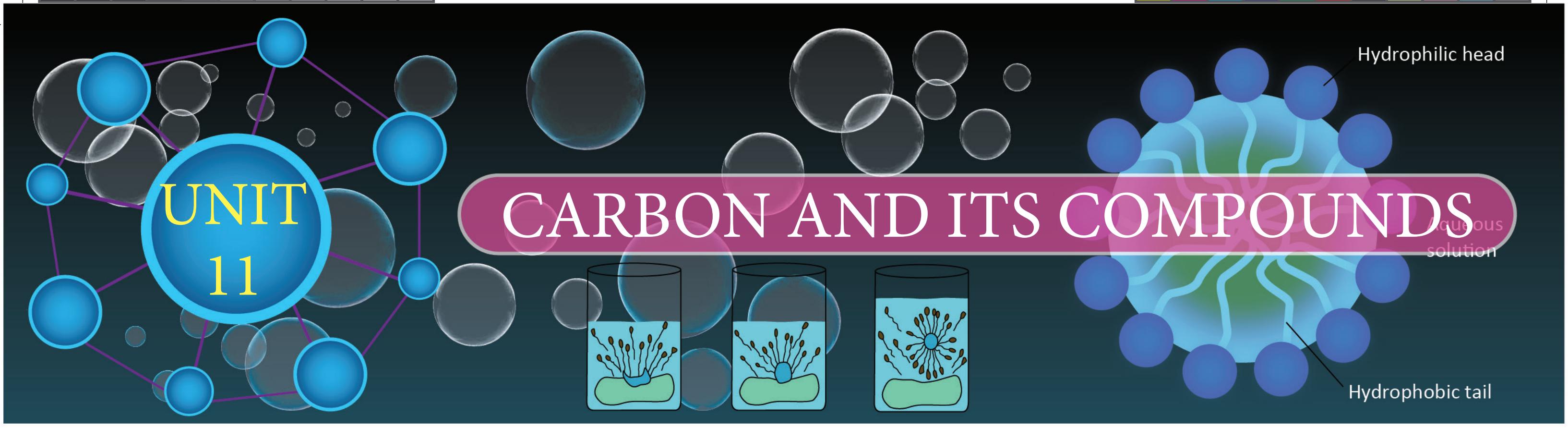

UNIT 11

CARBON AND ITS COMPOUNDS

HV8C7L

Learning Objectives

After studying this lesson, the student will be able to:

- know the importance of organic compounds.
- classify the organic compounds and name them based on IUPAC rules.
- identify the functional groups of organic compounds.
- explain the preparation, properties and uses of ethanol and ethanoic acids.
- know the composition and preparation of soap and detergent.
- understand the cleansing action of soap and detergents.
- differentiate soap and detergents.

INTRODUCTION

You have studied, in your lower classes, that carbon is an inseparable element in human life as we use innumerable number of carbon compounds in our day to day life. Because, the food we eat, medicines we take when ill, clothes we wear; domestic and automobile fuels, paint, cosmetics, automobile parts, etc., that we use contain carbon compounds. The number of carbon compounds found in nature and man-made, is much higher than that of any other element in the periodic table. Infact there are more than 5 million compounds of carbon. The unique nature of carbon, such as catenation, tetravalency and multiple bonding, enables it to combine with itself or other elements like hydrogen, oxygen, nitrogen,sulphur etc., and hence form large number of compounds. All these compounds are made of covalent bonds. These compounds are called **organic compounds.** In this lesson, you will learn about carbon compounds.

11.1 GENERAL CHARACTERISTICS OF ORGANIC COMPOUNDS

Everything in this world has unique character, similarly organic compounds are unique in their characteristics. Some of them are given below:

- Organic compounds have a high molecular weight and a complex structure.
- They are mostly insoluble in water, but soluble in organic solvents such as ether, carbon tetrachloride, toluene, etc.
- They are highly inflammable in nature
- Organic compounds are less reactive compared to inorganic compounds. Hence, the reactions involving organic compounds proceed at slower rates.

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- Mostly organic compounds form covalent bonds in nature.
- They have lower melting point and boiling point when compared to inorganic compounds
- They exhibit the phenomenon of isomerism, in which a single molecular formula represents several organic compounds that differ in their physical and chemical properties
- They are volatile in nature.
- Organic compounds can be prepared in the laboratory

11.2 CLASSIFICATION OF ORGANIC COMPOUNDS BASED ON THE PATTERN OF CARBON CHAIN

What is the significance of classification? There are millions of organic compounds known and many new organic compounds are discovered every year in nature or synthesized in laboratory. This may mystify organic chemistry to a large extent. However, a unique molecular structure can be assigned to each compound and it can be listed by using systematic methods of classification and eventually named on the basis of its structural arrangements. In early days, chemists recognised that compounds having similar structural features have identical chemical properties. So they began to classify compounds based on the common structural arrangements found among them.

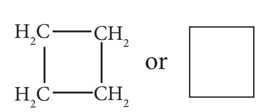
Organic chemistry is the chemistry of catenated carbon compounds. The carbon atoms present in organic compounds are linked with each other through covalent bonds and thus exist as chains. By this way, organic compounds are classified into two types as follows:

1. Acyclic or Open chain compounds: These are the compounds in which the carbon atoms are linked in a linear pattern to form the chain. If all the carbon atoms in the chain are connected by single bonds, the compound is called as **saturated.** If one or more double bonds or triple bonds exist between the carbon atoms, then the compound is said to **unsaturated**.

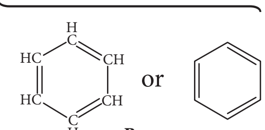
CH_3-CH_2-CH_3	CH_3-CH=CH_2
Propane	Propene
Saturated compound	Unsaturated compound

2. Cyclic Compounds: Organic compounds in which the chain of carbon atoms is closed or cyclic are called **cyclic compounds.** If the chain contains only carbon atoms, such compounds are called **carbocyclic compounds.** If the chain contains carbon and other atoms like oxygen, nitrogen, sulphur, etc., these compounds are called **heterocyclic compounds.** Carbocyclic compounds are further subdivided into **alicyclic** and **aromatic compounds.** Alicyclic compounds contain one or more carbocyclic rings which may be saturated or unsaturated whereas aromatic compounds contain one or more benzene rings (ring containing alternate double bonds between carbon atoms). E.g.

Carbo cyclic compounds

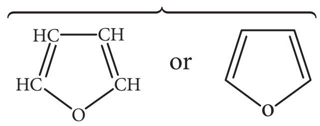


Cyclobutane
Alicyclic Compound



Benzene
Aromatic Compound

Hetrocyclic compounds



Furan

Figure 11.1 depicts the classification of organic compounds based on the pattern of carbon arrangements and their bonding in organic compounds:

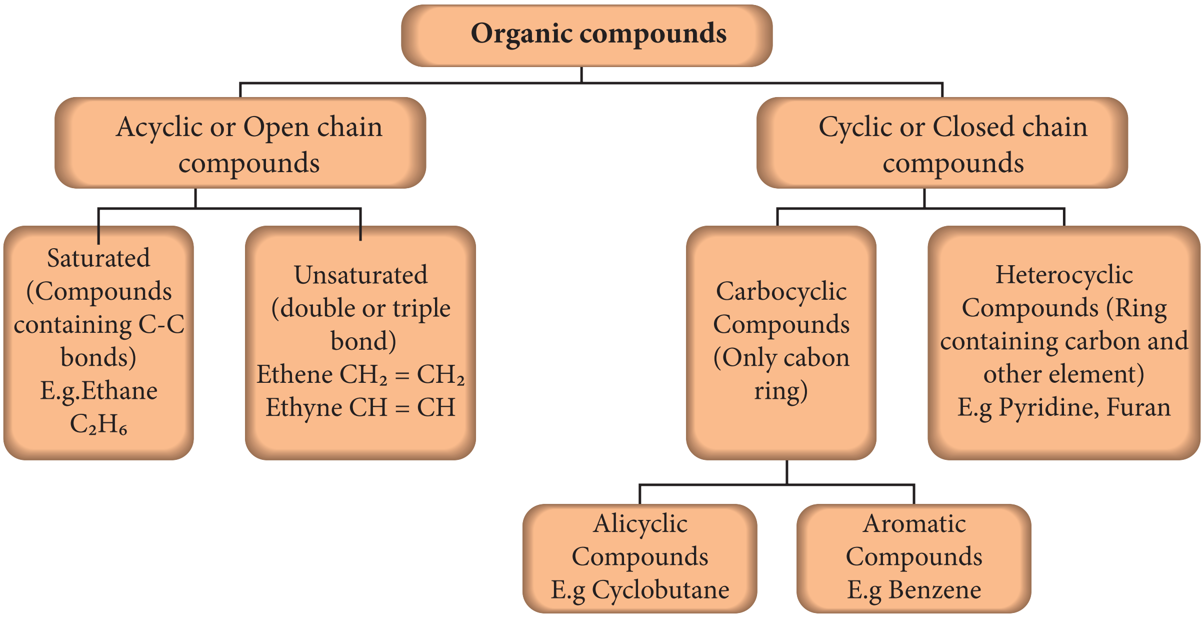


Figure 11.1 Classification of organic compounds

11.3 CLASSES OF ORGANIC COMPOUNDS (BASED ON THE KIND OF ATOMS)

Other than carbon, organic compounds contain atoms like hydrogen, oxygen, nitrogen, etc., bonded to the carbon. Combination of these kinds of atoms with carbon gives different classes of organic compounds. In the following section, let us discuss various classes of organic compounds.

11.3.1 Hydrocarbons

The organic compounds that are composed of only carbon and hydrogen atoms are called **hydrocarbons.** The carbon atoms join together to form the framework of the compounds. These are regarded as the parent organic compounds and all other compounds are considered to be derived from hydrocarbons by replacing one or more hydrogen atoms with other atoms or group of atoms. Hydrocarbons are, further, sub divided into three classes such as:

(a) Alkanes: These are hydrocarbons, which contain only single bonds. They are represented by the general formula C_nH_{2n+2} (where n = 1,2, 3, ……). The simplest alkane (for n=1) is methane (CH_4). Since, all are single bonds in alkanes, they are saturated compounds.

(b) Alkenes: The hydrocarbons, which contain one or more C=C bonds are called alkenes. These are unsaturated compounds. They are represented by the general formula C_nH_{2n}**.** The simplest alkene contains two carbon atoms (n=2) and is called ethylene (C_2H_4).

(c) Alkynes: The hydrocarbons containing carbon to carbon triple bond are called **alkynes.** They are also unsaturated as they contain triple bond between carbon atoms. They have the general formula C_nH_{2n-2}. Acetylene (C_2H_2) is the simplest alkyne, which contains two carbon atoms. Table 11.1 lists the first five hydrocarbons of each class:

Table 11.1 Hydrocarbons containing 1to 5 carbon atoms

No. of carbon atoms	Alkane (C_nH_{2n+2})	Alkene (C_nH_{2n})	Alkyne (C_nH_{2n-2})
1	Methane (CH_4)	-	-
2	Ethane (C_2H_6)	Ethene (C_2H_4)	Ethyne (C_2H_2)
3	Propane (C_3H_8)	Propene (C_3H_6)	Propyne (C_3H_4)
4	Butane (C_4H_{10})	Butene (C_4H_8)	Butyne (C_4H_6)
5	Pentane (C_5H_{12})	Pentene (C_5H_{10})	Pentyne (C_5H_8)

11.3.2 Characteristics of hydrocarbons:

- Lower hydrocarbons are gases at room temperature E.g. methane, ethane are gases.
- They are colourless and odourless.
- The boiling point of hydrocarbons increases with an increase in the number of carbon atoms.
- They undergo combustion reaction with oxygen to form CO_2 and water.
- Alkanes are least reactive when compared to other classes of hydrocarbons.
- Alkynes are the most reactive due to the presence of the triple bond.
- Alkanes are saturated whereas alkenes and alkynes are unsaturated.
- They are insoluble in water.

Test to identify saturated and unsaturated compounds:

- Take the given sample solution in a test tube.
- Add a few drops of bromine water and observe any characteristic change in colour.
- If the given compound is unsaturated, it will decolourise bromine water.
- Saturated compounds do not decolourise bromine.

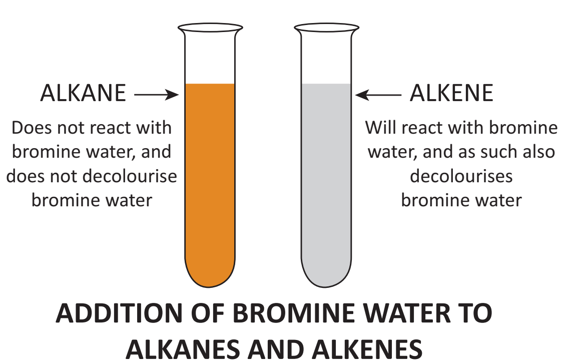


Figure 11.2 Test to identify unsaturated compounds

11.3.3 Classification of organic compounds based on functional groups

The structural frameworks of organic compounds are made of carbon and hydrogen, which are relatively less reactive. But, the presence of some other atoms or group of atoms makes the compounds more reactive and thus determines the chemical properties of the compound. These groups are called **functional groups.**

A functional group is an atom or group of atoms in a molecule, which gives its characteristic chemical properties.

The chemical properties of an organic compound depend on its functional group whereas its physical properties rely on remaining part of the structure. Carbon to carbon multiple bonds (C=C, C≡C) also are considered as functional groups as many of the properties are influenced by these bonds. Other functional groups include atoms of halogens, –OH, –CHO, –COOH, etc.

For example, ethane is a hydrocarbon having molecular formula C_2H_6. If one of its hydrogen is replaced by –OH group, you will get an alcohol. Leaving the functional group, the rest of the structure is represented by '**R**'. Thus an alcohol is represented by 'R-OH'

CH_3-CH_3	CH_3-CH_2-OH ← Functional Group
Ethane	Ethanol
Hydrocarbon	Alcohol

A series of compounds containing the same functional group is called a **class of organic compounds.** Table 11.2 shows various classes or families of organic compounds and their functional groups:

Table 11.2 Classes of organic compounds based on functional group

Class of the compound	Functional group	Common Formula	Examples
Alcohols	–OH	R-OH	Ethanol, CH_3CH_2OH
Aldehydes	$\overset{O}{\overset{\Vert}{-C-H}}$	R-CHO	Acetaldehyde, CH_3CHO
Ketones	$\overset{O}{\overset{\Vert}{-C-}}$	R–CO-R	Acetone, CH_3COCH_3
Carboxylic acids	$\overset{O}{\overset{\Vert}{-C-OH}}$	R-COOH	Acetic acid, CH_3COOH
Ester	$\overset{O}{\overset{\Vert}{-C-OR}}$	R-COOR	Methyl acetate, CH_3COOCH_3
Ether	–O–R	R-O-R	Dimethyl ether, CH_3OCH_3

11.4 HOMOLOGOUS SERIES

Homologous series is a group or a class of organic compounds having same general formula and similar chemical properties in which the successive members differ by a -CH_2 group.

Let us consider members of alkanes given in Table 11.1. Their condensed structural formulas are given below:

Methane	-	CH_4
Ethane	-	CH_3CH_3
Propane	-	$CH_3CH_2CH_3$
Butane	-	$CH_3(CH_2)_2CH_3$
Pentane	-	$CH_3(CH_2)_3CH_3$

If you observe the above series. you can notice that each successive member has one methylene group more than the precedent member of the series and hence they are called homologs.

11.4.1 Characteristics of homologous series

- Each member of the series differs from the preceding or succeeding member by one methylene group (–CH_2) and hence by a molecular mass of 14 amu.
- All members of a homologous series contain the same elements and functional group.
- They are represented by a general molecular formula. e.g. Alkanes, C_nH_{2n+2}.
- The members in each homologous series show a regular gradation in their physical properties with respect to their increase in molecular mass.
- Chemical properties of the members of a homologous series are similar.
- All the members can be prepared by a common method.

11.5 NOMENCLATURE OF ORGANIC COMPOUNDS

11.5.1 Why do we need nomenclature?

In ancient days, the names of organic compounds were related to the natural things from which they were obtained. For example, the formic acid was initially obtained by distillation of 'red ants'. Latin name of the red ant is 'Formica'. So, the name of the formic acid was derived from the Latin name of its source Later, the organic compounds were synthesized from sources other than the natural sources. So scientists framed a systematic method for naming the organic compounds based on their structures. Hence, a set of rules was formulated by IUPAC (**International Union of Pure and Applied Chemistry)** for the nomenclature of chemical compounds.

11.5.2 Components of an IUPAC name

The IUPAC name of the any organic compound consists of three parts:

i. Root word
ii. Prefix
iii. Suffix

These parts are combined as per the following sequence to get the IUPAC name of the compound:

Prefix + Root Word + Suffix ⟶ IUPAC Name

(i) Root word: It is the basic unit, which describes the carbon skeleton. It gives the number of carbon atoms present in the parent chain of the compound and the pattern of their arrangement. Based on the number of carbon atoms present in the carbon skeleton, most of the names are derived from Greek numerals (except the first four). Table 11.3 shows the root words for the parent chain of hydrocarbons containing 1to10 carbon atoms:

Table 11.3 Root words of hydrocarbons

No. of carbon atoms	Root word
1	Meth-
2	Eth-
3	Prop-
4	But-
5	Pent-
6	Hex-
7	Hept-
8	Oct-
9	Non-
10	Dec-

(ii) Prefix: The prefix represents the substituents or branch present in the parent chain. Atoms or group of atoms, other than hydrogen, attached to carbon of the parent chain are called substituents. Table 11.4 presents the major substituents of organic compounds and respective prefix used for them:

Table 11.4 Prefix for IUPAC Name

Substituent	Prefix used
-F	Fluoro
-Cl	Chloro
-Br	Bromo
-I	Iodo
$-NH_2$	Amino
$-CH_3$	Methyl
$-CH_2CH_3$	Ethyl

(iii) Suffix

The suffix forms the end of the name. It is divided into two parts such as **(a) Primary suffix** and **(b) Secondary suffix.** The primary suffix comes after the root word. **It represents the nature in carbon to carbon bonding of the parent chain**. If all the bonds between the carbon atoms of the parent chain are single, then suffix **'ane'** has to be used. Suffix **'ene'** and **'yne'** are used for the compounds containing double and triple bonds respectively. **The secondary suffix describes the functional group of the compound**.

Table 11.5 Suffix for IUPAC Name

Class of the Compound	Functional group	Suffix used
Alcohols	–OH	-ol
Aldehydes	–CHO	-al
Ketones	$\overset{O}{\overset{\|\|}{-C-}}$	-one
Carboxylic acids	–COOH	-oic acid

11.5.3 IUPAC rules for naming organic compounds:

- **Rule1:** Identify the longest chain of carbon atoms to get the parent name (root word).
- **Rule 2:** Number the carbon atoms of the parent chain, **beginning at the closest end of the substituent or functional group**. These are called **locant numbers**. *If both functional group and substituent are present, then the priority will be given to the functional group.*
- **Rule 3:** In case of alkenes and alkynes, locate the double bond or triple bond and use its locant number followed by a dash and a primary suffix. The carbon chain is numbered in such a way that the multiple bonds have the lowest possible locant number.
- **Rule 4:** If the compound contains functional group, locate it and use its locant number followed by a dash and a secondary suffix.
- **Rule 5:** When the primary and secondary suffixes are joined, the terminal 'e' of the primary suffix is removed.
- **Rule 6:** Identify the substituent and use a number followed by a dash and a prefix to specify its location and identity.

11.5.4 IUPAC Nomenclature of hydrocarbons – Solved examples

Let us try to name, systematically, some of the linear and substituted hydrocarbons by following IUPAC rules:

Example 1: CH_3-CH_2-CH_2-CH_2-CH_3

Step 1: It is a five- carbon chain and hence the root word is 'Pent'. (Rule 1)

Step 2: All the bonds between carbon atoms are single bonds, and thus the suffix is 'ane'.

So, its name is **Pent + ane = Pentane**

Example 2:

$$\begin{array}{l} CH_3 \\ | \\ CH_3-CH-CH_2-CH_2-CH_3 \end{array}$$

Step 1: The longest chain contains five carbon atoms and hence the root word is 'Pent'.

Step 2: There is a substituent. So, the carbon chain is numbered from the left end, which is closest to the substituent. (Rule 2)

$$\begin{array}{l} CH_3 \\ | \\ \overset{1}{CH_3}-\overset{2}{CH}-\overset{3}{CH_2}-\overset{4}{CH_2}-\overset{5}{CH_3} \\ \xrightarrow{\hspace{12em}} \end{array}$$

Step 2: All are single bonds between the carbon atoms and thus the suffix is 'ane'.

Step 3: The substituent is a methyl group and it is located at second carbon atom. So, its locant number is 2. Thus the prefix is '2-Methyl'. (Rule 6).

The name of the compound is

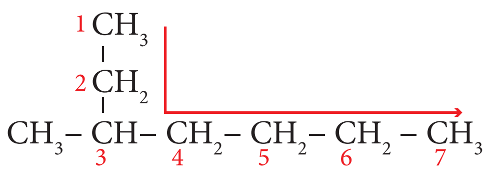
2-Methyl + pent +ane = 2-Methylpentane

Example 3:

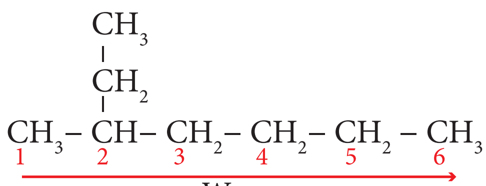
$$\begin{array}{l} CH_3 \\ | \\ CH_2 \\ | \\ CH_3-CH-CH_2-CH_2-CH_2-CH_3 \end{array}$$

Step 1: The longest chain contains seven carbon atoms and hence the root word is 'Hept'.

Step 2: There is a substituent. So, the carbon chain is numbered from the end, which is closest to substituent. (Rule 2)



Correct



Wrong

Step 2: All are single bonds between the carbon atoms and thus the suffix is 'ane'.

Step 3: The substituent is a methyl group and it is located at third carbon. So, its locant number is 3. Thus the prefix is '3-Methyl'. (Rule 6)

Hence the name of the compound is **3-Methyl + hept + ane = 3 –Methylheptane**

Example 4: CH_3-CH_2-CH_2-CH=CH_2

Step 1: It is a 'five- carbon atoms chain' and hence the root word is 'Pent'. (Rule 1)

Step 2: There is a carbon to carbon double bond. The suffix is 'ene'.

Step 3: The carbon chain is numbered from the end such that double bond has the lowest locant number as shown below: (Rule 3):

$$\overset{5}{CH_3}-\overset{4}{CH_2}-\overset{3}{CH_2}-\overset{2}{CH}=\overset{1}{CH_2}$$

Step 4: The locant number of the double bond is 1 and thus the suffix is '-1-ene'.

So, the name of the compound is **Pent + (-1-ene) = Pent-1-ene**

11.5.5 IUPAC Nomenclature of other classes – Solved examples

Example 1: CH_3-CH_2-CH_2-OH

Step1: The parent chain consists of 3 carbon atoms. The root word is 'Prop'.

Step 2: There are single bonds between the carbon atoms of the chain. So, the **primary suffix** is 'ane'.

Step 3: Since, the compound contains –OH group, it is an alcohol. The carbon chain is numbered from the end which is closest to –OH group. (Rule 3)

$$\overset{3}{CH_3}-\overset{2}{CH_2}-\overset{1}{CH_2}-OH$$

Step 4: The locant number of –OH group is 1 and thus the secondary suffix is '1-ol'.

The name of the compound is **Prop + ane + (1-ol) = Propan-1-ol**

Note: Terminal 'e' of 'ane' is removed as per Rule 5

Example 2: CH_3COOH

Step1: The parent chain consists of 2 carbon atoms. The root word is 'Eth'.

Step 2: All are single bonds between the carbon atoms of the chain. So the primary suffix is 'ane'.

Step 3: Since the compound contains the–COOH group, it is a carboxylic acid. The secondary suffix is 'oic acid'

The name of the compound is **Eth + ane + oic acid) = Ethanoic acid**

Table 11.6 lists IUPAC names homologs of various classes of organic compounds

Test yourself:

Obtain the IUPAC name of the following compounds systematically:

(a) CH_3CHO

(b) $CH_3CH_3COCH_3$

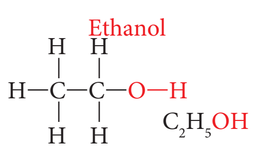
(c) $ClCH_2$-CH_2-CH_2-CH_3

Table 11.6 IUPAC Name of various classes of compounds

No. of carbons atoms	IUPAC Name			
	Alcohols	Aldehydes	Ketones	Carboxylic acid
1	Methanol (CH_3OH)	Methanal ($HCHO$)	-	Methanoic acid ($HCOOH$)
2	Ethanol (CH_3CH_2OH)	Ethanal (CH_3CHO)	-	Ethanoic acid (CH_3COOH)
3	Propanol ($CH_3CH_2CH_2OH$)	Propanal (CH_3CH_2CHO)	Propanone (CH_3COCH_3)	Propanoic acid (CH_3CH_2COOH)
4	Butanol ($CH_3CH_2CH_2CH_2OH$)	Butanal ($CH_3CH_2CH_2CHO$)	Butanone ($CH_3COCH_2CH_3$)	Butanoic acid ($CH_3CH_2CH_2COOH$)
5	Pentanol ($CH_3CH_2CH_2CH_2CH_2OH$)	Pentanal ($CH_3CH_2CH_2CH_2CHO$)	Pentanone ($CH_3COCH_2CH_2CH_3$)	Pentanoic acid ($CH_3CH_2CH_2CH_2COOH$)

11.6 ETHANOL (CH_3CH_2OH)

Ethanol is commonly known as alcohol. All alcoholic beverages and some cough syrups contain ethanol. Its molecular formula is C_2H_5OH. Its structural formula is



11.6.1 Manufacture of ethanol

Ethanol is manufactured in industries by the fermentation of molasses, which is a by-product obtained during the manufacture of sugar from sugarcane. Molasses is a dark coloured syrupy liquid left after the crystallization of sugar from the concentrated sugarcane juice. Molasses contain about 30% of sucrose, which cannot be separated by crystallization. It is converted into ethanol by the following steps:

(i) Dilution of molasses

Molasses is first diluted with water to bring down the concentration of sugar to about 8 to 10 percent.

(ii) Addition of Nitrogen source

Molasses usually contains enough nitrogenous matter to act as food for yeast during the fermentation process. If the nitrogen content of the molasses is poor, it may be fortified by the addition of **ammonium sulphate** or **ammonium phosphate**.

(iii) Addition of Yeast

The solution obtained in step (ii) is collected in large 'fermentation tanks' and yeast is added to it. The mixture is kept at about 303K for a few days. During this period, the enzymes invertase and zymase present in yeast, bring about the conversion of sucrose into ethanol.

$$\underset{\text{Sugar}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{\text{invertase}} \underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{fructose}}{C_6H_{12}O_6}$$

$$\underset{\text{glucose or fructose}}{C_6H_{12}O_6} \xrightarrow{\text{zymase}} \underset{\text{ethanol}}{2C_2H_5OH} + 2\,CO_2$$

The fermented liquid is technically called **wash**.

(iv) Distillation of 'Wash'

The fermented liquid (i.e. wash), containing 15 to 18 percent alcohol, is now subjected to fractional distillation. The main fraction drawn is an aqueous solution of ethanol which contains

95.5% of ethanol and 4.5% of water. This is called **rectified spirit**. This mixture is then refluxed over quicklime for about 5 to 6 hours and then allowed to stand for 12 hours. On distillation of this mixture, pure alcohol (100%) is obtained. This is called **absolute alcohol**.

More to know

Yeast and Fermentation: Yeasts are single–celled microorganisms, belonging to the class of fungi. The enzymes present in yeasts catalyse many complex organic reactions. Fermentation is conversion of complex organic molecules into simpler molecules by the action of enzymes. E.g. Curdling of milk

11.6.2 Physical properties

i) Ethanol is a colourless liquid, having a pleasant smell and a burning taste.

ii) It is a volatile liquid. Its boiling point is 78° C (351K), which is much higher than that of its corresponding alkane, i.e. ethane (Boiling Point = 184 K).

iii) It is completely miscible with water in all proportions.

11.6.3 Chemical Properties

(i) Dehydration (Loss of water)

When ethanol is heated with con H_2SO_4 at 443K, it loses a water molecule i.e. dehydrated to form ethene.

$$\underset{\text{Ethanol}}{CH_3CH_2OH} \xrightarrow[443K]{Conc.H_2SO_4} \underset{\text{Ethene}}{CH_2 = CH_2} + H_2O$$

(ii) Reaction with sodium:

Ethanol reacts with sodium metal to form sodium ethoxide and hydrogen gas.

$$2C_2H_5OH + 2Na \longrightarrow \underset{\text{sodium ethoxide}}{2C_2H_5ONa} + H_2 \uparrow$$

(iii) Oxidation:

Ethanol is oxidized to ethanoic acid with alkaline $KMnO_4$ or acidified $K_2Cr_2O_7$

$$CH_3CH_2OH \xrightarrow[2[O]]{K_2Cr_2O_7 / H^+} \underset{\text{Ethanoic acid}}{CH_3COOH} + H_2O$$

During this reaction, the orange colour of $K_2Cr_2O_7$ changes to green. Therefore, this reaction can be used for the identification of alcohols.

(iv) Esterification:

The reaction of an alcohol with a carboxylic acid gives a compound having fruity odour. This compound is called an **ester** and the reaction is called esterification. Ethanol reacts with ethanoic acid in the presence of conc. H_2SO_4 to form ethyl ethanoate, an ester.

$$\underset{\text{Ethanol}}{C_2H_5OH} + \underset{\text{Ethanoic acid}}{CH_3COOH} \xrightarrow{conc.H_2SO_4} \underset{\text{Ethyl ethanoate}}{CH_3COOC_2H_5} + H_2O$$

(v) Dehydrogenation:

When the vapour of ethanol is passed over heated copper, used as a catalyst at 573 K, it is dehydrogenated to acetaldehyde.

$$\underset{\text{Ethanol}}{CH_3CH_2OH} \xrightarrow[573K]{Cu} \underset{\text{Acetadehyde}}{CH_3CHO} + H_2\uparrow$$

(vi) Combustion:

Ethanol is highly inflammable liquid. It burns with oxygen to form carbon dioxide and water.

$$\underset{\text{Ethanol}}{C_2H_5OH} + 3O_2 \longrightarrow \underset{\text{Carbon dioxide}}{2CO_2} + 3H_2O$$

11.6.4 Uses of ethanol

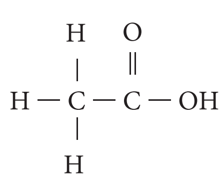
Ethanol is used

- in medical wipes, as an antiseptic.
- as an anti-freeze in automobile radiators.
- for effectively killing micro organisms like bacteria, fungi, etc., by including it in many hand sanitizers.

- as an antiseptic to sterilize wounds in hospitals.
- as a solvent for drugs, oils, fats, perfumes, dyes, etc.
- in the preparation of **methylated spirit** (mixture of 95% of ethanol and 5% of methanol) **rectified spirit** (mixture of 95.5% of ethanol and 4.5% of water), power alcohol (mixture of petrol and ethanol) and denatured spirit (ethanol mixed with pyridine).
- to enhance the flavour of food extracts, for example vanilla extract; a common food flavour, which is made by processing vanilla beans in a solution of ethanol and water.

11.7 ETHANOIC ACID (CH_3COOH)

Ethanoic acid or acetic acid is one of the most important members of the carboxylic acid family. Its molecular formula is $C_2H_4O_2$. Its structural formula is



11.7.1 Manufacture of ethanoic acid

Ethanoic acid is prepared in large scale, by the oxidation of ethanol in the presence of alkaline potassium permanganate or acidified potassium dichromate.

$$\underset{\text{Ethanol}}{CH_3CH_2OH} \xrightarrow[2[O]]{KMnO_4/\ OH^-} \underset{\text{Ethanoic acid}}{CH_3COOH + H_2O}$$

11.7.2 Physical Properties

(i) Ethanoic acid is a colourless liquid having an unpleasant odour.

(ii) It is sour in taste.

(iii) It is miscible with water in all proportions.

(iv) Its boiling point is higher than the corresponding alcohols, aldehydes and ketones.

(v) On cooling, pure ethanoic acid is frozen to form ice like flakes. They look like glaciers, so it is called **glacial acetic acid.**

11.7.3 Chemical Properties

(i) **Reaction with metal:** Ethanoic acid reacts with active metals like Na, Zn, etc., to liberate hydrogen and form sodium ethanoate.

$$2CH_3COOH + Zn \rightarrow (CH_3COO)_2\,Zn + H_2\uparrow$$

$$2CH_3COOH + 2Na \rightarrow 2CH_3COONa + H_2\uparrow$$

(ii) **Reaction with carbonates and bicarbonates:** Ethanoic acid reacts with sodium carbonate and sodium bicarbonate, which are weaker bases and liberates CO_2, with brisk effervescence.

$$2CH_3COOH + Na_2CO_3 \rightarrow 2CH_3COONa + CO_2\uparrow + H_2O$$

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

(iii) **Reaction with base:** Ethanoic acid reacts with sodium hydroxide to form sodium ethanoate and water.

$$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$$

(iv) **Decarboxylation (Removal of CO_2):**

When a sodium salt of ethanoic acid is heated with soda lime (solid mixure of 3 parts of NaOH and 1 part of CaO), methane gas is formed.

$$CH_3COONa \xrightarrow{NaOH\ /\ CaO} CH_4\uparrow + Na_2CO_3$$

11.7.4 Uses of ethanoic acid

Acetic acid, in lower concentration, is used as a food additive, a flavoring agent and a preservative.

Ethanoic acid is used

- in the manufacture of plastic.
- in making dyes, pigments and paint.
- in printing on fabrics.
- as a laboratory reagent.
- for coagulating rubber from latex.
- in the production of pharmaceuticals.

11.8 ORGANIC COMPOUNDS IN DAILY LIFE

Organic compounds are inseparable in human life. They are used by mankind or associated at all stages of life right from one's birth to death. Various classes of organic compounds and their uses in our daily life as follows:

Hydrocarbons

- Fuels like LPG, Petrol, Kerosene.
- Raw materials for various important synthetic materials.
- Polymeric materials like tyre, plastic containers.

Alcohols

- As a solvent and an antiseptic agent.
- Raw materials for various important synthetic materials.

Aldehydes

- Formaldehyde as a disinfectant.
- Raw materials for synthetic materials.

Ketones

- As a solvent.
- Stain Remover.

Ethers

- Anaesthetic agents.
- Pain Killer.

Esters

- All the cooking oils and lipids contain esters.

11.9 SOAPS AND DETERGENTS

Soaps and the Detergents are materials that are used by us for cleaning purposes because pure water alone cannot remove all types of dirt or any oily substance from our body or clothes. They contain 'surfactants', which are compounds with molecules that line up around water to break the 'surface tension'. Both of them having a different chemical nature. ***Soap*** is a cleaning agent that is composed of one or more salts of fatty acids. ***Detergent*** is a chemical compound or a mixture of chemical compounds, which is used as a cleaning agent, also. They perform their cleaning actions in certain specific conditions. You will learn more about this in detail, in the following units.

11.9.1 Soap

Soaps are sodium or potassium salts of some long chain carboxylic acids, called fatty acids. Soap requires two major raw materials: i) fat and ii) alkali. The alkali, most commonly used in the preparation of soap is sodium hydroxide. Potassium hydroxide can also be used. A potassium-based soap creates a more water-soluble product than a sodium-based soap. Based on these features, there are two types of soaps:

A. HARD SOAP

Soaps, which are prepared by the ***saponification of oils or fats with caustic soda*** (sodium hydroxide), are known as hard soaps. They are usually used for washing purposes.

B. SOFT SOAP

Soaps, which are prepared by the ***saponification of oils or fats with potassium salts***, are known as soft soaps. They are used for cleansing the body.

Manufacture of soap

KETTLE PROCESS:

This is the oldest method. But, it is still widely used in the small scale preparation of soap. There are mainly, two steps to be followed in this process.

i) Saponification of oil:

The oil, which is used in this process, is taken in an iron tank (kettle). The alkaline solution (10%) is added into the kettle, a little in excess. The mixture is boiled by passing steam through it. The oil gets hydrolysed after several hours of boiling. This process is called Saponification

ii) Salting out of soap:

Common salt is then added to the boiling mixture. Soap is finally precipitated in the tank. After several hours the soap rises to the top of the liquid as a 'curdy mass'. The neat soap is taken off from the top. It is then allowed to cool down.

Effect of hard water on soap

Hard water contains calcium and magnesium ions (Ca^{2+} and Mg^{2+}) that limit the cleaning action of soap. When combined with soap, hard water develops a thin layer (precipitates of the metal ions) called 'scum', which leaves a deposit on the clothes or skin and does not easily rinse away. Over time, this can lead to the deterioration of the fabric and eventually ruin the clothes. On the other hand, detergents are made with chemicals that are not affected by hard water.

DO YOU KNOW?

Why ordinary soap is not suitable for using with hard water?

Ordinary soaps when treated with hard water, precipitate as salts of calcium and magnesium. **They appear at the surface of the cloth as sticky grey scum.** Thus, the soaps cannot be used conveniently in hard water.

11.9.2 Detergents

Development of synthetic detergents is a big achievement in the field of cleansing. These soaps possess the desirable properties of ordinary soaps and also can be used with hard water and in acidic solutions. These are salts of sulphonic acids or alkyl hydrogen sulphates in comparison to soap, which are salts of carboxylic acids. The detergents do not form precipitates with Ca^{2+} and Mg^{2+} present in hard water. So, the cleansing action of detergents is better than that of soaps.

Preparation of detergents

Detergents are prepared by adding sulphuric acid to the processed hydrocarbon obtained from petroleum. This chemical reaction result in the formation of molecules similar to the fatty acid in soap. Then, an alkali is added to the mixture to produce the 'surfactant molecules', which do not bond with the minerals present in the hard water, thus preventing the formation of their precipitates.

In addition to a 'surfactant', the modern detergent contains several other ingredients. They are listed as follows:

i) Sodium silicate, which prevents the corrosion and ensures that the detergent does not damage the washing machine.

ii) Fluorescent whitening agents that give a glow to the clothes.

iii) Oxygen bleaches, such as 'sodium perborate', enable the removal of certain stains from the cloth.

iv) Sodium sulphate is added to prevent the caking of the detergent powder.

v) Enzymes are added to break down some stains caused by biological substances like blood and vegetable juice.

vi) Certain chemicals that give out a pleasant smell are also added to make the clothes fragrant after they are washed with detergents.

11.9.3 Cleansing action of soap

A soap molecule contains two chemically distinct parts that interact differently with water. It has one **polar end**, which is a ***short head*** with a carboxylate group (–COONa) and one **non-polar end** having the ***long tail made of the hydrocarbon chain***.

The polar end is ***hydrophilic (Water loving)*** in nature and this end is attracted towards water. The non-polar end is ***hydrophobic (Water hating)*** in nature and it is attracted towards dirt or oil on the cloth, but not attracted towards water. Thus, the hydrophobic part of the soap molecule traps the dirt and the hydrophilic part makes the entire molecule soluble in water.

When a soap or detergent is dissolved in water, the molecules join together as clusters called '**micelles**'. Their long hydrocarbon chains attach themselves to the oil and dirt. The dirt is thus surrounded by the non-polar end of the soap molecules (Figure 11.3). The charged carboxylate end of the soap molecules makes the micelles soluble in water. Thus, the dirt is washed away with the soap.

Advantages of detergents over soaps

Detergents are better than soaps because they:

- can be used in both hard and soft water and can clean more effectively in hard water than soap.
- can also be used in saline and acidic water.
- do not leave any soap scum on the tub or clothes.
- dissolve freely even in cool water and rinse freely in hard water.
- can be used for washing woollen garments, where as soap cannot be used.
- have a linear hydrocarbon chain, which is biodegradable.
- are active emulsifiers of motor grease.
- do an effective and safe cleansing, keeping even synthetic fabrics brighter and whiter.

Biodegradable and Non-biodegradable detergents:

a) Biodegradable detergents:

They have straight hydrocarbon chains, which can be easily degraded by bacteria.

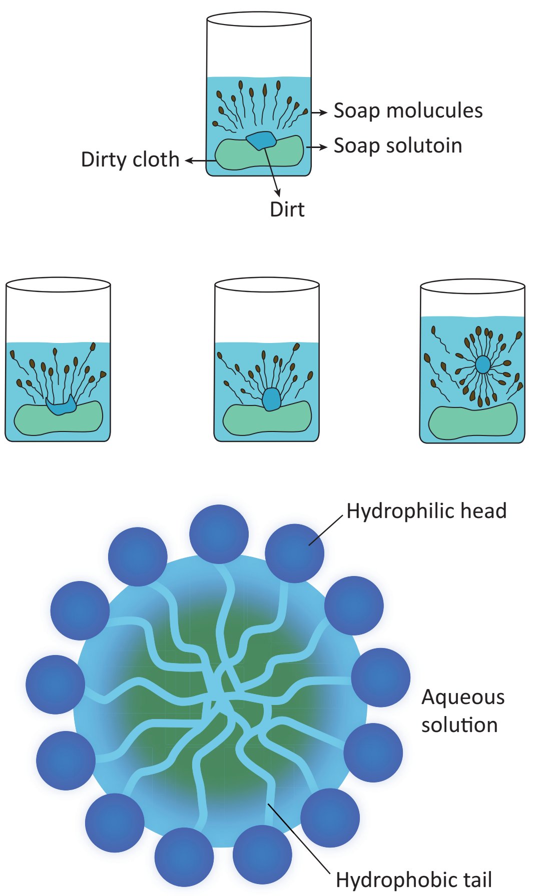


Figure 11.3 Cleansing action of soap

b) Non-biodegradable detergents:

They have highly branched hydrocarbon chains, which cannot be degraded by bacteria.

Disadvantages of Detergents

1. Some detergents having a branched hydro-carbon chain are not fully biodegradable by micro-organisms present in water. So, they cause water pollution.
2. They are relatively more expensive than soap.

11.9.4 Comparison between soap and detergents

Soap	Detergent
It is a sodium salt of long chain fatty acids.	It is sodium salts of sulphonic acids.
The ionic part of a soap is $-COO^{-}Na^{+}$.	The ionic part in a detergent is $-SO_3^{-}Na^{+}$.
It is prepared from animal fats or vegetable oils.	It is prepared from hydrocarbons obtained from crude oil.
Its effectiveness is reduced when used in hard water.	It is effective even in hard water.
It forms a scum in hard water.	Does not form a scum in hard water.
It has poor foaming capacity.	It has rich foaming capacity.
Soaps are biodegradable.	Most of the detergents are non-biodegradable.

Have you noticed the term "TFM" in soap

TFM means TOTAL FATTY MATTER. It is the one of the important factors to be considered to assess the quality of soap. A soap, which has higher TFM, is a good bathing soap.

Points to Remember

- A group or class of organic compounds related to each other by a general molecular formula constitutes homologous series.
- The IUPAC name of the any organic compound consist of three parts. **ROOTWORD, PREFIX and / or SUFFIX.**
- Functional group may be defined as an atom or group of atom or reactive part which is responsible for the characteristic properties of the compounds
- Ethanoic acid is most commonly known as acetic acid and belongs to a group of acids called carboxylic acids.
- Acetic acid is present in many fruits and it renders a sour taste to those fruits.
- Ethanol or ethyl alcohol or simply alcohol is one of the most important members of the family of alcohols.
- The slow chemical change that takes place in complex organic compounds by the action of enzymes leading to the formation of simple molecules is called fermentation.
- Soaps are sodium or potassium salts of some long chain carboxylic acids.
- Detergents are sodium salts of sulphonic acids. Thus instead of $-COOH$ group in soaps, detergents contain $-SO_3H$ group

TEXTBOOK EVALUATION

IQA2A9

I. Choose the best answer.

1. The molecular formula of an open chain organic compound is C_3H_6. The class of the compound is
   a. alkane b. alkene
   c. alkyne d. alcohol

2. The IUPAC name of an organic compound is 3-Methyl butan-1-ol. What type compound it is?
   a. Aldehyde b. Carboxylic acid
   c. Ketone d. Alcohol

3. The secondary suffix used in IUPAC nomenclature of an aldehyde is ____
   a. - ol b. – oic acid
   c. - al d. - one

4. Which of the following pairs can be the successive members of a homologous series?
   a. C_3H_8 and C_4H_{10}
   b. C_2H_2 and C_2H_4
   c. CH_4 and C_3H_6
   d. C_2H_5OH and C_4H_8OH

5. $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$ is a
   a. Reduction of ethanol
   b. Combustion of ethanol
   c. Oxidation of ethanoic acid
   d. Oxidation of ethanal

6. Rectified spirit is an aqueous solution which contains about _______ of ethanol
   a. 95.5 % b. 75.5 %
   c. 55.5 % d. 45.5 %

7. Which of the following are used as anaesthetics?
   a. Carboxylic acids b. Ethers
   c. Esters d. Aldehydes

8. TFM in soaps represents ___________ content in soap
   a. mineral b. vitamin
   c. fatty acid d. carbohydrate

9. Which of the following statements is wrong about detergents?
   a. It is a sodium salt of long chain fatty acids
   b. It is sodium salts of sulphonic acids
   c. The ionic part in a detergent is $-SO_3^-Na^+$
   d. It is effective even in hard water.

II. Fill in the blanks

1. An atom or a group of atoms which is responsible for chemical characteristics of an organic compound is called ____________.
2. The general molecular formula of alkynes is ______________
3. In IUPAC name, the carbon skeleton of a compound is represented by _________ (root word / prefix / suffix)
4. (Saturated / Unsaturated) ___________ compounds decolourize bromine water.
5. Dehydration of ethanol by conc. Sulphuric acid forms _______ (ethene/ ethane)
6. 100 % pure ethanol is called ____________
7. Ethanoic acid turns _______ litmus to _________
8. The alkaline hydrolysis of fatty acids is termed as _____________
9. Biodegradable detergents are made of _________(branched / straight) chain hydrocarbons

III. Match the following

Functional group –OH	-	Benzene
Heterocyclic	-	Potassium stearate
Unsaturated	-	Alcohol
Soap	-	Furan
Carbocyclic	-	Ethene

IV. Assertion and Reason:

Answer the following questions using the data given below:

i) A and R are correct, R explains the A.

ii) A is correct, R is wrong.

iii) A is wrong, R is correct.

iv) A and R are correct, R doesn't explains A.

1. **Assertion**: Detergents are more effective cleansing agents than soaps in hard water.

   Reason: Calcium and magnesium salts of detergents are water soluble.

2. **Assertion**: Alkanes are saturated hydrocarbons.

   Reason: Hydrocarbons consist of covalent bonds.

V. Short answer questions

1. Name the simplest ketone and give its structural formula.
2. Classify the following compounds based on the pattern of carbon chain and give their structural formula: (i) Propane (ii) Benzene (iii) Cyclobutane (iv) Furan
3. How is ethanoic acid prepared from ethanol? Give the chemical equation.
4. How do detergents cause water pollution? Suggest remedial measures to prevent this pollution?
5. Differentiate soaps and detergents.

VI. Long answer questions

1. What is called homologous series? Give any three of its characteristics?
2. Arrive at, systematically, the IUPAC name of the compound: $CH_3-CH_2-CH_2-OH$.
3. How is ethanol manufactured from sugarcane?
4. Give the balanced chemical equation of the following reactions:

   (i) Neutralization of NaOH with ethanoic acid.

   (ii) Evolution of carbon dioxide by the action of ethanoic acid with $NaHCO_3$.

   (iii) Oxidation of ethanol by acidified potassium dichromate.

   (iv) Combustion of ethanol.
5. Explain the mechanism of cleansing action of soap.

VII. HOT questions

1. The molecular formula of an alcohol is $C_4H_{10}O$. The locant number of its –OH group is 2.

   (i) Draw its structural formula.

   (ii) Give its IUPAC name.

   (iii) Is it saturated or unsaturated?
2. An organic compound 'A' is widely used as a preservative and has the molecular formula $C_2H_4O_2$. This compound reacts with ethanol to form a sweet smelling compound 'B'.

   (i) Identify the compound 'A'.

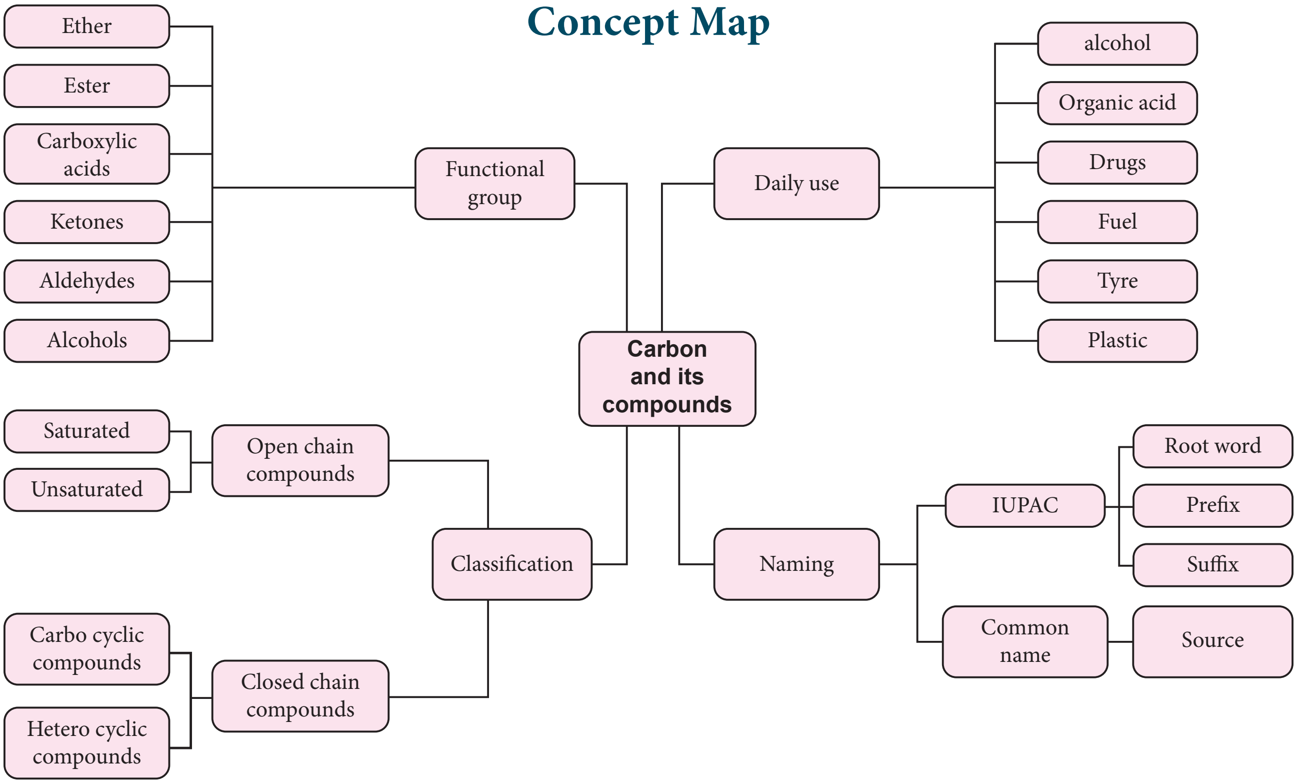
   (ii) Write the chemical equation for its reaction with ethanol to form compound 'B'.

   (iii) Name the process.

REFERENCE BOOKS

1. Organic chemistry - B.S.Bahl & Arun Bahl S.Chand publishers, New delhi.
2. Organic chemistry - R.T.Morrision & R.MN. Boyd - Prentice Hall Publishers. New Delhi

Concept Map



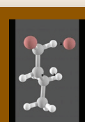
ICT CORNER

Organic Carbon and its Compounds

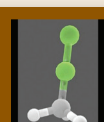
The students can know about the Hydrocarbons, its formulae, descriptions and also in animated form.

Steps

- Type the URL or use the QR code to access the application "Organic chemistry visualized / OCV" and install in the mobile.
- Click 'Content' to view the list of Hydrocarbon. Explore about the hydrocarbons by clicking those.
- On clicking '**anim**' button, you can view the formulae of hydrocarbon as well as in animated form.
- Click '**Quiz**' to evaluate yourself in this topic.



Step1



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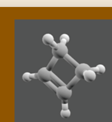

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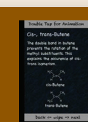

Step4

URL: https://play.google.com/store/apps/details?id=com.budgietainment.oc

or Scan the QR Code.

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*Pictures are indicative only