

Organic compounds are generally less stable than inorganic compounds. Due to covalent bonding in them, their reaction rates are often slow.

11.1.3 Condensed Structural Formulas

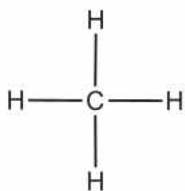
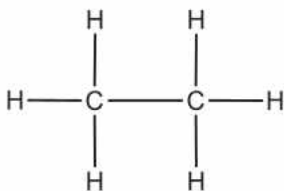
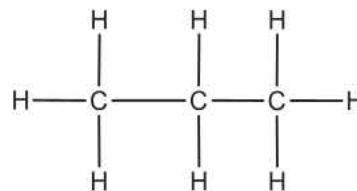
Frequently more than one organic compounds are represented by the same molecular formula. However, they have different properties. They have different structural formulas. For example, two organic compounds have the molecular formula C_2H_6O . they have different arrangements of atoms.

**Ethanol****Dimethyl ether**

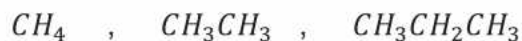
These formulas clearly show that the atoms are bonded to one another differently. In ethanol, the oxygen atom is bonded to only one carbon atom and a hydrogen atom. Whereas in dimethyl ether, the oxygen atom is bonded to two carbon atoms.

A formula that describes the arrangement of atoms in a molecule is called as structural formula.

The simple alkanes are straight-chain hydrocarbons. First three members of alkanes have following structural formulas.

**Methane****Ethane****Propane**

The condensed structural formulas of these alkanes are



The corresponding molecular formulas are CH_4, C_2H_6, C_3H_8 respectively

A condensed formula is a structural formula that uses established abbreviation for various groups of chain. In condensed structural formula, we list the main chain carbon atoms and the hydrogen atoms attached to them in the sequence in which they appear in the naming system.

For instance,

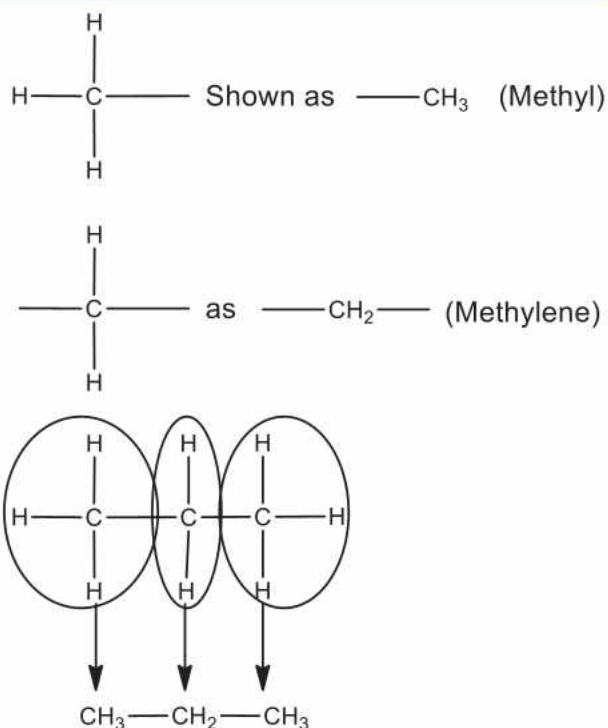


Table 11.1 shows the condensed structural formulas of some alkanes.

Table 11.1 Condensed structural formula of some alkanes

Name	Molecular Formula	Condensed Formula
Butane	C_4H_{10}	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$
Pentane	C_5H_{12}	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$
Hexane	C_6H_{14}	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$
Heptane	C_7H_{16}	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$
Octane	C_8H_{18}	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$
Nonane	C_9H_{20}	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$
Decane	$\text{C}_{10}\text{H}_{22}$	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$

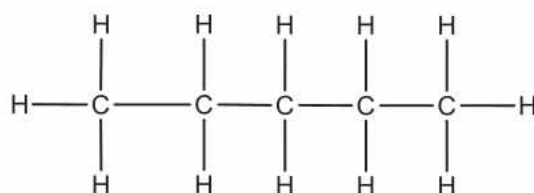
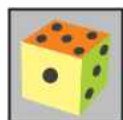
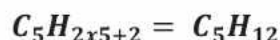
Example 11.1: Give the molecular formula, the structural formula and the condensed structural formula for pentane.

Problem Solving Strategy

- The stem pent –means five carbon atoms.
- The ending -ane indicates an alkane.
- Write a string or chain of five carbon atoms.



- iv) Attach hydrogen atoms to the carbons to give each carbon atom four bonds. This requires three hydrogen atoms on each end carbon and two each on others.
- v) For the condensed molecular formula, write each carbon atom's set of hydrogen atoms next to the carbon.
- vi) For molecular formula, simply count the carbon and hydrogen atoms or use the general formula C_nH_{2n+2} with $n=5$.

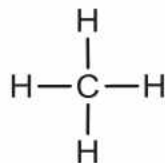
Solution:**Structural formula****Condensed Structural formula****Molecular formula****Self-Assessment Exercise 11.1**

Give the molecular, structural and condensed structural formulas for

- (a) Butane (b) Hexane (c) Octane

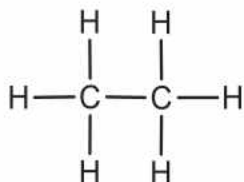
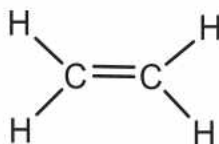
**Reading****11.1.4 Saturated and Unsaturated Hydrocarbons**

Hydrocarbons are compounds containing carbon and hydrogen only. **Hydrocarbons whose carbon – carbon bonds are all single bonds are called saturated.** Saturated hydrocarbons are also called alkanes. In alkanes each carbon atom is bonded to four other atoms. Methane is the simplest alkane. Other examples are ethane, propane, butane etc. (**See section 11.1.3** for more examples). The general formula of alkanes is C_nH_{2n+2} , where n is the number of carbon atoms.

**Methane**

Hydrocarbons containing carbon-carbon multiple bonds are called unsaturated.

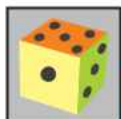
Which of the following are unsaturated hydrocarbons?

**Ethane****Ethene****Ethyne**

Unsaturated hydrocarbons are further divided into:

- (i) **Alkenes.**
- (ii) **Alkynes.**

Unsaturated hydrocarbons containing at least one carbon-carbon double bond are called alkenes. They have general formula $(\text{C}_n\text{H}_{2n})$, for example ethene. Unsaturated hydrocarbons that have at least one carbon-carbon triple bond are called alkynes. They have general formula $\text{C}_n\text{H}_{2n-2}$, for example ethyne.



Self-Assessment Exercise 11.2

Choose saturated and unsaturated compounds from the following.

- | | |
|---|--|
| (i) $\text{CH}_3-\text{CH}_2-\text{CH}_3$ | (ii) $\text{CH}_3-\text{C}\equiv\text{CH}$ |
| (iii) $\text{CH}_3-\text{CH}=\text{CH}_2$ | (iv) $\text{CH}_2=\text{CH}-\text{CH}=\text{CH}_2$ |



Reading

11.1.5. Naming Alkanes

An international body, the international union of pure and applied chemistry (IUPAC) has devised a system of naming organic compounds that depends on their structure. These names



indicate the number of carbon atoms present in the organic compounds. We can easily recognize organic compound by its IUPAC name. Such names are also called systematic names.

The key point in naming a straight chain alkane is that the name is based on the number of carbon atoms in the chain. The IUPAC name has two parts.

(i) Stem:

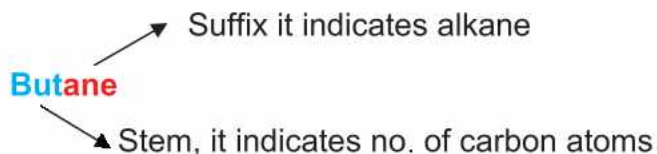
The stem tells the number of carbon atoms in the chain. Table 11.2 shows these stems.

Table 11.2: Numerical stems for carbon chains

Stem	Number of C - atoms
Meth-	1
Eth-	2
Prop-	3
But-	4
Pent-	5
Hex-	6
Hept-	7
Oct-	8
Non-	9
Dec-	10

(ii) Suffix:

Suffix is placed after the stem, it tells the class of compound. For alkane, the suffix “ane” is used.



Example 11.2: Writing names of alkanes

Write IUPAC names of the following compounds.

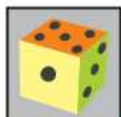


Problem solving strategy

- Count number of carbon atoms in the chain and select stem for it.
- Add suffix – ane to the stem.

**Solution**

- (i) No. of Carbon atoms 4
Stem $\rightarrow$ But
Name: Butane
- (ii) No. of Carbon atoms 5
Stem $\rightarrow$ Pent
Name: Pentane

**Self-Assessment Exercise 11.3**

Write IUPAC names of the following alkanes.

- (i) $\text{CH}_3\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_3$
- (ii) $\text{CH}_3\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_3$
- (iii) $\text{CH}_3\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_3$
- (iv) $\text{CH}_3\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_3$
- (v) $\text{CH}_3\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_3$

**Reading**

11.2 SOURCES OF ORGANIC COMPOUNDS

The major commercial sources of alkanes are coal, natural gas, petroleum, and living organisms.

Coal

Coal is a source of many organic compounds. When coal is heated in the absence of air at high temperature, it is converted into coal gas, coal tar and coke. This process is called destructive distillation. Coal is also used as solid fuel.

Coal gas contains methane, hydrogen and carbon monoxide gases. It is mainly used as a fuel in industry. Coal tar is a source of many organic compounds such as benzene and its derivatives. These compounds can be separated by fractional distillation. These are very useful substances in synthetic organic chemistry. These are used to synthesize plastics, dyes, fibers, drugs, paints, varnishes etc. The residue left behind called pitch is used to metal roads and roofs.



Natural gas

Natural gas is a mixture of low boiling hydrocarbons. Natural gas is mostly methane. It also contains smaller amounts of ethane, propane and butane.

Petroleum

Petroleum contains a wide variety of alkanes including those having very long chains. On fractional distillation petroleum separates into various hydrocarbon components, known as fractions. Can you name these fractions? Each fraction is not a pure compound but a mixture of different compounds that boil in a certain range of temperature. (See section 16.4)

Living Organisms

Many important organic compounds such as proteins, fats, carbohydrates, vitamins, drugs and medicines are obtained from plants and animals.

Synthesis in Laboratory:

Over ten million organic compounds have been prepared in the laboratories. They are being used in medicines, cosmetics, paints, plastics, fertilizer, detergents, etc.

11.3 USES OF ORGANIC COMPOUNDS.

- Natural gas and petroleum are used primarily as fuels (see figure 16.9). These are also used as starting materials for the productions of variety of organic compounds.
- Propane and butane which are gases obtained from natural gas are widely available as liquids in fuel cylinders (LPG).
- Ethylene is the major starting material for the manufacture of organic chemicals and products such as polyethylene (plastic), ethyl alcohol, acetic acid and ethylene glycol called antifreeze.
- Acetylene is widely used in the oxy-acetylene welding and cutting metals. Acetylene is also used in the preparation of polymers like PVC (polyvinyl chloride), polyvinyl acetate, synthetic rubber, nylon etc.
- Acetylene is used for artificial ripening of fruits.
- Compounds of phenol help to ensure antiseptic conditions in hospital operating rooms.
- Methanol is used as a solvent for fats, oils, paints and varnishes.
- Many organic compounds are used in the manufacturing of drugs, dyes, cosmetics, detergents and soaps, nylon, emulsions and paints etc.



Self-Assessment Exercise 11.4

1. List the names of major sources of alkanes.
2. What is natural gas?
3. Write some uses of acetylene.



Teacher's Point

Teacher may show different organic compounds to students.



Reading

11.4. ALKANE AND ALKYL RADICALS

Recall that an alkane is a hydrocarbon containing only single bonds and have general formula C_nH_{2n+2} .

An alkyl radical is a group of atoms obtained by removing one hydrogen atom from an alkane. Alkyl radicals are represented by the symbol R.

Example 11.3 Converting alkanes into alkyl radicals

Convert following alkanes into alkyl radical.

- (i) Methane (ii) Ethane

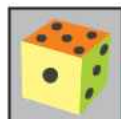
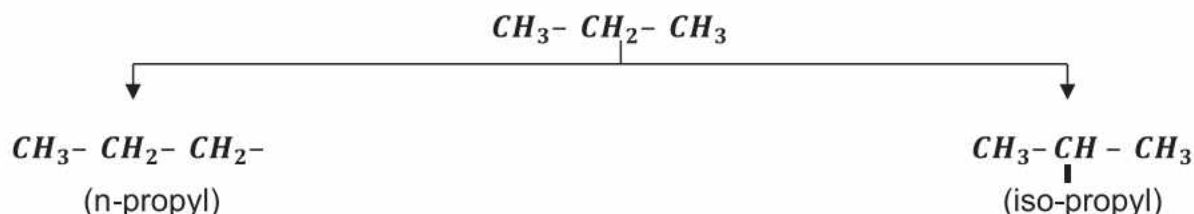
Problem Solving Strategy

- Write condensed structure formula for the given compound.
- Remove a hydrogen atom from the terminal carbon atom.
- Write name of the radical by removing ending -ane of alkane by -yl

Solution

- | | | |
|------|----------------|---------------|
| (i) | CH_4 | $CH_3 -$ |
| | Methane | Methyl |
| (ii) | CH_3CH_3 | $CH_3CH_2 -$ |
| | Ethane | Ethyl |

What is the difference between methane and methyl radical? Which one contain a free valency? Alkanes containing more than two carbon atoms form more than one alkyl groups. For instance, propane forms two alkyl groups or radicals. The group obtained by removing terminal hydrogen atom is called n-propyl and that obtained by removing H-atom from central carbon atom is called iso-propyl group.



Self-Assessment Exercise 11.5

Derive alkyl radicals from the following alkanes.

- a. Ethane b. Butane c. Propane

**Reading****11.1.6. Classification of Organic Compounds**

There are millions of organic compounds. It is not possible to study each compound individually. To make the study easy, they are classified into various groups and sub-groups. It is helpful to pick out these compounds which have similar structure. So you will learn here, the classification of organic compounds on the basis of carbon skeleton. They are broadly classified into two main groups.

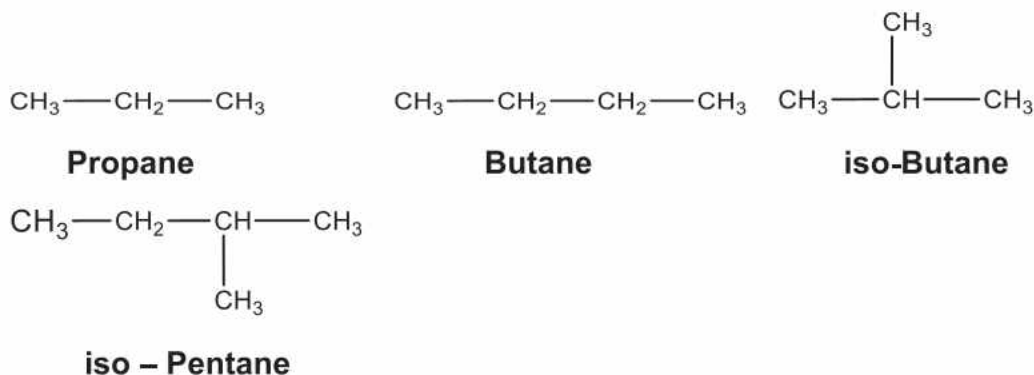
Do you know?

Alkyl radical contains one less hydrogen than its parent alkane.

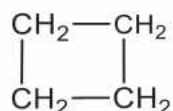
- (i) Open chain compounds or Acyclic compounds.
- (ii) Closed chain or Cyclic Compounds.

(i) Open chain compounds.

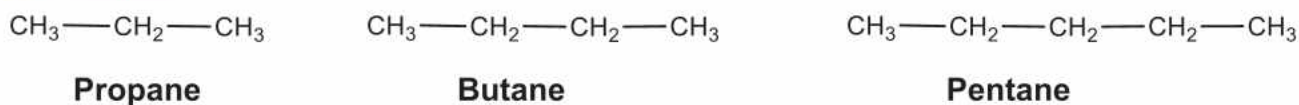
Open chain compounds contain an open chain of carbon atoms. For instance



Is the compound having following structure an open chain compound?



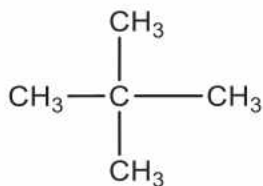
Open chain compounds may be either straight-chain or branched-chain. Those compounds which contain any number of carbon atoms joined one after the other in a chain or row are called **straight – chain compounds**.

For example**Teacher's Point**

Teacher may tell students that Sui Gas is mainly methane containing small amount of ethane, propane and butane.



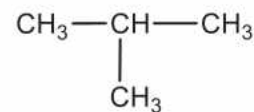
Those compounds which contain carbon atoms on the sides of chain are called branched chain compounds. Which of the following is a branched chain compound?



neo-Pentae



Butane

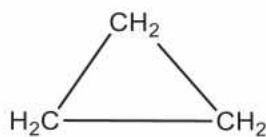


iso-Butane

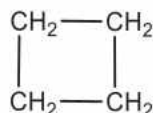
Open chain compound are also called alicyclic compounds

(ii) Closed Chain or Cyclic Compounds

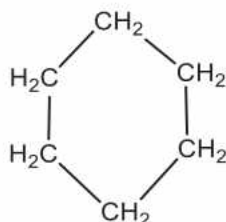
Organic compounds which contain rings of atoms are called closed chain or cyclic compounds. For example



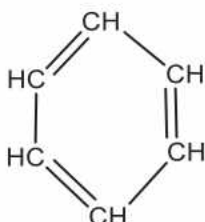
Cyclopropane



Cyclobutane



Cyclo hexane

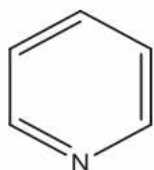


Benzene

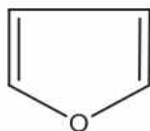
or



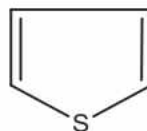
Cyclic compounds which contain rings of carbon atoms are called homocyclic or carbocyclic compounds. Which of the above cyclic compounds are carbocyclic? Cyclic compounds that contain one or more atoms other than carbon atoms in the ring are called heterocyclic compounds e.g.



Pyridine



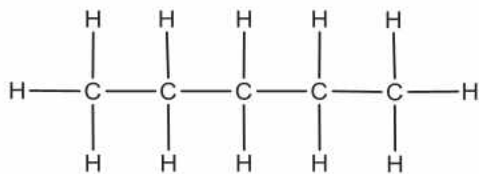
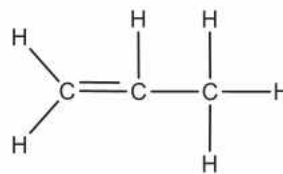
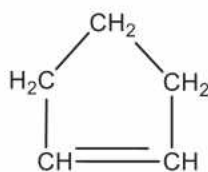
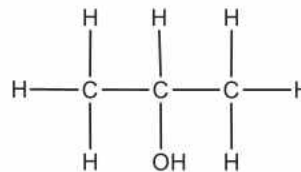
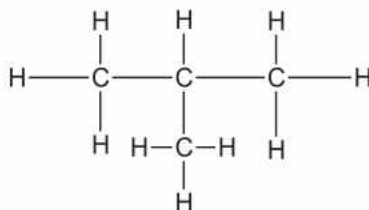
Furan



Thiophene

**Self-Assessment Exercise 11.6**

A to E are the structural formulas of some organic compounds.

**A****B****C****D****E**

Give the letters which represents

- (i) A branched chain compound.
- (ii) A cyclic compound.
- (iii) Two straight chain compounds.

**Reading**

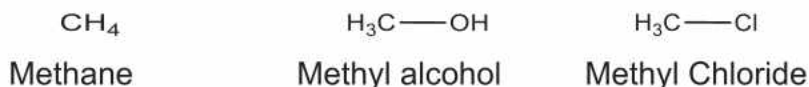
11.4 FUNCTIONAL GROUPS

The vast majority of organic compounds contain elements in addition to carbon and hydrogen. Most of these compounds are considered as derivatives of hydrocarbons. This means that they are basically hydrocarbons but they have additional atom or groups of atoms in place of one or more hydrogen atoms called functional groups. In many simple molecules, a functional group is attached to an alkyl group.



An atom or groups of atoms that give a family of organic compounds its characteristic chemical and physical properties is called a functional group.

What is the difference in the following compounds?



The common functional groups are listed in the table 11.2.

The study of organic chemistry is organized around functional groups. Each functional group defines a family of organic compounds. Although, there are millions of organic compounds, yet there are only a handful of functional groups. So functional groups make the study of millions of organic compounds easier.

Table 11.2: Some Common Functional groups

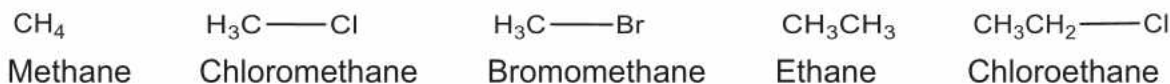
Name of class	Functional group	General formula
Alkane	None	$\text{R}-\text{H}$
Alkene	$\begin{array}{c} \quad \\ -\text{C}=\text{C}- \end{array}$	$\begin{array}{c} \text{R}' \quad \text{R}'' \\ \quad \\ \text{R}-\text{C}=\text{C}-\text{R}''' \end{array}$
Alkyne	$-\text{C}\equiv\text{C}-$	$\text{R}-\text{C}\equiv\text{C}-\text{R}'$
Alcohol	$\begin{array}{c} \\ -\text{C}-\text{O}-\text{H} \\ \end{array}$	$\text{R}-\text{O}-\text{H}$
Ether	$\begin{array}{c} \quad \\ -\text{C}-\text{O}-\text{C}- \\ \quad \end{array}$	$\text{R}-\text{O}-\text{R}'$
Aldehyde	$\begin{array}{c} \text{O} \\ \\ -\text{C}-\text{H} \end{array}$	$\begin{array}{c} \text{O} \\ \\ \text{R}-\text{C}-\text{H} \end{array}$
Ketone	$\begin{array}{c} \text{O} \\ \\ -\text{C}- \end{array}$	$\begin{array}{c} \text{O} \\ \\ \text{R}-\text{C}-\text{R}' \end{array}$
Amine	$\begin{array}{c} \\ -\text{C}-\text{N}- \\ \quad \end{array}$	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{R}-\text{N}-\text{H} \quad \text{R}-\text{N}-\text{R}' \end{array}$
Carboxylic acid	$\begin{array}{c} \text{O} \\ \\ -\text{C}-\text{O}-\text{H} \end{array}$	$\begin{array}{c} \text{O} \\ \\ \text{R}-\text{C}-\text{O}-\text{H} \end{array}$
Ester	$\begin{array}{c} \text{O} \\ \\ -\text{C}-\text{O}-\text{C}- \\ \end{array}$	$\begin{array}{c} \text{O} \\ \\ \text{R}-\text{C}-\text{O}-\text{R}' \end{array}$

Each functional group exhibits character



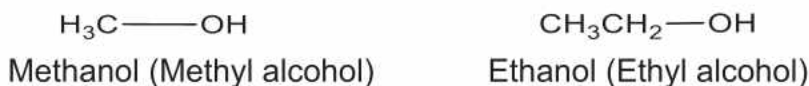
11.5.1 Functional groups containing Carbon, Hydrogen and Halogens: Haloalkanes

Haloalkanes are characterized by the presence of the halogen atom. The haloalkane is compound in which one hydrogen atom of an alkane is substituted by one halogen atom. Which of the following molecules are haloalkanes?



11.5.2 Functional groups containing Carbon, Hydrogen and Oxygen: Alcohols

Alcohols are characterized by the presence of the hydroxyl group. (-OH) attached to a hydrocarbon chain.

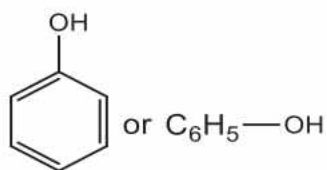


$\text{R}-\text{OH}$ is the general formula for alcohols. Which of the following compounds is alcohol?



Phenols

When an -OH group is attached to a benzene ring, the compound is called a phenol.

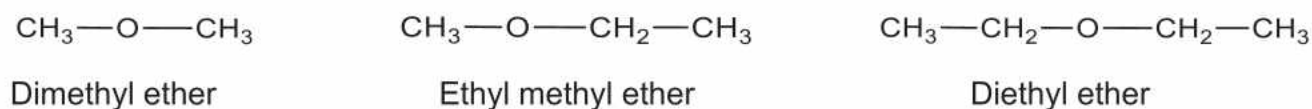


Phenol

Phenol was the first antiseptic used in an operation theatre.

Ethers

Organic compounds that have two alkyl groups attached to the same oxygen atom are called ethers. These compounds have C-O-C linkage in their molecules.

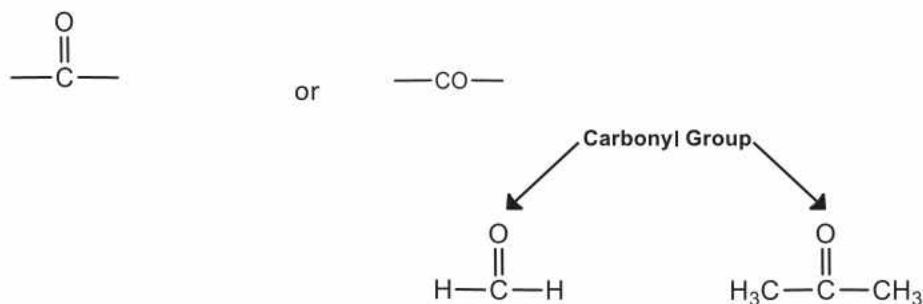


The general formula for ethers is $\text{R}-\text{O}-\text{R}'$. Where R and R' are alkyl groups which may be same or different.



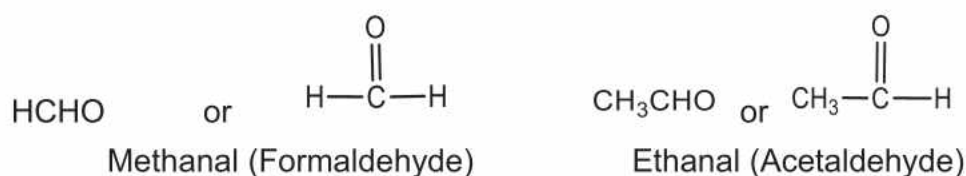
Aldehydes and ketones

Aldehydes and ketones contain the carbonyl group

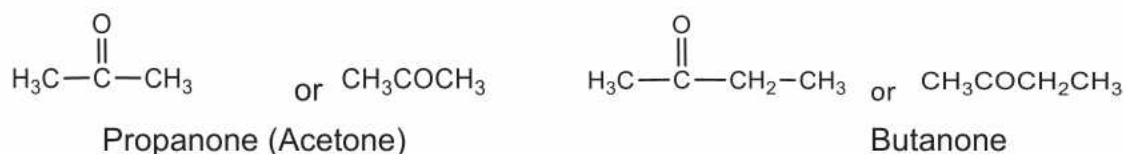


An aldehyde has at least one hydrogen atom or two hydrogen atoms attached to the carbonyl carbon atom. A ketone has two hydrocarbon groups (alkyl) bonded to the carbonyl carbon atom. Which of the above compound is an aldehyde? Which is a ketone?

$\begin{array}{c} \text{O} \\ \parallel \\ \text{—C—H} \end{array}$ group in condensed form is written as —CHO . It is characteristic group of aldehydes.

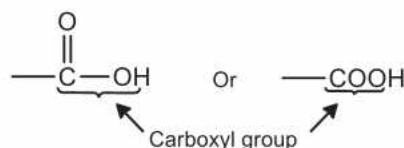


The general formula for ketone is $\text{R—}\begin{array}{c} \text{O} \\ \parallel \\ \text{C} \end{array}\text{—R'}$ and in condensed form it is written as RCOR' . Where R and R' are alkyl groups which may be same or different. For example



Carboxylic Acids:

The functional group of organic acid is called the carboxyl group.



What is the difference between a carbonyl group and a carboxyl groups?

Examples:

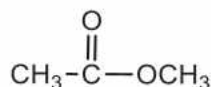


The general formula for carboxylic acids is R—COOH

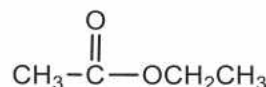
Where R = H or alkyl group

**Esters:**

Compounds having general formula $R-\overset{\overset{O}{\parallel}}{C}-OR'$ are called esters. R and R' are alkyl groups which maybe same or different.



(Methyl acetate) Methyl ethanoate



(Ethyl acetate) Ethyl ethanoate

$-\overset{\overset{O}{\parallel}}{C}-OR'$ is the functional group for esters.

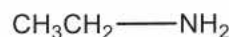
11.5.3 Functional groups containing Carbon, Hydrogen and Nitrogen

Amines

The functional group of amines is $-NH_2$



Methyl amine

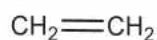


Ethyl amine

The general formula for amines is $R-NH_2$

11.5.4 Functional groups containing Double and Triple bond

An alkene is a hydrocarbon that contains one or more carbon-carbon double bond. $-C=C-$ is the functional group for alkenes. An alkyne is a hydrocarbon that contains one or more carbon-carbon triple bond. $-C\equiv C-$ is the functional group for alkynes. Which of the following compound is alkene, which is alkyne?



(II)



(II)



(III)

Example 11.4: Differentiating different organic compounds on the basis of their functional groups.

Classify the following compounds as an alcohol, ether or a phenol.

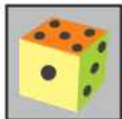
- $CH_3CH_2OCH_2CH_3$, is an anesthetic, but its' use as an anesthetic is now limited. This is because it is inflammable and causes nausea.
- C_6H_5OH is a strong germicide. It is commonly used as disinfectant for floors, furniture and washrooms.
- CH_3OH is poisonous and can cause blindness or death if taken internally.

Problem Solving Strategy:

- Identify alkyl group in the molecule and functional group.
- When $-OH$ group is attached to an alkyl group, the compound is an alcohol, but when $-OH$ is attached to benzene ring, the compound is a phenol.
- When O- atom is attached to two alkyl groups, the compound is an ether.

**Solution**

- (a) Ether (b) Phenol (c) Alcohol

**Self-Assessment Exercise 11.7**

Classify the following compound as alcohol, ether or phenol.

- (a) $\text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_3$ (b) $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$
 (c) $\text{C}_6\text{H}_5\text{OH}$ (d) $\text{C}_2\text{H}_5\text{OH}$

**Reading**

Example 11.5: Classify the following organic compounds on the basis of functional group.

Identify the following compounds as an aldehyde or a ketone or a carboxylic acid.

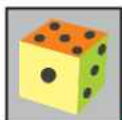
- (a) CH_3COCH_3 is a common solvent for organic materials such as fats, rubbers, plastic and varnishes.
 (b) $\text{CH}_3\text{CH}_2\text{CHO}$ has a foul irritating odour.
 (c) CH_3COOH is present in vinegar and is used to flavor food and making a polymer called polyvinyl acetate.

Problem Solving Strategy**Remember that**

- (i) In an aldehyde a hydrogen atom is attached to the carbonyl carbon atom.
 (ii) In a carboxylic acid $-\text{OH}$ group is attached to the carbonyl carbon atom.
 (iii) In a ketone, the carbonyl carbon is between two other carbon atoms.

Solution

- (a) A ketone (b) An aldehyde (c) An organic acid

**Self-Assessment Exercise 11.8**

Identify the following compounds as an aldehyde, or a ketone or a carboxylic acid.

- (a) $\text{CH}_3\text{COCH}_2\text{CH}_3$ (b) $\text{CH}_3\text{CH}_2\overset{\text{O}}{\parallel}\text{CH}$ (c) $\text{CH}_3\text{CH}_2\overset{\text{O}}{\parallel}\text{COH}$

Almost all synthesis involve the inter conversion of at least one functional group to another. A functional group is the active portion of the molecule. It plays a key role in the



synthesis of new compounds. The key to design most organic synthesis is the functional group in the target molecules.

SKILLS

Society, Technology and Science

Pharmaceutical chemists seek ideas for new drugs not only from plants but also from any part of animals. They isolate the active ingredients for drug material methods include cold maceration and methanolic or ethanolic extraction. Then, they test drug on animals and perform, other clinical tests. After successful tests, pharmacists develop a manufacturing process for new effective drug in a laboratory. They use computer-aided software for drug design.

To develop a synthesis scheme for a particular substance produced by plants and animals or new effective drug, pharmaceutical chemists first analyze the target molecule. They look for a suitable starting material. The synthesis involves two steps.

- (i) Changes in the carbon skeleton
- (ii) Inter conversion of functional groups.

So, pharmaceutical chemists determine whether the reaction changes the carbon skeleton or inter converts the functional groups. If both the molecules have the same number of carbon atoms, then they can accomplish the synthesis by one or more functional group inter-conversion. If they are of different sizes, then they modify the carbon skeleton. For this they look for a molecule that allows them to make a possible carbon containing skeleton to obtain the product. Then they look for ways to obtain the functional groups of the target molecule.



Activity 11.1

Differentiate between saturated and un-saturated compounds using, iodine bromine and potassium permanganate.

Carry out the following:

- Dissolve 2-3 cm³ of mustard oil in 5 cm³ of carbon tetrachloride. Divide this solution into three parts.
- To one part add few drops of bromine water and shake. What happens?
- To the second part add few drops of iodine solution and shake. What happens?
- To the third part add few drops of dilute alkaline $KMnO_4$ solution and shake (Baeyer's test). What happens?
- Repeat these steps with kerosene oil. What do you observe?

Un-Saturated Compounds Discharge

- i) Reddish brown colour of bromine water.
- ii) Purple colour of iodine solution
- iii) Purple colour of alkaline $KMnO_4$

Saturated compounds do not give these tests.



Activity 11.2

Identifying carboxylic acids, phenols, amines, aldehydes and ketones in terms of functional groups.

Perform this activity in chemistry laboratory

Carry out the following:

i) **Test for carboxylic acids**

- Take 5 cm³ of vinegar in a test tube and a pinch of NaHCO_3 , test the gas evolved with lime water: what happens?
- Dip blue litmus paper in vinegar. What happens? These two tests indicate the presence of carboxylic group in vinegar.

ii) **Test for phenol**

- Dissolve a pinch of carbolic acid (phenol) in 5 cm³ of water in a test tube.
- Add bromine water in the above solution.
- What happens? Phenol gives white ppt with bromine water.

iii) **Test for amine**

- Heat pinch of an amine in 2 cm³ of alcoholic solution of KOH and 0.5 cm³ of chloroform.
- Note the odour of fumes given out.

An amine gives extremely unpleasant or foul odour.

iv) **Test for Aldehyde**

- Mix equal volumes of Fehling's solution A and B in a test tube.
- Add a pinch of glucose init and boil for some time.
- What happens?

Aldehydes give red precipitate with Fehling's solution.

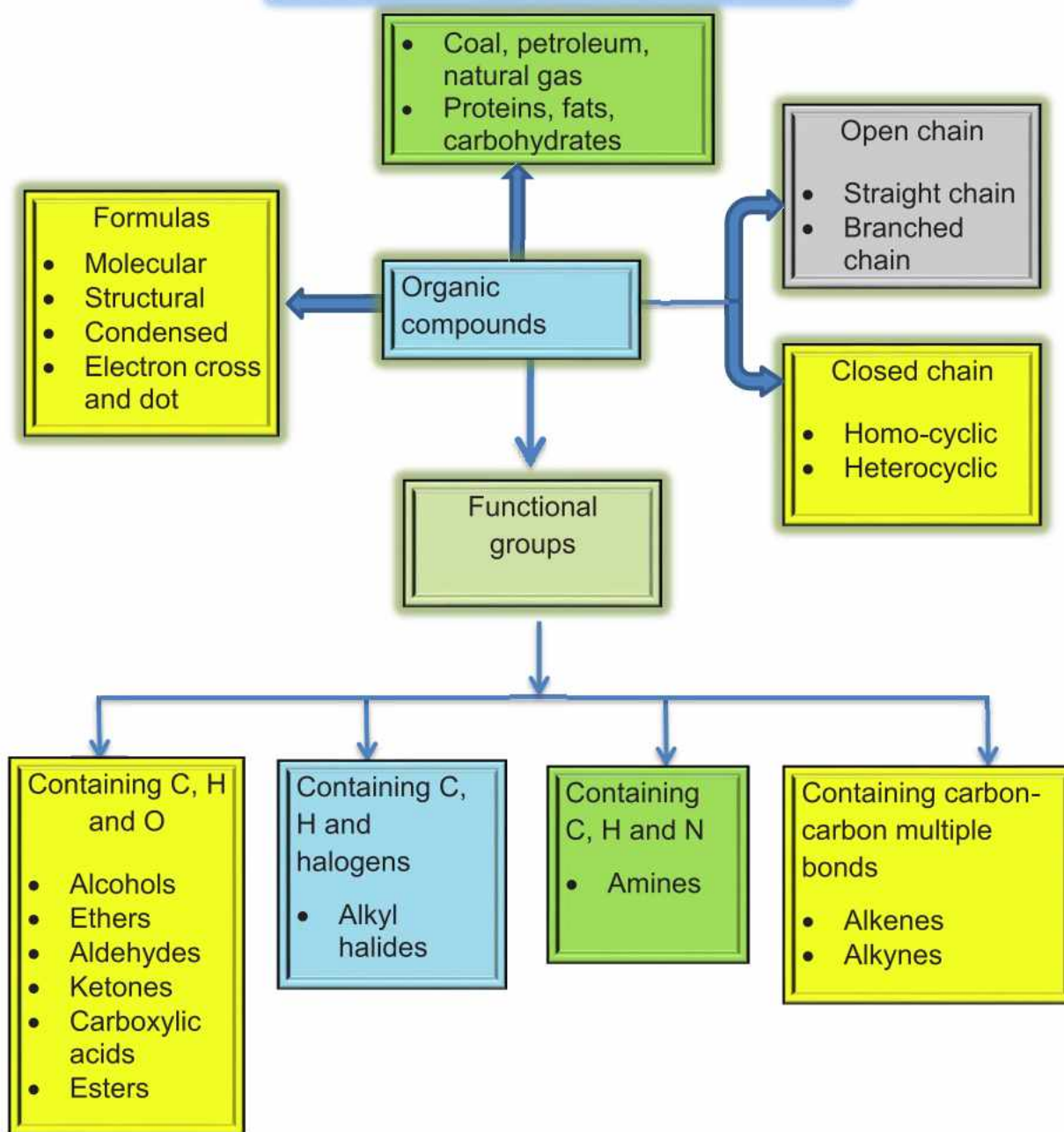
v) **Test for ketone**

- Take 2-3 cm³ of sodium nitro-prusside solution in a test tube and few drops of NaOH solution.
- Add one cm³ of acetone in the above test tube.
- What happens?

Ketones give red colour with alkaline sodium nitro-prusside solution.



Concepts in brief





Key Points

- ❖ The study of hydrocarbons and their derivatives is called organic chemistry.
- ❖ The self-linking ability of carbon atoms is called catenation.
- ❖ Structural formula describes the arrangement of atoms in a molecule.
- ❖ Condensed structural formula shows abbreviations for various group of chain.
- ❖ Hydrocarbons whose carbon-carbon bonds are all single bonds are called saturated hydrocarbons
- ❖ Hydrocarbons containing carbon-carbon multiple bonds are called unsaturated hydrocarbons.
- ❖ The stem is the part of the name of an organic compound that tells the number of carbon atoms in the chain.
- ❖ The suffix in the name of the compound tells the class of compound.
- ❖ Heating the coal in the absence of air at high temperature is called destructive distillation.
- ❖ Destructive distillation of coal gives coal gas, coal tar and coke.
- ❖ Fractional distillation of petroleum gives various hydrocarbon components known as fractions.
- ❖ An alkyl radical is a group of atoms obtained by removing one hydrogen atom from an alkane.
- ❖ Open chain compounds contain an open chain of carbon atoms.
- ❖ Straight chain compounds contain carbon atoms joined one after the other in a chain.
- ❖ Branched chain compounds contain carbon atoms on the side of chain.
- ❖ Cyclic compounds contain rings of carbon atoms.
- ❖ An atom or a group of atoms that give a family of organic compounds, its characteristics properties, is called a functional group.

References for additional information.

- ❖ Chemistry for changing times, John W. Hill, Doris K. Kolb.
- ❖ Longman chemistry for IGCSE, Jin Clark and Ray Oliver.

**Review Question****1. Encircle the correct answer.**

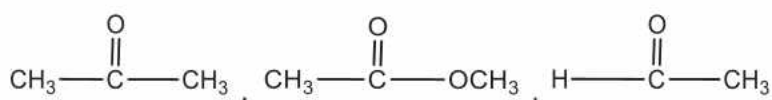
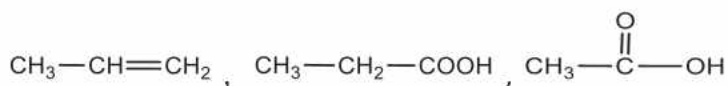
- (i) Condensed structural formula for butane is
(a) $\text{CH}_3\text{-CH}_2\text{-CH}_3$ (b) $\text{CH}_3\text{-CH}_2\text{-CH}_2\text{-CH}_3$
(c) $\text{CH}_3\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_3$ (d) $\text{CH}_3\text{-CH}_3$
- (ii) $\text{CH}_3\text{-CH}_2\text{-CH}_3$ is the chemical formula for
(a) Ethane (b) Propane (c) Butane (d) Pentane
- (iii) Which compound is not a saturated hydrocarbon?
(a) $\text{CH}_3\text{---CH}_3$ (b) CH_4
(c) $\text{CH}_3\text{---CH=CH}_2$ (d) $\text{CH}_3\text{---CH}_2\text{---CH}_3$
- (iv) Stem "But" stands for how many Carbon atoms.
(a) 2 (b) 3 (c) 4 (d) 5
- (v) Pitch is produced by
(a) Coal (b) Coal tar (c) Coal gas (d) Petroleum
- (vi) The functional group $\text{---}\overset{\text{O}}{\underset{\text{||}}{\text{C}}}\text{---}$ is found in
(a) Alcohols (b) Ketones (c) Carboxylic acids (d) Esters
- (vii) In which of the following Compounds, oxygen is attached to two alkyl carbon atoms?
(a) Alcohol (b) Phenol (c) Ether (d) Ester
- (viii) Which of the following is an alcohol?
(a) $\text{CH}_3\text{-CH}_2\text{-O-CH}_2\text{-CH}_3$ (b) $\text{CH}_3\text{-CH}_2\text{-COOH}$
(c) $\text{C}_6\text{H}_5\text{-OH}$ (d) $\text{CH}_3\text{-CH}_2\text{-OH}$
- (ix) The functional group of amines is
(a) -OH (b) -COOH (c) -NH_2 (d) -CHO
- (x) Formic acid contains functional group
(a) -OH (b) -CO- (c) -COOH (d) -CHO

2. Give short answer.

- (i) What is catenation?
(ii) Define isomerism.
(iii) Give three examples of alkyl groups.
(iv) Define a functional group.
(iv) What is the difference between an alkane and an alkyl radical?



3. What do you mean by the term destructive distillation?
4. List some general properties of organic compounds.
5. List major commercial sources of alkanes.
6. Identify the following compounds on the basis of functional groups they contain and encircle the functional group.

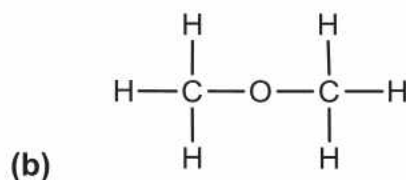
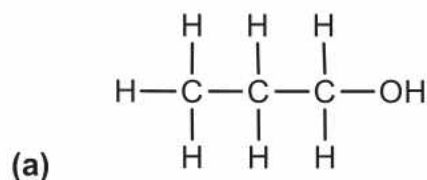


7. What is the name of alkane having seven carbon atoms in the chain?
8. What is the name of the alkyl group obtained by removing an end hydrogen atom from (i) propane (ii) ethane?
9. Give the structural formula of two simple alkanes and one alkyne.
10. What is meant by the term functional group?
11. Identify the type of following compounds as an alcohol, aldehyde or ketone:
 - (a) HCHO , which is used to manufacture polymers, such as urotropine which is used to treat urinary tract infection.
 - (b) CH_3COCH_3 , which is used in nail polish remover.
 - (c) $\text{CH}_3\text{CH}_2\text{OH}$, which is used in the preparation of many organic substances such as plastics, cosmetics, tinctures etc.



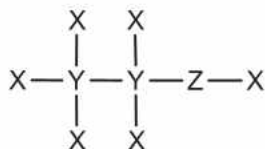
Think-Tank

11. Give molecular formula of a compound containing C, H and O and single bonds. List all the possible functional groups this compound can have?
12. Give the condensed structural formulas of the following compounds and classify each on the basis of functional group.



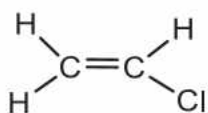


13. The diagram represents an organic compound that contains three different elements.



Select the possible compound from the following.

- a) Ethanoic acid b) Propene c) Ehanol d) Propane.
15. Polyvinyl chloride (PVC) is a polymer. It is used for making vinyl sheets, drainage pipes, wire insulation etc. It is obtained from vinyl chloride

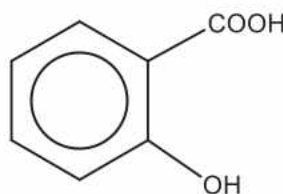


Classify Vinyl chloride as saturated or unsaturated compound.

16. For each of the following, sketch the structural formulas of a two-carbon compound containing the indicated functional group.

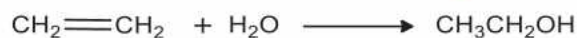
(a) alcohol (b) aldehyde (c) carboxylic acid (d) alkene

17. Aspirin is a mild pain killer and fever reducer. It is manufactured from salicylic acid.



Select functional groups present in it and encircle them. Justify your selection.

18. General formula for alkane is $\text{C}_n\text{H}_{2n+2}$. Construct the general formula for alkyl radical?
19. Water adds to ethene according to the following reaction



Compare the functional groups in the reactant and product molecules.

20. Bonding of carbon atom to heteroatoms increases the number of organic compounds. Justify it.