12 Organic Chemistry

SYLLABUS

(i) Introduction to Organic compounds.
Unique nature of Carbon atom – tetravalency, catenation, formation of single, double and triple bonds, straight chain, branched chain and cyclic compounds.

(ii) Structure and Isomerism.
Structure of compounds with single, double and triple bonds; Isomerism – structural (chain, position)

(iii) Homologous series — characteristics with examples
Alkane, alkene, alkyne series and their gradation in properties and the relationship with the molecular mass or molecular formula.

(iv) Simple nomenclature.
Simple nomenclature – of the hydrocarbons with simple functional groups – (double bond, triple bond, alcoholic, ether, aldehydic, keto, carboxylic group) longest chain rule and smallest number for functional groups rule – trivial and IUPAC names.

(v) Hydrocarbons : alkanes, alkenes, alkynes.
Alkanes – general formula; methane (green house gas) and ethane – methods of preparation from sodium ethanoate (sodium acetate), sodium propanoate (sodium propionate), from iodomethane (methyl iodide) and bromoethane (ethyl bromide). Oxidation of methane and ethane in presence of oxygen under suitable conditions reaction of methane and ethane with chlorine through substitution.
Alkenes – (unsaturated hydrocarbons with a double bond); ethene as an example. Methods of preparation of ethene by dehydro halogenation reaction and dehydration reactions.
Alkynes – (unsaturated hydrocarbons with a triple bond); ethyne as an example of alkyne; Methods of preparation from calcium carbide and 1, 2 dibromoethane ethylene dibromide). Only main properties, particularly addition products with hydrogen and halogen namely Cl, Br and I; structural formulae of hydrocarbons. Structural formula must be given for : alkanes (up to butane); alkene (C_2H_4); alkynes (C_2H_2). Uses of methane, ethane, ethene, acetylene.

(vi) Alcohols : ethanol – preparation, properties and uses
Preparation of ethanol :
- *hydration of ethene;*
- *by hydrolysis of alkyl halide;*
- *Properties — Physical : Nature, Solubility, Density, Boiling Points, Chemical : Combustion, Oxidation with acidified Potassium dichromate, action with sodium, ester formation with acetic acid, dehydration with conc. Sulphuric acid with reference to Ethanol*
- *hydration of ethene;*
- *by hydrolysis of alkyl halide;*
- *Denatured alcohol :*
- *Important uses of Ethanol*

(vii) Carboxylic acids (aliphatic – mono carboxylic acid) : Acetic acid – preparation, properties and uses of acetic acid.
Preparation of acetic acid from Ethyl alcohol.
Properties of Acetic Acid : Physical properties – odour (vinegar), glacial acetic acid (effect of sufficient cooling to produce ice like crystals). Chemical properties – action with litmus, alkalis and alcohol (idea of esterification)
Uses of acetic acid.

12A. ORGANIC COMPOUNDS

12.1 INTRODUCTION

The word 'organic' means *pertaining to life.* When comparatively little chemistry was known, people thought that substances like sugar, starch, protein and acetic acid could be obtained only from living sources like plants and animals. So they called such substances **organic compounds** (the compounds derived from living organisms) and the chemistry dealing with them was named **organic chemistry**. As against these compounds, substances like common salt, blue vitriol, nitrate, *etc.*, which could be produced from minerals and non-living sources, were called **inorganic compounds**, and the chemistry dealing with them was called **inorganic chemistry.**

Since these organic compounds were obtained straight from nature and there was no known method of preparing them in the laboratory, it was believed that they were the products of some "vital force" of nature.

The **vital force theory** of organic compounds was soon discarded when, in 1828, a German chemist named **Friedrich Wohler** showed that it was possible to obtain an organic compound **urea**, from the laboratory process.

$$\underset{\substack{\text{(Ammonium cyanate)} \\ \text{Inorganic compound}}}{NH_4CNO} \xrightarrow{\text{heat}} \underset{\substack{\text{(Urea)} \\ \text{Organic compound}}}{CO(NH_2)_2}$$

In 1845, **Kolbe** prepared acetic acid (CH_3COOH) from its constituent elements, carbon, hydrogen and oxygen. **Berthelot,** in 1856, synthesized methane gas (CH_4). In this manner, the old concept of organic chemistry was given up and it was accepted that **organic chemistry is essentially the chemistry of carbon compounds.**

12.2 ORGANIC COMPOUNDS

Based on the fact that all organic compounds essentially contain carbon, the term organic compounds now applies to the compounds of carbon and ***organic chemistry is defined as the study of carbon compounds****. This however excludes oxides of carbon, metallic carbonates and related compounds like metal cyanides, metal carbides, etc.*

Sources of organic compounds

1. **Plants :** Compounds like sugar, starch and cellulose, as well as several drugs, are obtained from plants.
2. **Animals :** Urea, proteins, fats, etc., are obtained from animals.
3. **Coal :** Destructive distillation of coal produces benzene, toluene, naphthalene, dyes, drugs, perfumes, etc.
4. **Petroleum :** A large number of organic compounds, like gasoline, fuel gases, petrol, naphtha, etc., are obtained from petroleum.
5. **Fermentation :** Compounds like ethyl alcohol and acetic acid are obtained by fermentation.
6. **Wood :** Methyl alcohol, acetone, etc., are obtained by destructive distillation of wood.
7. **Synthetic Methods :** Most organic compounds are synthesized in the laboratory.

12.2.1 Comparison between organic and inorganic compounds

Characteristics	*Organic compound*	*Inorganic compound*
1. *Presence of carbon*	Carbon is a necessary element in every organic compound.	Carbon is not an essential element in inorganic compounds.
2. *Solubility in water*	They generally do not dissolve in water.	They generally dissolve in water.
3. *Solubility in the organic solvents*	They dissolve in organic solvents like alcohol, benzene and chloroform.	All inorganic compounds do not dissolve in organic solvents.
4. *Melting and boiling point*	They have low m.p. and b.p. and easily decompose on heating.	They have high m.p. and b.p. and usually do not decompose on heating.
5. *Combustibility*	They are inflammable, *i.e.*, they catch fire easily.	They do not burn easily.
6. *Bonding*	They form covalent bonds.	Most of them form ionic bonds.
7. *Conductivity*	They are non-electrolytes.	Only those that form ionic bonds are good electrolytes.
8. *Isomerism*	They show the phenomenon of isomerism	No such phenomenon is shown by inorganic compounds.
9. *Colour and smell*	Organic compounds have characteristic colour and odour.	Most of them are colourless and odourless.
10. *Reactions*	Molecular reactions are slow, due to the presence of linkages. These reactions never proceed to completion.	Ionic reactions are fast and covalent reactions are slow.

Application of Organic Chemistry

Organic compounds are extremely useful to us in our daily life.

The soaps and shampoos we use while taking bath, the powders, perfumes, etc., we apply on the body, the clothes we wear, food we eat *i.e.*, carbohydrates, proteins, fats, vitamins, etc., fuels we use, natural gas, petroleum products, medicines, explosives, dyes, insecticides, etc., are all organic compounds. There is hardly any walk of life where we do not need organic compounds.

12.3 UNIQUE NATURE OF CARBON ATOMS

Carbon shows some unique properties like tetravalency and catenation, which are discussed below.

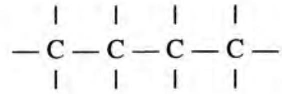
(i) Tetravalency of the carbon atom : Carbon has four valence electrons (*At. no. of C = 6; Elec. Config. = 2, 4*). Since it can neither lose nor gain electrons to attain octet, it forms covalent bonds by sharing its four electrons with other atoms. *This characteristic of the carbon atom, by virtue of which it forms four covalent bonds, is called the **tetravalency of carbon.***

(ii) Catenation : Carbon atom possesses an unique property to link together (self linking) to form very long chains. This property is referred to as catenation.

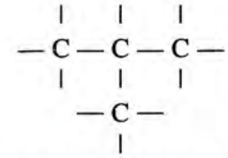
> *The property of **self-linking** of atoms of an element through covalent bonds in order to form straight chains, branched chains and cyclic chains of different sizes is known as* **catenation**.

The property of catenation is shown by other elements also but carbon exhibits this property to maximum extent. This is due to greater strength of carbon-carbon bond and due to tetra-covalency of carbon. In this process of catenation carbon atoms form straight, branch and cyclic chains of atoms, and can involve single (–), double (=) or triple (≡) covalent bonds.

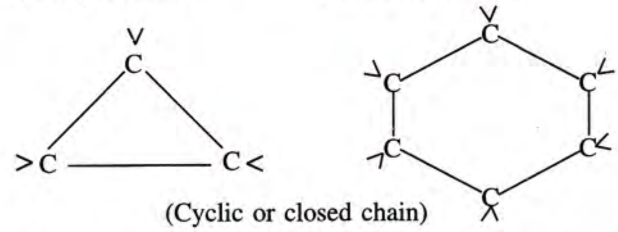
(a) Formation of straight, branched and cyclic chains of carbon atoms : The combination of carbon atoms with one another gives rise to *straight* or *branched* or *cyclic chains*.



(Straight chain)



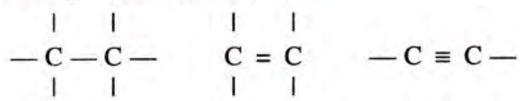
(Branched chain)



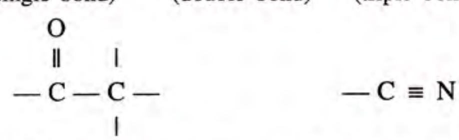
(Cyclic or closed chain)

The carbon-carbon chain can be very long. Organic molecules containing as many as seventy carbon atoms joined together, one after the other, are known to exist.

(b) Formation of single, double and triple covalent bonds : The valency of carbon is four, *i.e.* it is tetravalent. In order to satisfy its valency, it forms single, double and triple covalent bonds by sharing one, two or three pairs of electrons respectively between two carbon atoms as well as with other atoms like oxygen, nitrogen etc.



(single bond) (double bond) (triple bond)



(double bond with oxygen atom) (triple bond with nitrogen atom)

This **unique nature** of carbon atom (catenation and tetravalency) gives rise to the formation of a large number of compounds. **More than 5 million organic compounds are known today and thousands of new compounds are added every year to the existing lot.**

All this demands a separate branch of chemistry, *i.e.*, organic chemistry.

> *Organic chemistry may be defined as the chemistry of hydrocarbons and their derivatives.*

Features of covalent bonding involving carbon

- Carbon atoms can join to each other to form long chains. Atoms of other elements can then attach to the chain.

- The carbon atoms in a chain can be linked by single, double or triple covalent bonds.
- Carbon atoms can also arranged themselves in rings.

12.4 TYPES OF ORGANIC COMPOUNDS

The organic compounds have been classified as hydrocarbons whereas their derivatives are classified as alcohol, aldehydes, carboxylic acids, ethers, halides, etc. These compounds may contain any number of other elements, including hydrogen, nitrogen, oxygen, the halogens as well as phosphorus, silicon and sulphur.

Table 12.1 : Organic Compounds

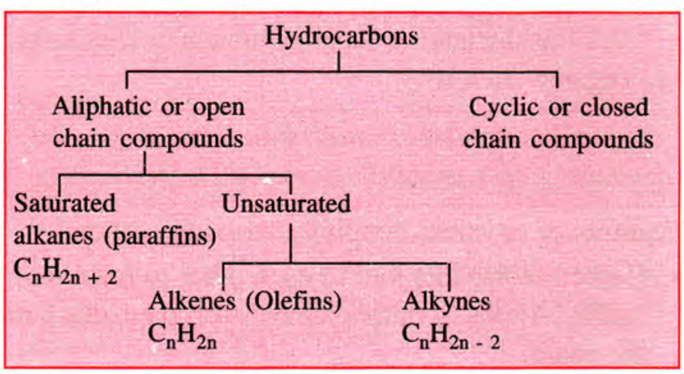
Types of compound	***Identified by the presence of***	***Example***
1. Hydrocarbon		
(a) alkane	—C—C— bond	Ethane $H_3C—CH_3$
(b) alkene	—C = C— bond	Ethene $H_2C = CH_2$
(c) alkyne	—C ≡ C— bond	Ethyne HC ≡ CH
2. Alcohol	—OH group	Methanol CH_3OH
3. Aldehyde	—CHO group	Ethanal CH_3CHO
4. Ketone	> C = 0	Propanone CH_3COCH_3
5. Carboxylic acid	—COOH group	Ethanoic acid CH_3COOH
6. Ether	C—O—C group	Dimethyl ether $H_3C—O—CH_3$
7. Halide	—X (F, Cl, Br, I)	Chloroethane C_2H_5Cl

12.5 HYDROCARBONS

Hydrocarbons are compounds that are made up only of carbon and hydrogen atoms.

Classification of Hydrocarbons

Hydrocarbons are sub-divided into two main groups, the aliphatic (open) and cyclic (closed) chain compounds.



The open chain compounds or aliphatic compounds are further sub-divided into ***saturated compounds*** and ***unsaturated compounds.***

Saturated Compounds

The simplest open chain hydrocarbon is **alkane.** It is represented by the formula C_nH_{2n+2}, where n represents natural number.

It is a saturated hydrocarbon, as all the four valencies of carbon are satisfied by a single covalent bond. (For further details refer section 12B).

Unsaturated Compounds

Open chain compounds where all the four valencies are not satisfied by single covalent bonds, double or triple bonds are required to satisfy the valencies. These compounds are known as **unsaturated compounds** *e.g.*, **Alkenes** are the hydrocarbons with double bond and **Alkynes** are the hydrocarbons with triple bond between two carbon atoms. (For further details refer sections 12C & 12D).

Comparison of Saturated and Unsaturated Hydrocarbons

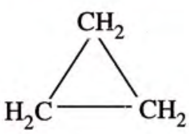
Saturated organic compounds	***Unsaturated organic compounds***
1. All the four valencies of each carbon atom are *satisfied* by forming single covalent bonds with carbon and with hydrogen atoms.	1. The valencies of at least two carbon atoms are *not fully satisfied* by the hydrogen atoms.
2. Carbon atoms are joined only by a ***single covalent bond.*** —C–C— (with single bonds above and below each C)	2. Carbon atoms are joined by ***double covalent bonds*** >C = C< or by ***triple covalent bonds.*** –C ≡ C–
3. They are *less reactive* due to the **non-availability of electrons** in the single covalent bond, and therefore they undergo *substitution reaction*.*	3. They are *more reactive* due to **the presence of electrons** in the double or the triple bond, and therefore undergo *addition reaction***.

* **Substitution reaction :** A reaction in which one atom of a molecule is replaced by another atom (or group of atoms) is called a substitution reaction. *e.g.* $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$.

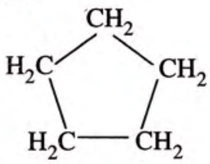
** **Addition reaction :** A reaction involving *addition* of atom(s) or molecule(s) to the double or the triple bond of an unsaturated compound so as to yield a *saturated* product is known as an addition reaction, *e.g.* $C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$.

Cyclic or closed chain hydrocarbons contain three or more carbon atoms in their molecules. These have properties similar to open chain hydrocarbons. They are also called **carbocyclic** compounds.

Examples : (i) Cyclic compounds containing single bond are called cycloalkanes.

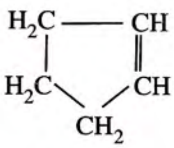


Cyclopropane (C_3H_6)

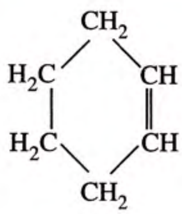


Cyclopentane (C_5H_{10})

(ii) Cyclic compounds containing double bond are called cycloalkenes.

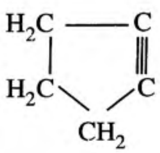


Cyclopentene (C_5H_8)

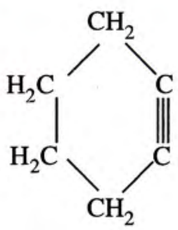


Cyclohexene (C_6H_{10})

(iii) Cyclic compounds containing triple bond are called cycloalkynes.

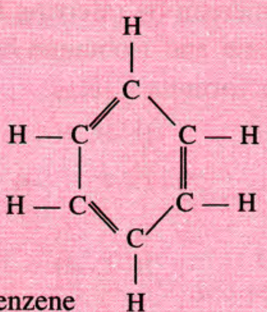


Cyclopentyne (C_5H_6)

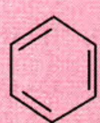


Cyclohexyne (C_6H_8)

Some hydrocarbons contain at least one benzene ring in their molecules. *The benzene ring is a specific type of ring structure of six carbon atoms having carbon-carbon single and carbon-carbon double bonds in alternate positions.*



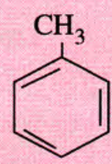
Benzene



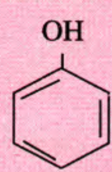
Benzene

Most of these compounds have pleasant smell.

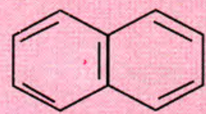
They are also known as aromatic compounds. Few other members of this class are :



Toluene



Phenol



Naphthalene

12.6 ALKYL GROUP

An alkyl group is obtained by removing one atom of hydrogen from an alkane molecule.

$$\underset{\textbf{Alkane}}{C_nH_{2n+2}} \xrightarrow{-H} \underset{\textbf{Alkyl}}{-C_nH_{2n+1}}$$

Table 12.2 : Alkyl radicals

Name	Molecular formula	Abbreviated formula	Structural formula
Methyl	$-CH_3$	$-CH_3$	H –C–H H
Ethyl	$-C_2H_5$	$-CH_2-CH_3$	H H –C–C–H H H
Propyl	$-C_3H_7$	$-CH_2-CH_2-CH_3$	H H H –C–C–C–H H H H
Butyl	$-C_4H_9$	$-CH_2-CH_2-CH_2-CH_3$	H H H H –C–C–C–C–H H H H H

Thus general formula of alkyl is – C_nH_{2n+1}.

$$\underset{\textbf{Methane}}{CH_4} \xrightarrow{-H} \underset{\textbf{Methyl}}{-CH_3}$$

An alkyl group is named by replacing the suffix **ane** of the alkane with the suffix - **yl.** All members of the alkyl group have an unpaired electron, which is indicated by a line with no symbol attached.

Table 12.3 : Some common functional groups

R represents the alkyl group ($-C_n H_{2n+1}$)

Functional group	General formulae	Types of Organic compounds	Suffix	Examples with common names and IUPAC names	
Halide - X (F, Cl, Br, I)	R—X	Haloalkanes	ane	CH_3Cl Methyl chloride Chloromethane	C_2H_5Cl Ethyl chloride Chloroethane
Hydroxyl - OH	R—OH	Alcohols	ol	CH_3OH Methyl alcohol Methanol	C_2H_5OH Ethyl alcohol Ethanol
Aldehyde -CHO	H(R)>C=O	Aldehydes	al	HCHO Formaldehyde Methanal	CH_3CHO Acetaldehyde Ethanal
Carboxyl - COOH	R—C(=O)—O-H	Carboxylic acids	oic acid	CH_3COOH Acetic acid Ethanoic acid	CH_3CH_2COOH Propionic acid Propanoic acid
Keto —C(=O)—	R—C(=O)—R′	Ketones	one	CH_3COCH_3 Acetone Propanone	$C_2H_5COC_2H_5$ Diethyl ketone Pentanone
Ethers —C—O—C—	R—O—R′	Ethers	oxy	$CH_3—O—CH_3$ Dimethyl ether Methoxy methane	$CH_3—O—C_2H_5$ Ethyl methyl ether Methoxy ethane

12.7 FUNCTIONAL GROUP

A functional group is an atom or a group of atoms that defines the structure (or the properties of a particular family) of organic compounds.

Alkanes do not contain any functional group. The functional group of alkenes is considered as double bond > C=C < while in alkynes it is triple bond —C≡C—. For other examples refer table 12.3.

12.7.1 Characteristics of functional groups:

(i) The chemical properties of the compounds containing the same functional group are similar. Therefore, the compounds of the same functional groups are identified using the same type of tests.

(ii) The physical and chemical properties of the compounds of different functional groups are different.

(iii) There exists a homologous series of compounds containing a particular type of functional group. *For example*, the homologous series of alcohols is CH_3OH, C_2H_5OH and C_3H_7OH.

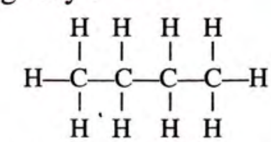
12.8. STRUCTURE

Hydrocarbons are usually represented by their structural formula.

*The formula that shows how atoms of different elements are linked together in a molecule is known as **structural formula**.*

For example : Butane (C_4H_{10}) can be represented in the following way :

Structural formula



A molecule having the bigger structural formula is often cumbersome. We represent it by **abbreviated formula**.

Abbreviated or Condensed formula of butane

$CH_3—CH_2—CH_2—CH_3$

A structure that shows only the linking of carbon atoms in a molecule is called the **carbon skeleton.**

Carbon skeleton of batane

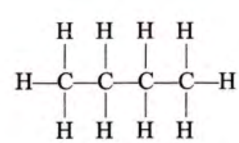
C—C—C—C

12.9 ISOMERS

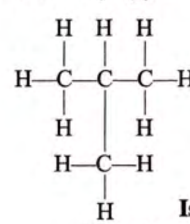
Compounds having the same molecular formula but different structural formula are known as ISOMERS and the phenomenon as ISOMERISM (ISO = same, meros = parts).

Isomers differ in physical properties or chemical properties or both.

We can illustrate isomerism by referring to two different compounds, butane and isobutane both of which have the molecular formula C_4H_{10}.

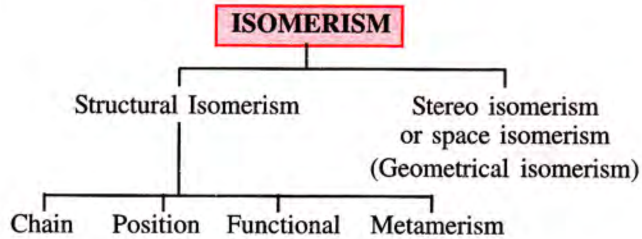


Butane
(liquefies at 0°C)



Isobutane
(liquefies at –12°C)

The following flow chart shows different types of isomerism :



There are two main causes of isomerism

1. Difference in the mode of linking of atoms :

For example : $C_4H_{10}O$ shows different types of linkages and thus it stands for three different types of *ether*.

This type of isomerism is structural isomerism.

$C_2H_5-O-C_2H_5$	$CH_3-O-C_3H_7$	$CH_3-O-CH(CH_3)_2$
Diethyl ether	**Methyl propyl ether**	**Methyl iso-propyl ether**

2. Difference in the arrangement of atoms or groups in space

This type of isomerism is stereo isomerism.

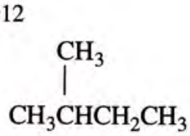
For example : 1, 2-dichloro ethene

Different types of structural isomerism are :

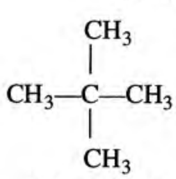
(i) *Chain Isomerism :* When two or more compounds have a similar molecular formula but are different in the arrangement of carbon atoms in straight or branched chains the compounds are referred to as **chain isomers** and the phenomenon is termed as **chain isomerism**.

For example : Pentane C_5H_{12}

$CH_3CH_2CH_2CH_2CH_3$
Pentane



iso-pentane
(2-methyl butane)



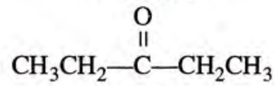
neo-pentane
(2, 2-dimethyl propane)

(ii) *Position isomerism :* When two or more compounds with the same molecular formula differ in the position of substituent atom or functional group on the carbon atom, they are called position isomers and this phenomenon is termed position isomerism.

For example :

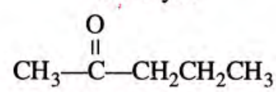
(i) $CH_3—CH_2C \equiv C—H$ (but-1-yne) and $CH_3—C \equiv C—CH_3$ (but-2-yne)

(ii)



pentan-3-one

and



pentan-2-one

(iii) *Functional isomerism : Two or more compounds with the same molecular formula but different functional groups are called functional isomers and this phenomenon is termed as functional isomerism

For example :

CH_3CH_2OH (ethanol) and $CH_3—O—CH_3$ (dimethyl ether)

(iv) *Metamerism : It arises due to unequal distribution of alkyl groups on either side of the functional groups in the molecules.

For example :

$CH_3OC_3H_7$ (methoxy propane, methyl propyl ether) and $C_2H_5OC_2H_5$ (ethoxyethane, Diethyl ether)

> ***Note :*** The number of isomers increases with the number of carbon atoms; butane with 4 carbon atoms has 2 isomers, hexane has 5 isomers. An organic compound having formula $C_{21}H_{44}$ has about a million isomers and so on.

12.10 HOMOLOGOUS SERIES

A **homologous series** *is a group of organic compounds having a similar structure and similar chemical properties in which the successive compounds differ by a* CH_2 *group.*

By adding CH_2 group (known as methylene group) in a given hydrocarbon, another hydrocarbon with a higher number of carbon atoms is obtained, *e.g.,*

$$\underset{\text{Methane}}{CH_4} + CH_2 \rightarrow \underset{\text{Ethane}}{C_2H_6}.$$

** Not in syllabus*

Similarly, by removing CH_2 group from a hydrocarbon, another hydrocarbon with a lesser number of carbon atoms is obtained, *e.g.*,

$$\underset{\text{Butane}}{C_4H_{10}} \rightarrow \underset{\text{Propane}}{C_3H_8} + CH_2$$

12.10.1 Characteristics of a homologous series

1. Each member of the series differs from the preceding one by the addition of CH_2 group and by molecular mass of 14 a.m.u.
2. All members of a *homologous series* share the *general formula.* (Same elements and same functional group).

   For example, the general formula for alkane is $C_n H_{2n+2}$, alkene is $C_n H_{2n}$.
3. The physical properties of the members change gradually i.e. show *gradation in properties* as the number of carbon atoms per molecule increases, *i.e.,* as molecular mass increases.

   For example, melting point, boiling point and the density of the successive members of the homologous series *increase with the increase in molecular mass.*

   Examples :

	Alkane	*Molar mass*	*Boiling point*	*Physical state*
(i)	Methane	16	–161.4°C	gas
(ii)	Ethane	30	–88.3°C	gas
(iii)	Propane	44	–44.5°C	gas
(iv)	Butane	58	0°C	gas
(v)	Pentane	72	36.2°C	liquid

4. Members of a homologous series have similar chemical properties. *For example :* Methane reacts with chlorine to form methyl chloride.

   $$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl.$$

   Similarly, ethane reacts to form ethyl chloride

   $$C_2H_6 + Cl_2 \rightarrow C_2H_5Cl + HCl.$$
5. All the members of a homologous series can be prepared by using the same general method of preparation.

   For example : Alcohols are prepared by alkyl halides.

   $$CH_3Br + \underset{\text{(aqueous)}}{KOH} \xrightarrow{\text{boil}} CH_3OH + KBr.$$

   $$C_2H_5Br + \underset{\text{(aqueous)}}{KOH} \xrightarrow{\text{boil}} C_2H_5OH + KBr.$$

Examples of Homologous Series.

1. ALKANE :

Gen. formula [C_nH_{2n+2}]	Molecular formula
Methane	CH_4
Ethane	C_2H_6
Propane	C_3H_8
Butane	C_4H_{10}
Pentane	C_5H_{12}
Hexane	C_6H_{14}
Heptane	C_7H_{16}
Octane	C_8H_{18}
Nonane	C_9H_{20}
Decane	$C_{10}H_{22}$

2. ALKENE :

Gen. formula [C_nH_{2n}]	Molecular formula
Ethene	C_2H_4
Propene	C_3H_6
Butene	C_4H_8
Pentene	C_5H_{10}
Hexene	C_6H_{12}
Heptene	C_7H_{14}
iOctene	C_8H_{16}
Nonene	C_9H_{18}
Decene	$C_{10}H_{20}$

3. ALKYNE :

Gen. formula [C_nH_{2n-2}]	Molecular formula
Ethyne	C_2H_2
Propyne	C_3H_4
Butyne	C_4H_6
Pentyne	C_5H_8
Hexyne	C_6H_{10}
Heptyne	C_7H_{12}
Octyne	C_8H_{14}

4. ALCOHOLS :

Gen. formula [$C_nH_{2n+1}OH$]	Molecular formula
Methanol	CH_3OH
Ethanol	C_2H_5OH
Propanol	C_3H_7OH
Butanol	C_4H_9OH
Pentanol	$C_5H_{11}OH$
Hexanol	$C_6H_{13}OH$
Heptanol	$C_7H_{15}OH$
Octanol	$C_8H_{17}OH$

12.10.2 Significance of the homologous series

(i) The nature of any member of that family of compounds can be ascertained, if the properties of the first few members of that series are known.

(ii) It helps to predict the properties of even those members of the series that are yet to be prepared.

(iii) Knowledge of homologous series is useful for the systematic study of organic chemistry, since it saves learning time.

Note : In an organic compound the alkyl group determines mainly the physical properties, whereas the functional group is responsible for the chemical properties or reactivity of the compounds.

Intext Questions

1. (a) What are organic compounds?
   (b) What is vital force theory? Why was it discarded?
2. (a) Name a few sources of organic compounds.
   (b) Give the various applications of organic chemistry.
3. Organic chemistry plays a key role in all walks of life. Discuss.
4. Carbon shows some unique properties, name them.
5. Explain the following :
   (a) tetravalency,
   (b) catenation.
6. Write any four properties of organic compounds that distinguish them from inorganic compounds.
7. Why are organic compounds studied as a separate branch of chemistry ?
8. What are hydrocarbons ? Compare saturated and unsaturated hydrocarbons?
9. Give reason for the existence of the large number of organic compounds.
10. Give at least one example in each case to show structure of isomers of :
    (a) single bond compound,
    (b) double bond compound,
    (c) triple bond compound.
11. Name a compound of each type and draw the figure.
    (a) Cyclic compound with single bond.
    (b) Cyclic compound with triple bond.
12. Give the name of one member of each of the following :
    (a) saturated hydrocarbons,
    (b) unsaturated hydrocarbons.
13. Define substitution and addition reaction. Give an example for each.
14. Define or explain chain isomerism and position isomerism with examples in each case.
15. (a) Define the term isomerism. State two main causes of isomerism.
    (b) Draw the chain isomers of hexane (C_6H_{12}).
    (c) Draw position isomers of butene (C_4H_8).
16. Define a functional group and give the structural formula of the following functional groups:
    (a) ketone, (b) alcohols, (c) aldehydes.
17. Write the name and formula of fourth member of the following homologous series :
    (a) Alkyne (b) Alcohol
18. Which part of an organic compound determines (i) physical properties (ii) chemical properties ?
19. Name the alkyl radical and the functional group of the following organic compounds :
    (a) CH_3OH, (b) C_2H_5OH,
    (c) C_3H_7CHO, (d) C_4H_9COOH,
    (e) CH_3COOH (f) HCHO.
20. (a) What is an alkyl group ?
    (b) Give the names of any three alkyl radicals. How are they formed ?
21. Give the names and the structural formula of the first three members of the homologous series of alkanes.
22. (a) What is a homologous series ?
    (b) What is the difference in the molecular formula of any two adjacent homologues :
    (i) in terms of molecular mass,
    (ii) in terms of number and kind of atoms per molecule?

12.11 NOMENCLATURE

Nomenclature is the system of assignment of names to organic compounds.

System of nomenclature are Trivial system and IUPAC (International Union of Pure and Applied Chemistry) system.

In the early days, the name of a compound depended on the source from which it was obtained. For example, CH_4 was named *marsh gas,* since it was obtained from marshy places. Acetic acid (Latin : *acetum* = vinegar) was obtained from vinegar, methyl alcohol (*methus* = spirit, *hule* = wood) was obtained from wood, and citric acid from the botanical source *citrus*. Such names are called **common names** or **trivial names.**

However, the nomenclature was systematized by the chemists of IUPAC in 1957.

According to this system, the name of an organic compound consists of three parts :

(i) root word, (ii) suffix, (iii) prefix.

(i) Root word : It depends upon the number of carbon atoms present in the longest carbon chain selected (Table 12.4).

Table 12.4

Number of carbon atoms		Root Word (Greek name)
One carbon atom	C_1	Meth
Two carbon atoms	C_2	Eth
Three carbon atoms	C_3	Prop
Four carbon atoms	C_4	But
Five carbon atoms	C_5	Pent
Six carbon atoms	C_6	Hex
Seven carbon atoms	C_7	Hept
Eight carbon atoms	C_8	Oct
Nine carbon atoms	C_9	Non
Ten carbon atoms	C_{10}	Dec

(ii) Suffix : The root word is followed by an appropriate suffix, which represents the nature of the bond in a carbon — carbon atom *i.e.*

C—C [single bond] ***–ane***

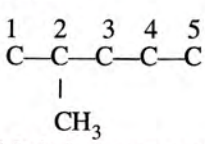
C=C [double bond] ***–ene***

C≡C [triple bond] ***–yne***

Table 12.5

Nature of bond	Suffix	General name	General formula
Single bond (C—C)	– ane	Alkane	C_nH_{2n+2}
Double bond (C=C)	– ene	Alkene	C_nH_{2n}
Triple bond (C≡C)	– yne	Alkyne	C_nH_{2n-2}
Group (R –)	– yl	Alkyl	C_nH_{2n+1}

(iii) Prefix : It denotes the substituent, alkyl or functional group and its position in the carbon chain.



2-Methyl (because methyl is attached to second C)

Prefix also indicates additional substituent or functional group. *Di-, tri-, tetra-, are used for two, three and four groups of the same type respectively.*

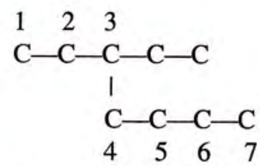
In naming an organic compound, the following simple rules are followed :

1. *Selection of carbon chains :* The longest continuous chain of 'C' atoms, known as ***parent chain,*** is selected. *The longest chain need not be straight. For example :*

(i) 1 2 3 4 5
C—C—C—C—C

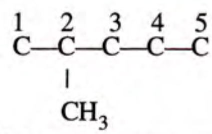
The longest chain is of 5 carbon atoms so root word is 'pent'.

(ii)



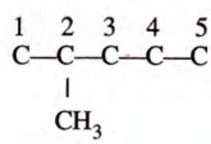
Here the longest chain is of 7 carbon atoms so root word is 'hept'. The remaining two carbon atoms (unnumbered) are for substituent.

2. The branch chains are considered to be *substituents,* and their positions are indicated by the number of carbon atoms to which they are attached. *For example :*

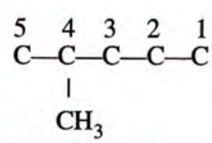


2-Methyl (because methyl is attached to second C)

3. The carbon atoms of the longest chain are numbered in such a way that the alkyl groups (substituents) get the smallest possible number. *For example :*



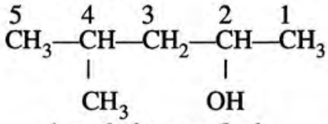
2-Methyl
Right



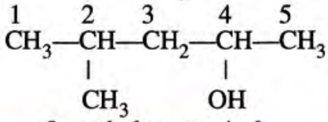
4-Methyl
Wrong

4. In case, any functional group is also present in the chain, then the carbon atoms are numbered in such a way that the functional group gets the smallest possible number.

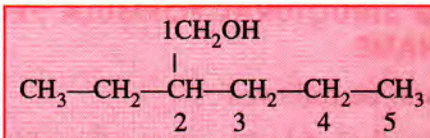
For example :



4-methylpentan-2-ol **Right**



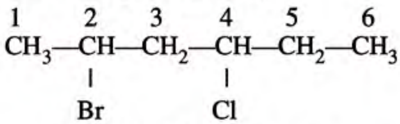
2-methylpentan-4-ol **Wrong**



2-ethylpentan -1-ol

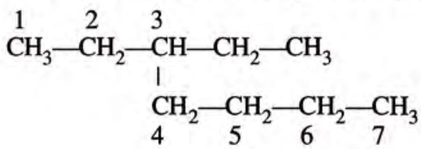
Note : In nomenclature, 'e' of alkane is replaced by suffix of functional group indicating the position.

5. In case, different types of substituents are attached to the chain, they are arranged and named alphabetically.



2-Bromo 4-chloro hexane

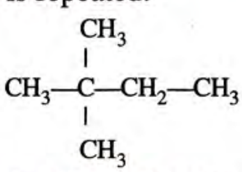
6. The position(s) of alkyl group(s) are indicated by writing the position and name of the alkyl group just before the name of parent hydrocarbon.



3-ethylheptane

7. Multiple alkyl groups are labelled with the Greek numerical prefixes such as 'di' for two, 'tri' for three, 'tetra' for four, 'penta' for five.

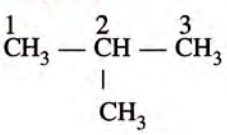
   If two alkyl groups are on the same carbon atom, the numeral is repeated.



2, 2-dimethyl butane

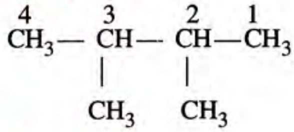
Examples of IUPAC names

Example 1 :



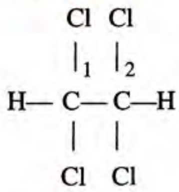
Word Root : Prop–
Suffix : –ane
Prefix : 2 methyl
IUPAC name : 2-methyl propane

Example 2 :



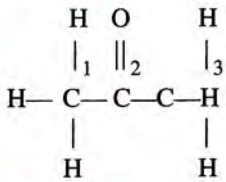
Word Root : But–
Suffix : –ane
Prefix : 2, 3-dimethyl
IUPAC name : 2, 3-dimethyl butane

Example 3 :



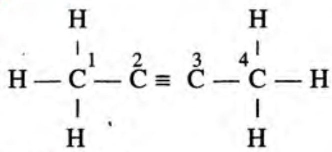
Word Root : Eth–
Suffix : –ane
Prefix : 1, 1, 2, 2-tetrachloro
IUPAC name : 1, 1, 2, 2-tetrachloro ethane

Example 4 :



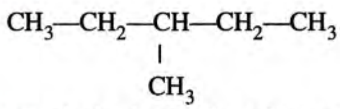
Word Root : Prop
Suffix : –ane
Prefix : 2-one
IUPAC name : Propan-2-one
Common name : Acetone

Example 5 :



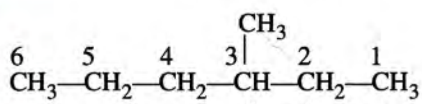
Word Root : But–
Suffix : –yne
Prefix : 2
IUPAC name : But-2-yne

Example 6 :



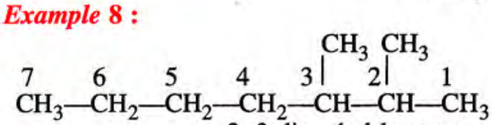
The longest chain is of 5 carbon atoms so root word is Pent. The nature of carbon chain is C – C [*single bond*] – Suffix -ane and the substituent is an (alkyl) methyl – CH_3 group. Thus name of compound is : ***3-methyl pentane***.

Example 7 :



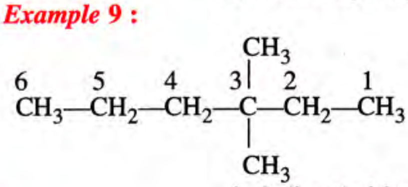
3-methyl hexane

Example 8 :



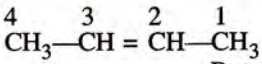
2, 3-dimethyl heptane

Example 9 :



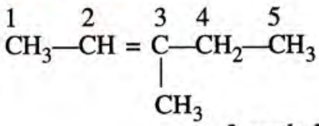
3, 3-dimethyl hexane

Example **10 :**



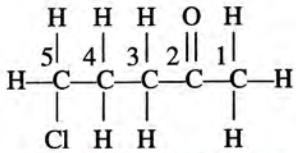
But–2–ene

Example **11 :**



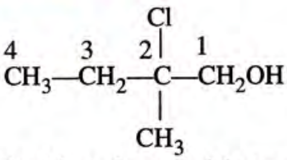
3-methylpent–2–ene

Example **12 :**



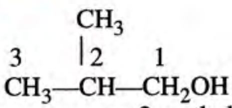
5–chloropentan–2–one

Example **13 :**



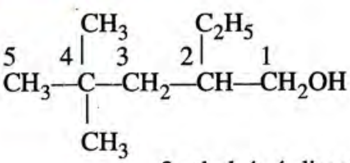
2–chloro–2–methyl butan–1–ol.

Example **14 :**



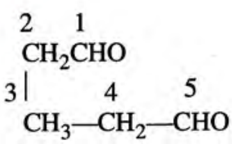
2-methyl propan–1–ol.

Example **15 :**



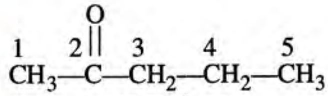
2-ethyl 4, 4-dimethyl pentan-1-ol.

Example **16 :**



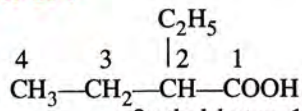
Pentan-1, 5-dial

Example **17 :**



pentan-2-one.

Example **18 :**



2-ethyl butan–1–oic acid

12.12 WRITING STRUCTURAL FORMULA FROM IUPAC NAME

Following steps to be followed :

1. Write the number of carbon atoms according to the word root (carbon skeleton).
2. Number the carbon atoms from any end.
3. According to the suffix ane, ene or yne, the position of the bond is specified in the parent chain.
4. Attach the substituent or functional group at the mentioned carbon atom.
5. Satisfy the four valencies of carbon atom by attaching hydrogen atoms.

For example :

2–Bromo–4–methyl pent–2–ene

Step 1 : Write the carbon atoms of the parent chain,

C – C – C – C – C

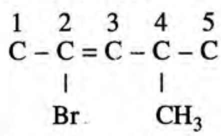
Step 2 : Number it,

1 2 3 4 5
C – C – C – C – C

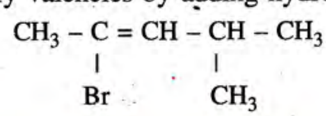
Step 3 : Locate the suffix,

1 2 3 4 5
C – C = C – C – C

Step 4 : Attach substituents,

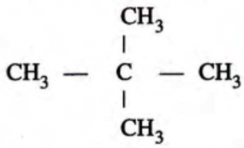


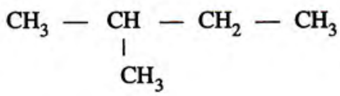
Step 5 : Satisfy valencies by adding hydrogen atoms,

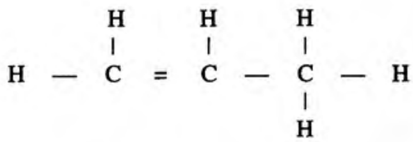


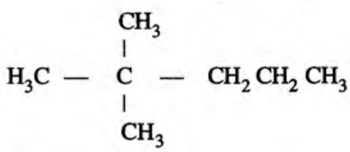
EXERCISE 12A

1. Write the IUPAC name of the following :

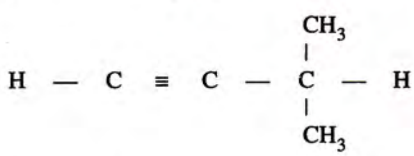
(a) 

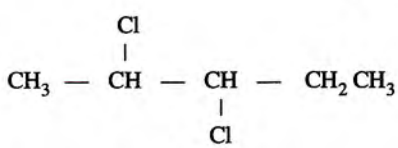
(b) 

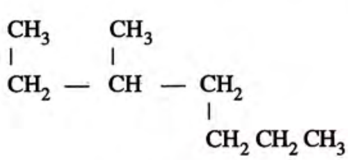
(c) 

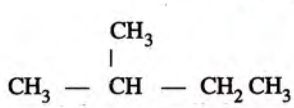
(d) 

(e) $CH_3-C\equiv C-CH_2CH_3$

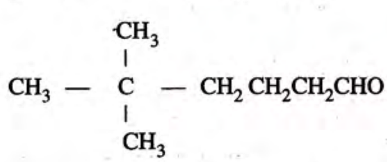
(f) 

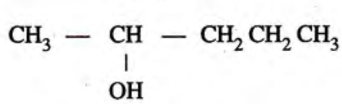
(g) 

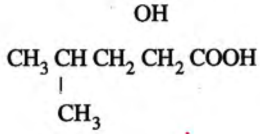
(h) 

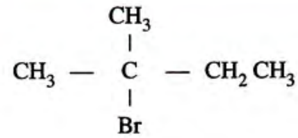
(i) 

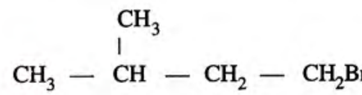
(j) $CH_3-C\equiv C-CH_2CH_2CH_2CH_3$

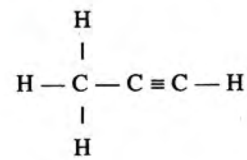
(k) 

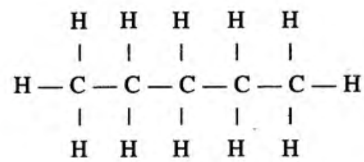
(l) 

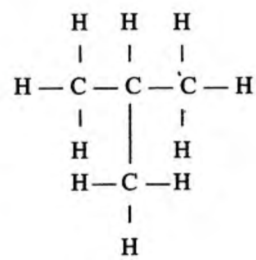
(m) 

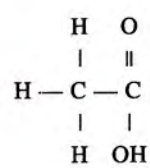
(n) 

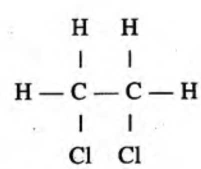
(o) 

(p) 

(q) 

(r) 

(s) 

(t) 

2. Write the structures of the following compounds:

(a) Prop-1-ene, (b) 2, 3-dimethylbutane,
(c) 2-methylpropane, (d) 3-hexene,
(e) Prop-1-yne, (f) 2-methylprop-1-ene,
(g) Alcohol with molecular formula $C_4H_{10}O$.

3. Choose the correct answer :

(a) C_5H_{11} is an

(i) alkane (ii) alkene
(iii) alkyne (iv) alkyl group

(b) A hydrocarbon of the general C_nH_{2n} is

(i) $C_{15}H_{30}$ (ii) $C_{12}H_{26}$

(iii) C_8H_{20} (iv) C_6H_{14}

(c) A hydrocarbon with molecular mass 72 is

(i) an alkane (ii) an alkene (iii) an alkyne

(d) The total number of different carbon chains that four carbon atoms form in alkane is

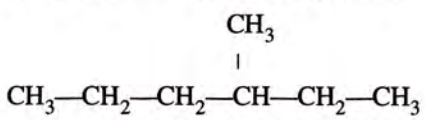
(i) 5 (ii) 4 (iii) 3 (iv) 2

(e) $CH_3—CH_2—OH$ and $CH_3—O—CH_3$ are

(i) position isomers (ii) chain isomers

(iii) homologous (iv) functional-group isomers

(f) The IUPAC name of the compound is



(i) 3-trimethylhexane (ii) 3-methyl hexane

(iii) 4-methyl hexane

4. Fill in the blanks.

(a) Propane and ethane are .... (homologous, isomers)

(b) A saturated hydrocarbon does not participate in a/an .... reaction (substitution, addition)

(c) Succeeding members of a homologous series differ by .... (CH, CH_2, CH_3)

(d) As the molecular masses of hydrocarbons increase, their boiling points .... and melting point .... (increase, decrease)

(e) $C_{25}H_{52}$ and $C_{50}H_{102}$ belong to ..... homologous series (the same, different)

(f) CO is an .... compound. (organic, inorganic)

(g) The chemical properties of an organic compound are largely decided by the .... and the physical properties of an organic compound are largely decided by the .... (functional group, number of carbon atoms)

(h) CHO is the functional group of an .... (alcohol, aldehyde)

(i) The root in the IUPAC name of an organic compound depends upon the number of carbon atoms in .... (any chain, principal chain)

(j) But-1-ene and but-2-ene are examples of .... isomerism. (chain, position, functional)

5. Draw structural formula for each of the following compounds :

(a) isomer of n-butane, (b) vinegar,

(c) 2-propanol (d) ethanal,

(e) acetone (f) diethyl ether

What is used to describe these compounds taken together ?

6. (a) What is the special feature of the structure of : (i) C_2H_4, (ii) C_2H_2 ?

(b) What type of reaction is common to both these compounds ? Why methane does not undergo this type of reaction.

7. Give the names and structural formula of :

(a) saturated hydrocarbon,

(b) unsaturated hydrocarbon.

Which type of reaction will they undergo ?

8. Choosing only words from the following list, write down appropriate words to fill in the blanks from (a) to (e) given below. Addition, carbohydrates, C_nH_{2n-2}, C_nH_{2n}, C_nH_{2n+2}, electrochemical homologous, hydrocarbon, saturated, substitution, unsaturated.

The alkanes form an (a) .... series with the general formula (b) .... The alkanes are (c) .... (d) .... which generally undergo (e) .... reactions.

9. Draw the structural formula of a compound with two carbon atoms in each of the following cases.

(a) An alkane with a carbon to carbon single bond,

(b) An alcohol containing two carbon atoms,

(c) An unsaturated hydrocarbon with a carbon to carbon triple bond.

10. Ethane, Ethene, Ethanoic acid, Ethyne, Ethanol

From the above, name

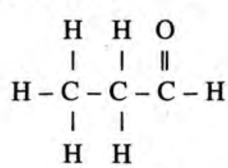
(a) The compound with –OH as the part of its structure.

(b) The compound with –COOH as the part of its structure.

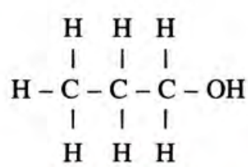
(c) Homologue of Homologous series with general formula C_nH_{2n}.

11. Give the correct IUPAC name and the functional group for each of the compounds whose structural formulae are given below :

(a)



(b)



12B HYDROCARBONS : ALKANES

12.13 ALKANES

Alkanes are hydrocarbons in which all the linkages between the carbon atoms are **single covalent bonds.**

These compounds are known as saturated hydrocarbons since all the four valencies of carbon are fully satisfied in the formula C_nH_{2n+2} by a **single bond (saturated by C – C and C – H single bonds)** (refer to Table 12.6).

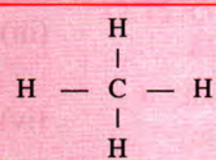
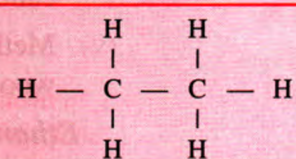
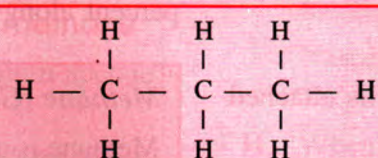
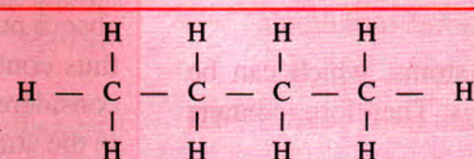
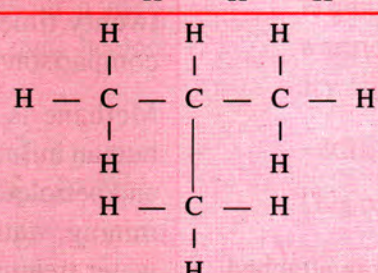
The simple alkanes share many properties in common. All enter into combustion reactions with oxygen to produce carbon dioxide and water vapour. In other words, many alkanes are flammable. This makes them good fuels. For example, methane is the principle component of natural gas, and butane is common lighter fluid.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

The combustion of methane

These hydrocarbons are relatively unreactive under ordinary conditions and so, they are also known as **paraffins** (*parum*–little, *affinis*–affinity).

Table 12.6 Homologous series of alkanes (General formula C_nH_{2n+2})

Name	Molecular formula	Structural formula	Abbreviated formula (Condensed formula)
Methane	CH_4		CH_4
Ethane	C_2H_6		$CH_3\ CH_3$
Propane	C_3H_8		$CH_3\ CH_2\ CH_3$
Normal butane	C_4H_{10}		$CH_3\ CH_2\ CH_2\ CH_3$
Isobutane (common name) or 2-methyl propane (IUPAC name)	$C_4\ H_{10}$		$CH_3\ CH\ CH_3$ | CH_3

Note : *Since a number of organic compounds have the same molecular formula but different properties, it is appropriate to represent them by* ***structural formula*** *or by* ***condensed (abbreviated) formula.***

12.13.1 Sources of alkanes

The principal sources of alkanes are natural gas and petroleum. Natural gas contains mainly methane, with smaller amounts of ethane, propane and butane.

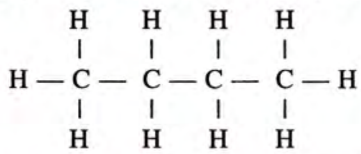
12.13.2 Isomerism in alkanes, *i.e.*, single bond hydrocarbons

Alkanes with *more than three carbon atoms form isomers.* The various isomers differ in the framework of the carbon chains. Therefore, they show chain isomerism.

Examples :

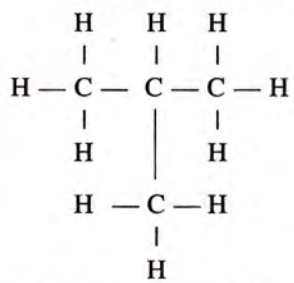
Isomers of butane (C_4H_{10})

Butane has four carbon atoms. These four carbon atoms can be arranged in two distinct ways. Therefore, there are two isomers of butane.



n–butane (C_4H_{10}), where '*n*' stands for *normal*

IUPAC Name : Butane



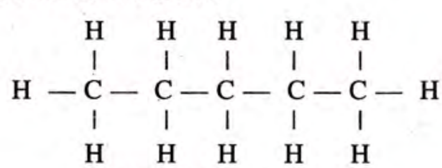
Iso-butane (C_4H_{10})

IUPAC Name : 2 Methyl propane

['iso', *i.e.,* at least one carbon atom is attached to three other carbon atoms].

Isomers of pentane (C_5H_{12})

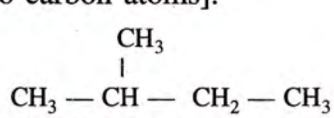
Pentane has five carbon atoms, which can be arranged in three different ways. Therefore, pentane can form three isomers.



IUPAC Name : Pentane

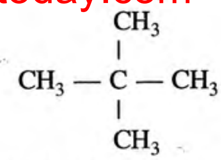
Common name : *n*-pentane

['*n*', means normal *i.e.* carbon atom is attached to maximum two carbon atoms].



IUPAC Name : 2–methyl butane

Common name : iso-pentane



IUPAC Name : 2, 2-dimethyl propane

Common name : neo-pentane

['neo', *i.e.,* at least one carbon atom is attached to 'four' other carbon atoms].

12.14 METHANE AND ETHANE

12.14.1 Occurrence of methane and ethane

Methane (Marsh gas)

(i) Marsh gas is formed at the bottom of marshes due to the fermentation of cellulose by a special type of bacteria.

(ii) It is also present in the air exhaled by animals whose food contains cellulose.

(iii) It is contained in intestinal gases and in the blood of animals and human beings.

(iv) Cavities in coal contain 90% methane. It is called **'fire-damp'**.

(v) Methane is produced also by dry distillation of wood, peat (coal).

***Ethane** : It occurs* to the extent of 10-20 percent alongwith methane.

Methane (Green house gas)

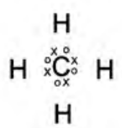
Methane is a primary constituent of natural gas. It absorb outgoing heat radiation from the earth, and thus contribute to the *green house effect* and so considered as a green house gas. Methane remains in the atmosphere for approximately 10 years. It is twenty times more effective in trapping heat in comparison to carbondioxide.

Methane is emitted from variety of natural and human influenced sources like landfills, natural gas and petroleum systems, agricultural activities, coal mining, stationary and mobile combustion, waste water treatment and certain industrial process.

Methane is an important energy source so efforts to prevent or utilize methane emissions can provide significant economical and environmental benefits.

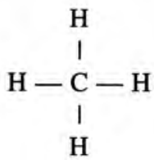
12.14.2 Structure of methane

The methane molecule is three-dimensional. The four outer electrons in the carbon atom move as far apart from each other as possible, because electrons repel each other (remember that particles with similar charge always repel each other). It is a fact that the electrons will have the greatest distance between themselves when the carbon-hydrogen bonds are in the shape of a **tetrahedron**. *A tetrahedron ('tetra' is a Greek word meaning "four") is pyramid-shaped.*



Electron dot formula

or



Structural formula

METHANE

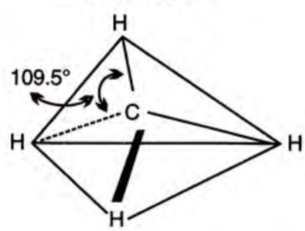


Fig. 12.1 The tetrahedral arrangement of four atoms of hydrogen around a carbon atom in a molecule of methane

12.14.3 Laboratory preparation of methane

Reactants : *Sodium ethanoate* (sodium acetate) and *soda lime.*

(Soda lime is in the form of a white porous mass or granules. It is a mixture of sodium hydroxide and calcium oxide).

Procedure : A mixture of sodium ethanoate (sodium acetate) and soda lime is taken in a hard glass test tube (as shown in Fig. 12.2), and heated with a bunsen flame.

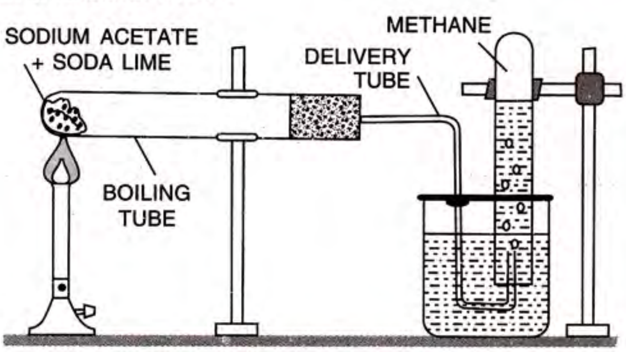


Fig. 12.2 Preparation of methane

Reaction :*

$$CH_3COONa + NaOH \xrightarrow[300^\circ C]{CaO} Na_2CO_3 + CH_4\uparrow$$

Collection : The gas evolved is collected by downward displacement of water since it is slightly soluble in water and is lighter than air.

12.14.4 Laboratory preparation of ethane

Reactants : Sodium propionate and soda lime.

Procedure : A mixture of sodium propionate and soda lime is taken in a boiling tube and heated with a bunsen flame (apparatus similar to Fig. 12.2).

Reaction :*

$$C_2H_5COONa + NaOH \xrightarrow[300^\circ C]{CaO} Na_2CO_3 + C_2H_6\uparrow$$

Collection : The gas evolved is collected by downward displacement of water.

12.15 OTHER METHODS OF PREPARATION OF METHANE AND ETHANE

I. ***Iodomethane*** (methyl iodide) or ***bromoethane*** (ethyl bromide) is reduced by nascent hydrogen at ordinary room temperature.

$$\underset{\text{Iodomethane}}{CH_3I} + 2[H] \rightarrow CH_4 + HI$$

$$\underset{\text{Bromoethane}}{C_2H_5Br} + 2[H] \rightarrow \underset{\text{Ethane}}{C_2H_6} + HBr$$

Nascent hydrogen is produced by the action of Zn powder and dil. HCl.

II. When water is added at room temperature to aluminium carbide, methane is prepared.

$$Al_4C_3 + 12H_2O \rightarrow 3CH_4\uparrow + 4Al(OH)_3\downarrow$$

III. ***Ethane from alkyl halides :***

When methyl iodide or methyl bromide is warmed with sodium metal in the presence of dry ether, ethane is produced.

$$2CH_3I + 2Na \xrightarrow[\text{ether}]{\text{dry}} H_3C - CH_3 + 2NaI$$

This reaction is referred to as ***Wurtz reaction***.

Note : *Method cannot be prepared by this method. This method is not suitable for the preparation of alkanes with odd number of carbon atoms.*

* This reaction is known as **decorboxylation** reaction as carbon dioxide molecule is eleminated from a carboxylic acid. CO_2 is eleminated as carbonate.

12.15.1 Physical properties

Methane

(i) It is a colourless and an odourless gas.

(ii) Its melting point is –183 °C and its boiling point is –162 °C.

(iii) It is negligibly soluble in water and soluble in organic solvents.

Ethane

(i) It is a colourless, odourless, tasteless and non-poisonous gas.

(ii) Its b.p. is –89 °C and its m.p. is –172 °C.

(iii) It is sparingly soluble in water but wholly soluble in organic solvents like alcohols, acetone and ether.

12.15.2 Chemical properties

Methane and ethane are saturated hydrocarbons. *They do not react with bases such as sodium hydroxide, or with oxidising agents such as potassium permanganate, or with reducing agents such as sodium metal.*

They undergo substitution reactions as well as combustion reaction.

1. Substitution reaction

(i) *Reaction with halogens*

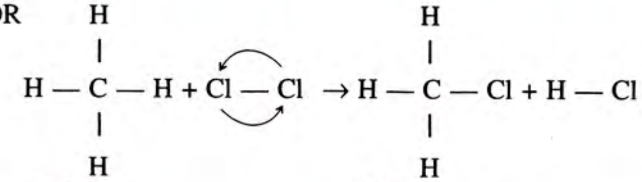
Alkanes react with **chlorine, bromine** or **iodine** in the presence of sunlight or ultraviolet light to give halogen substituted products that are known as *alkyl halides*.

Alkyl halides contain one or more halogen atoms.

Methane reacts with chlorine in diffused sunlight, or when heated to 600 K, to give chloromethane.

$$CH_4 + Cl_2 \xrightarrow[\text{or } 600K]{\text{diffused sunlight}} CH_3Cl + HCl$$

OR



Methane   Chloromethane

In this reaction, CH_3Cl is formed by the substitution of hydrogen atom of a methane molecule, by a chlorine atom. This type of reaction is known as **substitution reaction** and the product formed is known as **substitution product**.

The product formed (chloromethane) further reacts with chlorine, substituting one more hydrogen atom and producing dichloromethane. This further produces trichloromethane and finally, tetrachloromethane.

$$\underset{\text{Chloromethane}}{CH_3Cl} + Cl_2 \rightarrow \underset{\text{Dichloromethane}}{CH_2Cl_2} + HCl$$

$$\underset{\text{Dichloromethane}}{CH_2Cl_2} + Cl_2 \rightarrow \underset{\text{Trichloromethane (Chloroform)}}{CHCl_3} + HCl$$

$$\underset{\text{Trichloromethane}}{CHCl_3} + Cl_2 \rightarrow \underset{\text{Tetrachloromethane (Carbon tetrachloride)}}{CCl_4} + HCl$$

The substitution products can be separated by fractional distillation because of the appreciable differences in their respective boiling points.

Ethane also reacts with chlorine in the same way, producing successively chloroethane, dichloroethane, trichloroethane, tetrachloroethane, pentachloroethane and hexachloroethane.

Alkane	+	Halogen	→	Substituted product	+	Acid
C_2H_6 (ethane)	+	Cl_2	→	C_2H_5Cl (monochloroethane)	+	HCl
C_2H_5Cl (chloroethane)	+	Cl_2	→	$C_2H_4Cl_2$ (dichloroethane)	+	HCl
$C_2H_4Cl_2$ (dichloroethane)	+	Cl_2	→	$C_2H_3Cl_3$ (trichloroethane)	+	HCl
$C_2H_3Cl_3$ (trichloroethane)	+	Cl_2	→	$C_2H_2Cl_4$ (tetrachloroethane)	+	HCl
$C_2H_2Cl_4$ (tetrachloroethane)	+	Cl_2	→	C_2HCl_5 (pentachloroethane)	+	HCl
C_2HCl_5 (pentachloroethane)	+	Cl_2	→	C_2Cl_6 (hexachloroethane)	+	HCl

Note : *All alkanes react with chlorine, bromine and iodine in a similar manner, producing the corresponding substituted products.*

(ii) *Reaction with oxygen*

Methane and *ethane* burn in air with a *bluish non-sooty flame* to form carbon dioxide and water vapour. A large amount of heat is also given out, so alkanes are good gaseous fuels.

Methane :	$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
Ethane :	$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$

During combustion, due to the low carbon content in methane and ethane, they get fully oxidised to carbon dioxide, and *burn with a non-sooty flame.*

Insufficient supply of air

When alkanes burn in an *insufficient supply of air* (oxygen), they form carbon monoxide and water.

$$2CH_4 + 3O_2 \rightarrow 2CO + 4H_2O$$

$$2C_2H_6 + 5O_2 \rightarrow 4CO + 6H_2O$$

$CH_4 + O_2 \rightarrow C + 2H_2O$ **(with still less oxygen).**
(soot)

> *Soot is used in the manufacture of printing inks and tyres.*

2. Decomposition of alkanes (Cracking or pyrolysis)

The decomposition of a compound by heat in the absence of air is called ***Pyrolysis***. When pyrolysis occurs in alkanes, the process is termed **cracking**.

The alkanes, on heating under high temperature or in the presence of a catalyst in absence of air are broken down into lower alkanes, alkenes and hydrogen.

$$\underset{\text{Methane}}{2CH_4} \xrightarrow{1500^\circ C} \underset{\text{Ethyne}}{HC\equiv CH} + 3H_2$$

$$\underset{\text{Ethane}}{H_3C-CH_3} \xrightarrow[Al_2O_3]{500^\circ C} \underset{\text{Ethene}}{H_2C=CH_2} + H_2$$

$$\underset{\text{pentane}}{C_5H_{12}} \xrightarrow[\text{Alumina or silica}]{400-600^\circ C} \underset{\text{propane}}{C_3H_8} + \underset{\text{ethene}}{C_2H_4}$$

$$\underset{\text{heptane}}{C_7H_{16}} \xrightarrow[\text{Alumina or silica}]{400-600^\circ C} \underset{\text{butane}}{C_4H_{10}} + \underset{\text{propene}}{C_3H_6}$$

3. Catalytic oxidation of alkanes

On controlled oxidation or catalytic oxidation, alkanes give alcohols or aldehydes or carboxylic acids, *depending upon the reaction conditions.*

(i) When a mixture of methane and oxygen in the ratio 9:1 by volume is compressed to about 120 atm pressure and passed over copper tubes at 475 K, **methyl alcohol** is formed.

$$2CH_4 + O_2 \xrightarrow[120\,\text{atm.}]{475\,\text{K Cu tube}} 2CH_3OH$$

(ii) When a mixture of methane and oxygen is passed through heated *molybdenum oxide (MoO)*, the mixture is oxidised to **formaldehyde**.

$$CH_4 + O_2 \xrightarrow{MoO} HCHO + H_2O$$

(iii) When a manganese based catalyst is used at 100°C, methane can be oxidised to formic acid.

$$2CH_4 + 3O_2 \xrightarrow{\text{Mn compound}} 2HCOOH + 2H_2O$$

Similarly, ethane oxidises to either ethyl alcohol or acetaldehyde or acetic acid.

$$2C_2H_6 + O_2 \xrightarrow[\text{Cu tubes 475K}]{120\,\text{atm}} \underset{\text{Ethyl alcohol}}{2C_2H_5OH}$$

$$C_2H_6 + O_2 \xrightarrow{MoO} \underset{\text{Acetaldehyde}}{CH_3CHO} + H_2O$$

$$C_2H_5OH + O_2 \xrightarrow[300^\circ C]{Pt} \underset{\text{Acetic acid}}{CH_3COOH} + H_2O$$

4. Slow combustion

Methane or ethane can be treated with oxidising agents like acidified $K_2Cr_2O_7$ or acidified $KMnO_4$ at high pressure and at comparatively low temperature.

$$\text{Alkane} \xrightarrow[K_2Cr_2O_7]{[O]} \text{Alcohol} \xrightarrow[K_2Cr_2O_7]{[O]} \text{Aldehyde} \xrightarrow[K_2Cr_2O_7]{[O]} \text{Carboxylic acid} \rightarrow \text{Carbon dioxide and water vapour}$$

or

$$\underset{\text{Methane}}{CH_4} \xrightarrow{[O]} \underset{\text{Methyl alcohol}}{CH_3OH} \xrightarrow{[O]} \underset{\text{Formaldehyde}}{HCHO} \xrightarrow{[O]} \underset{\text{Formic acid}}{HCOOH} \xrightarrow{[O]} CO_2 + H_2O$$

([O] represents contribution of the oxidising agent)

Other alkanes also form similar products when reacts with oxidising agent.

12.15.3 Uses

Methane

(i) Methane is a source of carbon monoxide and hydrogen.

(ii) It is used in the preparation of useful compounds like ethyne (acetylene), methanal (formal-dehyde), methanol, chloro-methane and tetrachloro-methane (carbon tetrachloride).

Earlier chloroform was used for anaesthesia. Since its higher dose can kill a person therefore, now-a-days HALOTHANE ($CF_3CHBrCl$) is used for anaesthetic purposes.

(iii) It is employed as a domestic fuel.

Ethane

(i) Ethane is used in the preparation of ethene, ethanol, ethanal (acetaldehyde) and ethanoic acid (acetic acid).

(ii) It forms ethyl chloride, which is used to make tetraethyllead. 1, 1, 1-trichloroethane is one solvent that is used a lot, in dry cleaning.

(iii) Ethane is also a good fuel.

EXERCISE 12B

1. State the sources of Alkanes.
2. Methane is a green house gas. Comment.
3. Give the general formula of alkanes.
4. Draw the structures of isomers of :
   (a) butane, (b) pentane.
   Write the IUPAC and common names of these isomers.
5. Write the :
   (a) molecular formula,
   (b) electron dot formula and
   (c) structural formula of methane and ethane.
6. How is :
   (a) methane and
   (b) ethane prepared in the laboratory ?
7. How are methane and ethane prepared from methyl iodide and ethyl bromide ?
8. What is a substitution reaction ?
   Give the reaction of chlorine with ethane and name the product formed.
9. Name the compounds formed when methane burns in :
   (a) sufficient air,
   (b) insufficient air.
   Give a balanced equation.
10. Write the names and the formula of the products formed when :
    (a) methane, (b) ethane,
    reacts with : (i) chlorine (ii) bromine
    Write the chemical equations.
11. Name the compound prepared from :
    (a) sodium propionate, (b) methyl iodide and
    (c) ethyl bromide.
    Write a balanced equation for the same.
12. What is pyrolysis or cracking ? Explain with example.
13. Convert :
    (a) Methane into chloroform,
    (b) Sodium acetate into methane,
    (c) Methyl iodide into ethane,
    (d) Aluminium carbide into methane.
14. Give three uses of :
    (a) methane, (b) ethane.
15. Under what conditions does ethane get converted to :
    (a) ethyl alcohol, (b) acetaldehyde,
    (c) acetic acid.
16. Give the inter-relationship of methane, methyl alcohol, formaldehyde and formic acid with conditions.

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12C HYDROCARBONS : ALKENES

12.16 ALKENES

Alkenes are also called ***olefins*** (oil-forming) because the lower members of alkenes form oily products when they are treated with chlorine or bromine. Alkenes form a homologous series having the **general formula C_nH_{2n}** (refer to Table 12.7).

Table 12.7 : Homologous series of alkenes, general formula C_nH_{2n}

Molecular formula	*Condensed formula*	*Structural formula*	*Trivial name (Common name)*	*IUPAC name*
C_2H_4	$CH_2 = CH_2$	H H | | H—C = C—H	Ethylene	Ethene
C_3H_6	$CH_3 - CH = CH_2$	H H H | | | H—C—C = C—H | H	Propylene	Propene
C_4H_8	$CH_3–CH_2–CH = CH_2$	H H H H | | | | H—C—C—C = C—H | | H H	Butylene	Butene

Alkenes are unsaturated aliphatic hydrocarbons that contain one double bond.

Occurrence : Since alkenes are reactive, they seldom occur free in nature. Lower alkenes occur in minute quantities in coal gas. They are produced on a large scale by the cracking of petroleum.

Isomers in alkenes

Alkenes with 4 or more than 4 carbon atoms can form isomers.

For example : Butene has three isomers :

(i) $CH_3CH_2CH = CH_2$
But-1-ene

(ii) $CH_3CH = CHCH_3$
But-2-ene

(iii) $CH_2 = C - CH_3$ (with CH_3 on the middle C)
2–methyl propene

Types of isomerism shown by Alkenes

(i) Chain Isomerism :
Example
$CH_3CH_2CH = CH_2$ — 1-butene
$CH_3 — C(CH_3) = CH_2$ — 2-methyl propene

(ii) Position isomerism :
Example
$CH_3CH_2CH = CH_2$ — 1-butene
$CH_3CH = CHCH_3$ — 2-butene

12.16.1 Ethene (Ethylene) C_2H_4

It is the first member of the alkene series. It is present in natural gas. In small amounts, it occurs as a plant hormone and is responsible for the **ripening of fruits**.

12.16.2 Structure of ethene

Each carbon atom of ethene is attached to two hydrogen atoms by single covalent bonds and to another carbon atom by a double covalent bond. There are four C–H single covalent bonds and one C=C double covalent bond. It is a **planar** (flat) **molecule**. All bond angles (H–C–H and H–C=C) *are* of 120°, as shown in Fig. 13.3.

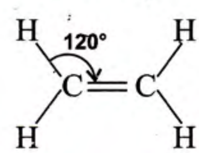


Fig. 12.3 Structure of ethylene

12.16.3 Preparation of ethene (ethylene)

(i) Dehydration of ethyl alcohol

Reactants : Ethanol and conc. sulphuric acid.

Procedure : Arrange the apparatus as shown in Fig. 12.4. Take one part of ethyl alcohol in a flask. Add two parts of concentrated sulphuric acid and heat gradually to about 170°C. Ethylene is evolved. The gas is passed through NaOH solution which removes CO_2 and SO_2 (impurities formed by oxidation of the acid). Ethylene is collected by downward displacement of water (*add some aluminium sulphate to the water in order to avoid frothing*).

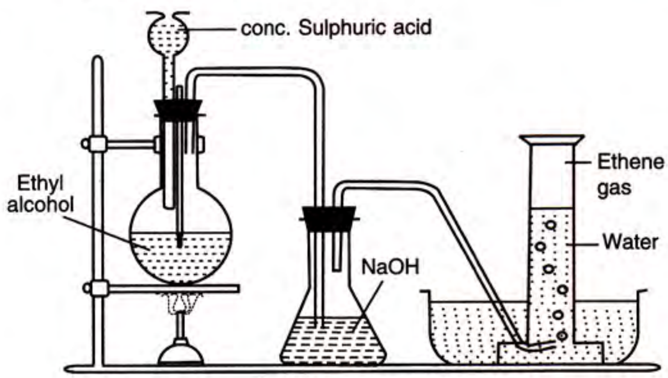


Fig. 12.4 Preparation of ethene from ethyl alcohol

Reaction :

$$\underset{\text{(Ethanol)}}{CH_3CH_2OH} + H_2SO_4 \rightarrow \underset{\text{(Ethyl hydrogen sulphate)}}{CH_3CH_2HSO_4} + H_2O$$

$$CH_3CH_2HSO_4 \xrightarrow[170°C]{\text{excess } H_2SO_4} \underset{\text{Ethene}}{CH_2 = CH_2} + H_2SO_4$$

Or

$$C_2H_5OH \xrightarrow[170°\,C]{\text{Conc. } H_2SO_4} C_2H_4 + H_2O$$

Collection : The gas is collected by downward displacement of water because :

(i) it is an inflammable gas.

(ii) it is insoluble in water.

(ii) By dehydration : Industrial preparation

By passing *ethanol vapours through a tube containing alumina* (Al_2O_3) at 300°C.

$$C_2H_5OH \xrightarrow[350°C]{Al_2O_3} C_2H_4 + H_2O$$

(iii) Dehydrohalogenation :

$$C_2H_5Cl + \underset{\text{(alc. hot and conc.)}}{KOH} \rightarrow C_2H_4 + KCl + H_2O$$

$$C_2H_5Br + \underset{\text{(alcoholic) (hot and conc.)}}{KOH} \rightarrow C_2H_4 + KBr + H_2O$$

$$C_2H_5I + \underset{\text{(alcoholic) (hot and conc.)}}{KOH} \rightarrow C_2H_4 + KI + H_2O$$

12.16.4 Properties of Alkenes

A. Physical properties

(i) Ethene is a colourless and inflammable gas with a peculiar odour (faint sweetish smell).

(ii) Its boiling point is –102°C and melting point is –169°C.

(iii) It is sparingly soluble in water but highly soluble in organic solvents like alcohol, ether and chloroform.

(iv) It produces an anaesthetic effect upon inhalation.

B. Chemical properties

1. Addition Reactions

(i) Addition of hydrogen (hydrogenation)

When ethene and hydrogen are passed over finely divided catalysts such as **platinum or palladium** at ordinary temperature or **nickel at 200°C**, the two atoms of hydrogen molecule are added to the unsaturated molecule, which thus becomes a saturated one.

$$\underset{\text{Ethene}}{C_2H_4} + H_2 \xrightarrow[Ni]{200°C} \underset{\text{Ethane}}{C_2H_6}.$$

(ii) Addition of halogens (halogenation)

Reaction with fluorine is explosive, hence the compound formed is not stable.

Chlorine, bromine and iodine are added to the double bond of ethene (ethylene) at room temperature to form saturated ethylene chloride, ethylene bromide and ethylene iodide.

$$\underset{\text{Ethene}}{CH_2 = CH_2} + Cl_2 \rightarrow \underset{\text{1, 2-dichloro ethane (ethylene chloride)}}{\underset{|\quad\;\;|}{\overset{}{CH_2 - CH_2}}\atop{Cl\quad\; Cl}}$$

$$CH_2 = CH_2 + Br_2 \rightarrow \underset{\text{Br}}{\underset{|}{CH_2}} - \underset{\text{Br}}{\underset{|}{CH_2}}$$

Ethene — 1, 2-dibromo ethane (ethylene bromide)

Bromine solution in CCl_4 has an orange colour. When added dropwise to ethene, the orange colour of bromine disappears due to the formation of the colourless ethylene bromide.

$$C_2H_4 + I_2 \rightarrow C_2H_4I_2$$

1, 2-di-iodoethane (ethylene iodide)

Reaction with iodine is very slow and ethylene iodide formed is unstable. It eliminates the iodine readily and regenerates the ethene.

(iii) *Addition of water (hydration)*

A water molecule gets added to alkenes in the presence of acids (e.g., sulphuric acid) to form alcohols.

$$CH_2 = CH_2 + H_2O \xrightarrow{H^+} C_2H_5OH.$$

(iv) *Addition of HCl*

When ethene gas is treated with HCl, chloroethane is formed.

$$CH_2 = CH_2 + HCl\,(aq) \rightarrow CH_3 - CH_2Cl.$$

Ethene — Ethyl chloride (chloroethane)

If chloroethane is treated with aqueous potassium hydroxide, ethanol is formed.

$$CH_3CH_2Cl + KOH \rightarrow CH_3CH_2OH + KCl.$$

2. Reaction with ozone (ozonolysis) : When a stream of ozone is passed through a solution of ethene in ether, ethene ozonide is formed.

$$H_2C = CH_2 + O_3 \rightarrow H_2C - O - CH_2.$$

Ethene, Ozone → (the two C atoms also joined through O — O) Ethene ozonide

3. Polymerization : When two or more molecules of the same compound associate to form a bigger molecule, the reaction is called polymerisation.

Ethene polymerises to produce polyethene

$$n\,H_2C = CH_2 \xrightarrow[\text{high pressure catalyst}]{\text{high temperature}} [H_2C - CH_2]_n.$$

(ethene) — (Polyethene)

4. Oxidation : Ethene is oxidised with alkaline $KMnO_4$ at room temperature.

$$H_2C = CH_2 + H - O - H + [O] \rightarrow \underset{\text{OH}}{\underset{|}{H_2C}} - \underset{\text{OH}}{\underset{|}{CH_2}}.$$

Ethene; Cold alkaline $KMnO_4$ solution [oxidising agent]; 1, 2-Ethanediol (Ethylene glycol)

The purple colour of $KMnO_4$ decolourises.

5. Combustion of ethene : Ethene burns in air with a *sooty flame* producing a large amount of heat. However, if the supply of air is in excess, it burns with a *pale blue flame* to produce carbon dioxide, water and a large amount of heat.

$$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O + \text{Heat}.$$

12.16.5 Uses of ethene

(i) Ethene is used in making **polythene.**

(ii) It is converted into ethanol which is used as a starting material for other products, mainly cosmetics and toiletry preparations.

(iii) It is used for **ripening of fruits.**

(iv) It is used in making **epoxyethane** (used in the manufacture of detergents).

(v) It is used for producing **oxy-ethylene flame,** which is used for **cutting and welding of metals.**

(vi) It is used in the manufacture of synthetic chemicals.

EXERCISE 12C

1. Write : (a) molecular formula, (b) electron dot formula and (c) structural formula of ethene (ethylene).

2. The molecules of alkene family are represented by a general formula C_nH_{2n}. Answer the following:

(a) What do n and $2n$ signify ?

(b) What is the name of alkene when $n = 4$?

(c) What is the molecular formula of alkene when $n = 4$?

(d) What is the molecular formula of the alkene if there are ten H atoms in it ?

(e) What is the structural formula of the third member of the alkene family ?

(f) Write the molecular formula of lower and higher homologous of an alkene which contains four carbon atoms.

3. Draw the structures of butene and write IUPAC names.

4. Give a balanced equation for the lab. preparation of ethylene. How is the gas collected ?

5. How is ethene prepared by :
   (a) dehydrohalogenation reaction ?
   (b) dehydration reaction ?
   Give equations and name the products formed.

6. (a) Ethylene when reacts with halogens (chlorine and bromine) form saturated products. Name them and write balanced equations.
   (b) Give the conditions and the main product formed by hydrogenation of ethylene.

7. How is ethanol converted into ethene using
   (a) solid dehydrating agent
   (b) hot conc. H_2SO_4 ? Give only balanced equations.

8. Write the following properties of ethene :
   (a) Physical state, (b) Odour,
   (c) Density as compared to air, (d) Solubility.

9. How would you convert :
   (a) ethene into 1, 2-dibromoethane ?
   (b) ethene into ethyl bromide ?

10. Give balanced equations when :
   (a) ethene is burnt in excess of oxygen.
   (b) ethene reacts with chlorine.
   (c) ethene combines with hydrogen chloride.
   (d) a mixture of ethene and hydrogen is passed over nickel at 200°C.

11. Give the formula and names of A, B, C and D in the following equations :
   (a) $CH_4 \xrightarrow[-HCl]{Cl_2} A \xrightarrow[-HCl]{Cl_2} B \xrightarrow[-HCl]{Cl_2} C \xrightarrow[-HCl]{Cl_2} D$
   (b) $C_2H_2 \xrightarrow{H_2} A \xrightarrow{H_2} B \xrightarrow[-HBr]{Br_2} C \xrightarrow[-HBr]{Br_2} D$
   (c) $C_2H_4 + Cl_2 \rightarrow A$
   (d) $C_2H_4 + B \xrightarrow[Ni]{200°C} C_2H_6$

12. Write the name and formula of the product formed in each case below :
   (a) $C_2H_4 + Cl_2 \longrightarrow$ ....
   (b) $C_2H_5Br + KOH\ (alc.) \xrightarrow{\Delta}$ ....
   (c) $H_2C = CH_2 \xrightarrow{alk.KMnO_4}$ ....
   (d) $H_2C = CH_2 + HBr \longrightarrow$ ....
   (e) $H_2C = CH_2 + O_3 \longrightarrow$ ....

13. What do you observe when ethylene is passed through alkaline $KMnO_4$ solution ?

14. Name three compounds formed by ethylene and give the use of these compounds.

12D HYDROCARBONS : ALKYNES

12.17 ALKYNES

The aliphatic hydrocarbons that contain a triple bond (–C ≡ C–), *i.e.,* **acetylenic bond,** between two carbon atoms are known as alkynes. They are unsaturated compounds, due to the triple bond between two carbon atoms. They form a homologous series, with the general formula $\mathbf{C_nH_{2n-2}}$ (Refer to Table 12.8).

Table 12.8 : Homologous series of alkynes (General formula : C_nH_{2n-2})

Molecular formula	Condensed formula	Structural formula	Trivial name	IUPAC name of the compound
C_2H_2	CH ≡ CH	H — C ≡ C–H	Acetylene	Ethyne
C_3H_4	$CH_3 - C \equiv CH$	H | H — C—C ≡ C—H | H	Allylene	Propyne
C_4H_6	$CH_3 - CH_2\ C \equiv CH$	H H | | H— C—C—C ≡ C—H | | H H	Crotonylene	Butyne

Sources of alkynes : Natural gas and petroleum.

Isomers in alkynes

Alkynes with four or more than four carbon atoms can form isomers. Alkynes show position isomerism as well as chain isomerism. *For example,*

Butyne

It shows position isomerism.

(i) $CH_3 - CH_2 - C \equiv CH$
IUPAC Name : But–1–yne

(ii) $CH_3 - C \equiv C - CH_3$
IUPAC Name : But–2–yne

12.17.1 Ethyne

(Common name : acetylene)

Molecular formula : C_2H_2.

Ethyne (Acetylene) is the first member of the alkyne series. Ethyne being an unsaturated hydrocarbon, is not found in free state.

Sources : Traces of ethyne are present in coal gas and in gases obtained by the decomposition of certain complex organic compounds. It is obtained by cracking of alkanes from various fractions of petroleum.

12.17.2 Structure of ethyne (acetylene)

Each carbon atom in acetylene is attached to one hydrogen atom by single covalent bond and to another carbon atom by a triple covalent bond.

Electron dot formula

$H - C \equiv C - H$

Structural formula

The shape of ethyne molecule is **linear.**

12.17.3 Laboratory preparation of ethyne (acetylene)

Reactants : Water and calcium carbide.

Procedure : Arrange the apparatus as shown in Fig. 12.5. Take a few pieces of calcium carbide in a conical flask. Add a few drops of water through the thistle funnel. Calcium carbide reacts with water to produce colourless gas with ether like odour (acetylene gas). The reaction is exothermic.

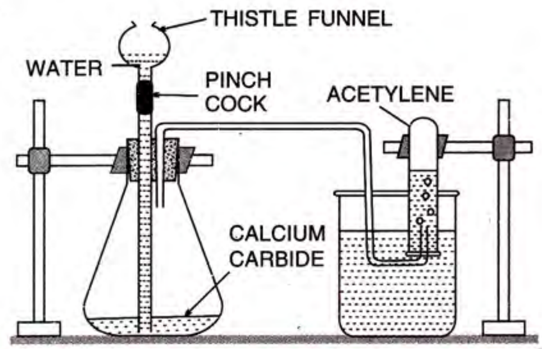


Fig. 12.5 Lab. preparation of (acetylene) ethyne.

Reaction :

$$\underset{\text{Calcium carbide}}{CaC_2} + 2H_2O \rightarrow \underset{\text{Calcium hydroxide}}{Ca(OH)_2} + \underset{\text{acetylene}}{C_2H_2\uparrow}$$

Collection : The gas is collected by downward displacement of water, since it is insoluble in water.

Purification : Impurities like phosphine, hydrogen sulphide, ammonia and arsenic are formed along with acetylene due to the contamination of calcium sulphide and calcium phosphide in calcium carbide. On passing through water, all impurities except *phosphine* are absorbed. Phosphine is *absorbed by passing through acidified copper sulphate solution or acidified potassium dichromate.*

Note : Flask should not contain air as acetylene forms explosive mixture with air. The air of the flask is displaced with oil gas.

Preparation from 1, 2-dibromoethane (ethylene dibromide).

When 1, 2-dibromoethane (ethylene dibromide) is boiled with alcoholic potassium hydroxide, ethyne is formed.

$$\begin{matrix} CH_2Br \\ | \\ CH_2Br \end{matrix} + \underset{\text{(alcoholic)}}{2KOH} \xrightarrow[\text{boiling}]{200°C} \underset{\text{(Ethyne)}}{\begin{matrix} CH \\ ||| \\ CH \end{matrix}} + 2KBr + 2H_2O$$

12.17.4 Properties of acetylene (ethyne)

A. *Physical properties*

(i) Acetylene is a colourless gas with an ether-like odour when it is pure *(the one prepared from calcium carbide has garlic odour due to the presence of traces of phosphine and hydrogen sulphide).*

(ii) It is negligibly soluble in water but highly soluble in organic solvents like acetone and alcohol.

(iii) It is lighter than air (V.D. = 13).

(iv) It liquefies at –84 °C.

(v) Its boiling point is –75 °C.

B. *Chemical properties*

Ethyne is a highly reactive compound due to the presence of triple bond between its two carbon atoms.

1. Oxidation of ethyne (combustion)

Ethyne contains a greater proportion of carbon content than does alkanes (ethane) and alkenes (ethene). Since all the carbon particles do not get oxidised completely, it burns with a **sooty flame**.

Ethyne burns in excess air with a *brilliant white flame* to produce carbon dioxide, water vapours and a large amount of heat.

$$2CH \equiv CH + 5O_2 \rightarrow 4CO_2 + 2H_2O + \text{Heat}$$

2. Addition reactions

Alkynes are unsaturated compounds, so they are associated with addition reactions, since triple bonds break up easily. The breaking up of a triple bond gives a product that is still unsaturated (double bond). Further breaking up of the double bond gives a saturated product.

(i) *Addition of hydrogen (catalytic hydrogenation)*

In the presence of nickel, platinum or palladium, ethyne first takes up two atoms of hydrogen to change to ethene, which further takes up two atoms of hydrogen to give ethane.

First stage of reaction

$$\underset{\text{Ethyne}}{C_2H_2} + H_2 \xrightarrow{Ni} \underset{\text{Ethene}}{C_2H_4}$$

Second stage

$$\underset{\text{Ethene}}{C_2H_4} + H_2 \xrightarrow{Ni} \underset{\text{Ethane}}{C_2H_6}$$

Therefore,

$$\underset{\text{Ethyne}}{HC \equiv CH} \xrightarrow[Ni]{+H_2} \underset{\text{Ethene}}{CH_2 = CH_2} \xrightarrow[Ni]{+H_2} \underset{\text{Ethane}}{CH_3 - CH_3}$$

(ii) *Addition of halogen*

Reaction with chlorine : Ethyne in an inert solvent of carbon tetra chloride [CCl_4] adds chlorine to change into an ethene derivative with carbon-carbon double bond, and then to an ethane derivative with carbon-carbon single bond.

$$\begin{matrix} CH \\ ||| \\ CH \end{matrix} \xrightarrow{Cl_2} \begin{matrix} CHCl \\ || \\ CHCl \end{matrix} \xrightarrow{Cl_2} \begin{matrix} CHCl_2 \\ | \\ CHCl_2 \end{matrix}$$

Acetylene ethyne; Acetylene dichloride 1, 2-dichloro ethene; Acetylene tetrachloride 1, 1, 2, 2 – tetrachloro ethane

Acetylene reacts vigorously with chlorine gas in the presence of sunlight to give out flames.

$$C_2H_2 + Cl_2 \rightarrow 2C + 2HCl.$$

Reaction with bromine : When bromine, in carbon tetrachloride, is added to ethyne, *its brown colour disappears due to the formation of addition products.* The reaction is similar to the addition of chlorine.

$$\underset{\text{Ethyne (Acetylene)}}{C_2H_2} \xrightarrow{+Br_2} \underset{\text{Acetylene dibromide}}{C_2H_2Br_2} \xrightarrow{+Br_2} \underset{\text{Acetylene tetrabromide}}{C_2H_2Br_4}.$$

Reaction with iodine : Iodine reacts slowly in the presence of alcohol to form di-iodo derivative.

$$CH \equiv CH + I_2 \rightarrow ICH = CHI.$$

(1, 2,–di-iodoethene)

(iii) *Reaction with HCl*

Ethyne reacts with hydrochloric acid to first form chloroethene and finally 1, 1-dichloro ethane.

$$\underset{\text{Acetylene}}{\begin{matrix} CH \\ ||| \\ CH \end{matrix}} \xrightarrow{+HCl} \underset{\text{Chloro ethene}}{\begin{matrix} CH_2 \\ || \\ CHCl \end{matrix}} \xrightarrow{+HCl} \underset{\text{1,1-dichloro ethane}}{\begin{matrix} CH_3 \\ | \\ CHCl_2 \end{matrix}}$$

(iv) *Reaction with ozone*

Ethyne reacts with ozone at room temperature to produce acetylene ozonide.

$$\underset{\text{Ethyne}}{HC \equiv CH} + O_3 \rightarrow \begin{matrix} & O & \\ & / \quad \backslash & \\ H - C & & C - H \\ | & & | \\ O & — & O \end{matrix}$$

(Acetylene ozonide)

12.17.5 Uses of ethyne (acetylene)

It is used

(i) for oxy-acetylene welding at very high temperatures. These temperatures are obtained when ethyne burns in oxygen.

(ii) as an illuminant in oxy-acetylene lamp.

(iii) for artificial ripening and preservation of fruits.

(iv) also for the manufacture of synthetic products like polymers, artificial rubber and oxalic acid, *etc.*

(v) for the manufacture of important organic compounds like acetaldehyde, acetic acid, plastic and rubber, *etc.*

12.17.6 Chemical Tests to distinguish between Alkanes, Alkenes and Alkynes

No.	Test	Alkanes (Methane and ethane) Saturated compound	Alkenes (Ethylene) Unsaturated compound	Alkynes (Acetylene) unsaturated compound
1	On adding a few drops of bromine solution in carbon tetrachloride to the hydrocarbon.	No change is observed.	The reddish brown colour of bromine solution gets decolorised.	The reddish brown colour gets decolorised.
2	On adding a few drops of alkaline potassium permanganate (purple colour) to the hydrocarbon.	No change is observed.	The purple colour fades.	The purple colour fades. (Baeyer's test) $CH \equiv CH + 4[O]$ Ethyne $\xrightarrow[\text{potassium permanganate}]{\text{alkaline}}$ $\begin{matrix} COOH \\ \vert \\ COOH \end{matrix}$ oxalic acid
3	On adding a few drops of ammonical cuprous chloride to the hydrocarbon.	No change is observed.	No change is observed.	Red precipitate of copper acetylide is formed.
4.	On adding ammonical Silver nitrate	No observation	No observation	White precipitate of silver acetylide is formed.

EXERCISE 12D

1. What are the sources for alkynes ? Give the general formula of alkynes.
2. Give an example of isomers shown by triple bond hydrocarbon (alkynes) and write its IUPAC name.
3. How is acetylene prepared in the laboratory ?
   (a) Draw a diagram. (b) Give an equation.
   (c) How is pure dry gas collected ?
4. Give the method of preparation of ethyne by : 1, 2-dibromoethene.
5. Name the hydrocarbon which :
   (a) is a tetrahedral molecule,
   (b) is a planar molecule,
   (c) is a linear molecule,
   (d) forms a red precipitate with ammoniacal solution of copper (I) chloride,
   (e) is known as paraffin,
   (f) is known as olefin.
   (g) a compound which will give acetylene (Ethene) gas when treated with water.
6. Classify the following compounds as alkanes, alkenes and alkynes. C_3H_4, C_3H_8, C_5H_8, C_3H_6
7. Give a chemical test to distinguish between
   (a) saturated and unsaturated compounds.
   (b) ethane and ethene,
   (c) ethene (ethylene) and ethyne (acetylene).
8. Name the products formed and write an equation when ethyne is added to the following in an inert solvent :
   (a) chlorine, (b) bromine,
   (c) iodine, (d) hydrogen.
   (e) excess of hydrochloric acid.

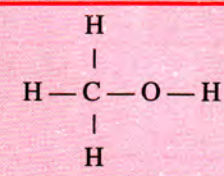
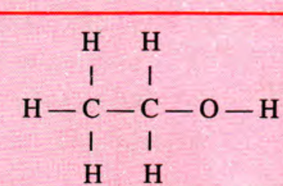
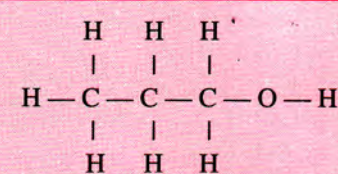
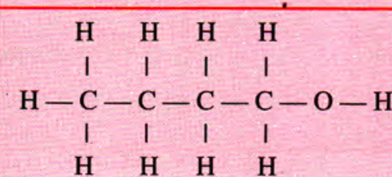
12E ALCOHOLS

12.18 ALCOHOLS

Alcohols are the hydroxyl derivatives of alkanes. They are formed by replacing one or more hydrogen atoms of the alkane with OH group.

Homologous series of alcohols and structural formula are given in Table 12.9.

TABLE 12.9 : HOMOLOGOUS SERIES OF ALCOHOLS (General formula : $C_nH_{2n+1}OH$)

Common Name	Molecular formula	Abbreviated formula	Structural formula	IUPAC Name
Methyl alcohol	CH_3OH	$CH_3–OH$		Methanol
Ethyl alcohol	C_2H_5OH	$CH_3 – CH_2 – OH$		Ethanol
Propyl alcohol	C_3H_7OH	$CH_3 – CH_2 – CH_2 – OH$		Propanol
Butyl alcohol	C_4H_9OH	$CH_3 – CH_2 – CH_2 – CH_2 – OH$		Butanol

Alcohols can be ***monohydric***, *i.e.*, with one OH group attached to the carbon atom.

Example :

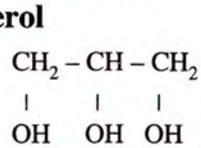
Methyl alcohol (CH_3OH) and **ethyl alcohol** (C_2H_5OH).

They can be ***dihydric***, *i.e.*, with two OH groups attached to the carbon atom.

Example : **Glycol** $C_2H_4(OH)_2$.

They can be ***trihydric***, *i.e.*, with three OH groups attached to the carbon atom.

Example : **Glycerol**



IUPAC name : 1, 2, 3–propane triol.

12.19 ETHANOL

12.19.1 Occurrence

Since alcohols are not found naturally in the earth's atmosphere, so they are obtained by synthesis.

For example, methanol (wood spirit) is obtained from destructive distillation of wood, while ethanol is obtained from fermentation* of sugar.

$$C_6H_{12}O_6\ (aq.) \xrightarrow[37°C]{enzymes} 2C_2H_5OH + 2CO_2$$

> Cracking of petroleum is a source of ethane, which is used for preparing ethanol.

* Fermentation is an anaerobic process. It takes place under conditions where there is no air or oxygen available.

Ethyl alcohol is an essential constituent of all wines and is called SPIRIT OF WINE. It is obtained from starchy grain and is also known as GRAIN ALCOHOL.

12.19.2 Laboratory preparation

Alcohol can be prepared by the ***hydrolysis of alkyl halides*** *(haloalkanes) on reaction with a hot dilute alkali.* [R stands for alkyl group]

Alkyl halide +	Alkali	→	Alcohol	+ Alkali halide
RX +	KOH (aqueous)	$\xrightarrow{\text{boil}}$	ROH	+ KX
CH_3Br +	KOH (aqueous)	$\xrightarrow{\text{boil}}$	CH_3OH	+ KBr
C_2H_5Cl +	KOH (aqueous)	$\xrightarrow{\text{boil}}$	C_2H_5OH	+ KCl
C_2H_5Br +	NaOH (aqueous)	$\xrightarrow{\text{boil}}$	C_2H_5OH	+ NaBr

12.19.3 Industrial method (large scale method)

Hydration of ethene : When concentrated sulphuric acid is added to ethene (obtained from cracking of petroleum) at a temperature of 80°C and pressure of 30 atm, ethyl hydrogen sulphate is produced. Ethyl hydrogen sulphate, on hydrolysis with boiling water, gives ethanol.

$$\underset{\text{Ethene}}{C_2H_4} + H_2SO_4 \xrightarrow[30\,\text{atm}]{80°C} C_2H_5HSO_4$$

$$\underset{\text{Ethyl hydrogen sulphate}}{C_2H_5HSO_4} + \underset{\text{(Boiling)}}{H_2O} \rightarrow \underset{\text{Ethanol}}{C_2H_5OH} + H_2SO_4$$

Alternatively, ethanol is produced when ethene is heated with water at 300°C and 60 atmosphere pressure in presence of phosphoric acid catalyst.

$$C_2H_4 + H_2O \xrightarrow[300°C,\ 60\ \text{atm.}]{H_3PO_4} C_2H_5OH$$

12.19.4 Properties of alcohols

A. ***Physical properties :***

(i) **Nature :** They are inflammable volatile liquids.

(ii) **Boiling point :** Their boiling point increases with an increase in molecular weight.

Examples : CH_3OH = 64·5°C

CH_3CH_2OH = 78·3°C

(iii) **Solubility :** They are soluble in water as well as in organic solvents.

(iv) **Density :** Ethanol is lighter than water its specific gravity is 0·79 at 293 K.

(v) They are **colourless** and have a faint odour and a burning taste.

(vi) They are toxic.

For example : methyl alcohol, *if consumed, causes blindness and even death.*

> **Ethyl alcohol** affects *that part of the brain which controls our muscular movements and then gives temporary relief from tiredness. But it damages the liver and kidney too.*

B. ***Chemical properties :***

Alcohols are a reactive class of compounds.

1. Combustion (burning)

Alcohol burns readily in air to produce carbon dioxide and water vapours. A lot of heat is produced during the combustion of alcohols.

$$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$$

Ethanol burns with a pale blue flame.

2. Oxidation with acidified potassium dichromate (oxidising agents)

Alcohols react with oxidising agents like acidified *potassium dichromate* and acidified *potassium* manganate.

These oxidising agent supply nascent oxygen [O] for oxidation and thus alcohols first get converted into aldehydes and later change into their respective acids.

Alcohol	*Oxidising agent*	*Aldehyde*	*Oxidising agent*	*Carboxylic acid*
CH_3OH Methyl alcohol	$\xrightarrow[K_2Cr_2O_7]{[O]}$	$HCHO + H_2O$ Formaldehyde (methanal)	$\xrightarrow[K_2Cr_2O_7]{[O]}$	HCOOH Formic acid (methanoic acid)
C_2H_5OH Ethyl alcohol	$\xrightarrow[K_2Cr_2O_7]{[O]}$	$CH_3CHO + H_2O$ Acetaldehyde (ethanal)	$\xrightarrow[K_2Cr_2O_7]{[O]}$	CH_3COOH Acetic acid (ethanoic acid)

> If wine or beer is left open in the air, ethanol is oxidised to ethanoic acid. This is why wine tastes like vinegar after it's been left open for a couple of days.

3. Action with sodium

When sodium reacts with methyl alcohol and ethyl alcohol at room temperature, hydrogen is evolved with the formation of sodium methoxide and sodium ethoxide respectively.

$$2CH_3OH + 2Na \rightarrow \underset{\text{Sodium methoxide}}{2CH_3ONa} + H_2$$

$$2C_2H_5OH + 2Na \rightarrow \underset{\text{Sodium ethoxide}}{2C_2H_5ONa} + H_2$$

Effervescence of Hydrogen serves as a test for alcohols.

4. Reactions with acetic acid

When alcohols react with acetic acid in the presence of conc. H_2SO_4 at high temperature, the respective esters are produced and the process is known as *esterification*.

$$CH_3OH + CH_3COOH \xrightarrow{\text{conc. } H_2SO_4} \underset{\text{(Methyl acetate)}}{CH_3COOCH_3} + H_2O$$

$$C_2H_5OH + CH_3COOH \xrightarrow{\text{conc. } H_2SO_4} \underset{\text{(Ethyl acetate)}}{CH_3COOC_2H_5} + H_2O$$

Esters can be detected by their fruity smell.

5. Dehydration with conc. sulphuric acid

When concentrated sulphuric acid is added to ethyl alcohol and the mixture is heated upto 170°C, it causes dehydration of ethyl alcohol to give ethene.

$$\underset{\text{Ethyl alcohol}}{C_2H_5OH} \xrightarrow[170°C]{\text{conc. } H_2SO_4} \underset{\text{Ethene}}{CH_2 = CH_2} + H_2O$$

Ethanol can also be dehydrated by aluminium oxide at 350°C.

$$C_2H_5OH \xrightarrow[350°C]{Al_2O_3} C_2H_4 + H_2O$$

At 140°C conc. H_2SO_4 dehydrates alcohol to give the respective ethers.

$$\underset{\text{Methyl alcohol}}{2CH_3OH} \xrightarrow[140°C]{\text{conc. } H_2SO_4} \underset{\text{Dimethyl ether}}{CH_3 - O - CH_3} + H_2O$$

$$\underset{\text{Ethyl alcohol}}{2C_2H_5OH} \xrightarrow[140°C]{\text{conc. } H_2SO_4} \underset{\text{Diethyl ether}}{C_2H_5 - O - C_2H_5} + H_2O$$

6. Reaction with phosphorus halide

Alcohols react with phosphorus trichloride at room temperature to give chloroalkane and phosphorus acid.

$$3CH_3OH + PCl_3 \rightarrow \underset{\text{Chloromethane}}{3CH_3Cl} + H_3PO_3$$

$$3C_2H_5OH + PCl_3 \rightarrow \underset{\text{Chloroethane}}{3C_2H_5Cl} + \underset{\text{Phosphorus acid}}{H_3PO_3}$$

12.19.5 Uses of ethyl alcohol

(i) It is a good solvent for gums and resins.

(ii) It is used in thermometers and as preservative for biological specimens, due to its low freezing point.

(iii) It is used in the manufacture of chemicals such as chloroform, iodoform, ether, acetic acid and synthetic products like dyes, esters (perfumes), antiseptics, preservatives, etc.

(iv) Ethyl alcohol is used in alcoholic drinks (beverages) like whisky, wine and beer. Beers contain about 4% ethanol, wines about 11% and spirits (rum, brandy and whisky) 40% or more.

(v) As a fuel in form of power alcohol and as an antifreeze for automobile radiators.

Different commerical forms of ethanol

The alcohol obtained by distillation is 95% pure. It forms a constant boiling mixture of 5% water and 95% ethanol. Absolute alcohol may be obtained by distilling moist alcohol with benzene (an organic solvent). The mixture of water and benzene distills off and anhydrous alcohol is left behind.

1. Denatured alcohol or methylated spirit

Ethyl alcohol is a part of drinking beverages and is also a widely used solvent in industries. In order to make it undrinkable, certain poisonous substances like **pyridine, methyl alcohol** and **copper sulphate** are added to it.

Methylated spirit or denatured alcohol is ethyl alcohol with 5% methyl alcohol, a coloured dye and some pyridine. It is used for industrial applications.

2. Spurious alcohol

This is illicit liquor made by improper distillation. It contains large proportions of methanol in a mixture of alcohols. It is fatal for human consumption.

Spurious alcohol, though impure, can be used as a solvent for paints and varnishes.

EXERCISE 12E

1. (a) What are alcohols ? State their sources.
   (b) Give general formulae of monohydric alcohol.
2. Give the :
   (a) dot diagram,
   (b) abbreviated formula,
   (c) structure of second member of the alcohol group.
   (d) structure of alcohol with 4 carbon atoms.
3. State the method of preparation of ethanol :
   (a) by hydrolysis of ethene,
   (b) by hydrolysis of ethyl bromide.
4. Halo alkanes reacts with alkalies to produce alcohol. Give the equation for the preparation of second member of homologous series of alcohol. State under what condition the reaction occur.
5. (a) How do the boiling point and melting point change in the homologous series of alcohols ?
   (b) Name the product formed when ethanol reacts with acetic acid. Give an equation.
   (c) What is the name given to this type of reaction ?
6. Complete and balance the following equations. State the conditions wherever necessary.
   (a) $CH \equiv CH + H_2 \rightarrow$ ________ $+ H_2 \rightarrow$ ________
   (b) $C_2H_4 + Cl_2 \rightarrow$ ________
   (c) $C_2H_4 + HCl \rightarrow$ ________
   (d) $CaC_2 + H_2O \rightarrow$ ________
   (e) $C_2H_2 + Br_2 \rightarrow$ ________
   (f) $C_2H_5OH \xrightarrow[K_2Cr_2O_7]{[O]}$ ________
7. What is the effect of ethanol on human body ?
8. How are the following obtained :
   (a) absolute alcohol, (b) spurious alcohol,
   (c) methylated spirit ?
9. Name the products formed and give appropriate chemical equations for the following :
   (a) Sodium reacting with ethyl alcohol.
   (b) Ethanol oxidised by acidified potassium dichromate.
10. Give the trivial (common) names and the IUPAC names of the following :
    (a) C_3H_6, (b) C_2H_4,
    (c) C_2H_2, (d) CH_3OH,
    (e) C_2H_5 OH.
11. Ethanol can be oxidised to ethanoic acid. Write the equation and name the oxidising agent.
12. Name an organic compound which is :
    (a) used for illuminating country houses,
    (b) used for making a household plastic material,
    (c) called 'wood spirit',
    (d) poisonous and contain OH group,
    (e) consumed as a drink,
    (f) made from water gas,
    (g) solvent for ethanol.

12F. CARBOXYLIC ACIDS

12.20 CARBOXYLIC ACIDS

An organic compound containing the carboxyl group (–COOH) is known as carboxylic acid. These compounds possess acidic properties.

General formula $C_nH_{2n+1}COOH$ (or RCOOH)

Functional group $-\overset{\overset{\large O}{\|}}{C}-OH$

An organic compound may contain one or more of these groups. Those which contain one —COOH group are called **monocarboxylic acid**.

For example : HCOOH (Formic acid), CH_3COOH (Acetic acid)

Those which contain two COOH groups are called **dicarboxylic acid**.

For example :

COOH
|
COOH

OR $(COOH)_2$

Oxalic acid

IUPAC Name : Ethane-di-oic acid

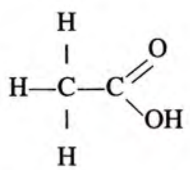
Table 12.10 : Homologous series of monocarboxylic acid

Formula	Common name	IUPAC name
$H-\overset{\overset{O}{\parallel}}{C}-OH$	Formic acid	Methanoic acid
$CH_3-\overset{\overset{O}{\parallel}}{C}-OH$	Acetic acid	Ethanoic acid
$CH_3CH_2-\overset{\overset{O}{\parallel}}{C}-OH$	Propionic acid	Propanoic acid
$CH_3CH_2CH_2-\overset{\overset{O}{\parallel}}{C}-OH$	Butyric acid	Butanoic acid

IUPAC name : IUPAC name is given by replacing '*e*' of the corresponding alkane by 'oic acid', because they are derived from alkanes by replacing one hydrogen atom with the carboxyl (–COOH) group. Thus they are also known as **Alkanoic acid**.

12.21 ACETIC ACID CH_3COOH

Structural formula :



The name acetic acid comes from latin word '**ACETUM**'. Acetic acid (IUPAC name ethanoic acid) occurs in free state in many fruits and as esters in a number of essential oils.

Dilute (4-5 percent) solution of acetic acid is also called vineger. The presence of a colouring matter gives vinegar a greyish colour while the presence of some other organic compound imparts it the usual taste and flavour. Vinegar is used for flavouring and preserving foods.

12.21.1 Lab preparation

Acetic acid can be prepared in the lab by oxidation of ethyl alcohol or acetaldehyde with acidified **potassium dichromate** or acidified sodium dichromate

$$\underset{\text{(ethanol)}}{CH_3CH_2OH} \xrightarrow{[O]} \underset{\text{(ethanal)}}{CH_3CHO} \xrightarrow{[O]} \underset{\text{ethanoic acid}}{CH_3COOH.}$$

12.21.2 Manufacture

(i) From acetylene

Acetylene is first converted into acetaldehyde by passing through 40% H_2SO_4 at 60°C in the presence of 1% $HgSO_4$ (catalyst).

$$C_2H_2 + H_2O \xrightarrow[HgSO_4]{H_2SO_4 \text{ (dil.)}} CH_3CHO.$$

The acetaldehyde is oxidised to acetic acid by passing a mixture of acetaldehyde vapours and air over **manganous acetate** at 70°C.

$$2CH_3CHO + O_2 \xrightarrow[\text{Catalyst}]{\Delta} 2CH_3COOH.$$

(ii) From ethanol

Acetic acid can also be prepared by passing alcohol vapours over platinum black as catalyst at 300°C in the presence of oxygen.

$$C_2H_5OH + O_2 \xrightarrow[\text{Platinum}]{300°C} CH_3COOH + H_2O$$

12.21.3 Physical properties

1. **Physical state :** Pure acetic acid is a colourless liquid.
2. **Odour :** Characteristic pungent smell.
3. **Boiling point :** It boils at 118°C.
4. **Melting point :** The anhydrous acid on cooling forms crystalline mass resembling ice; melting point 17°C and for this reason, it is called *glacial acetic acid.*
5. **Nature :** It is *hygroscopic liquid*, sp. gr. at 0°C is 1·08.
6. **Solubility :** It is miscible with water, alcohol and ether in all proportions.

12.21.4 Chemical properties

1. It is a weak acid, hence

(i) turns blue litmus red.

(ii) reacts with active metals (*i.e.*, Zn and Mg) evolving hydrogen.

$$2CH_3COOH + Zn \rightarrow \underset{\text{Zinc acetate}}{(CH_3COO)_2Zn} + H_2\uparrow$$

$$\underset{\text{Acetic acid}}{2CH_3COOH} + Mg \rightarrow \underset{\text{Magnesium acetate}}{(CH_3COO)_2Mg} + H_2\uparrow$$

(iii) forms salt and water with bases

Acid	+	Base	→	Salt	+	Water
CH_3COOH	+	NaOH	→	CH_3COONa	+	H_2O
Acetic acid				Sod. acetate		

(iv) liberates carbon dioxide with carbonates or hydrogen carbonates.

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

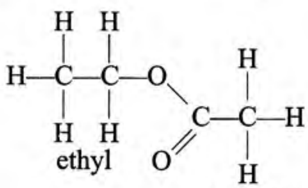
$$CH_3COOH + NaHCO_3 \rightarrow CH_3COONa + H_2O + CO_2\uparrow$$

2. Acetic acid forms ester (pleasant fruity smelling compound) on reacting with alcohol in the presence of conc. H_2SO_4.

$$\underset{\text{Acetic acid}}{CH_3COOH} + \underset{\text{Ethanol}}{HOC_2H_5} \xrightarrow{H_2SO_4} \underset{\text{Ethyl acetate}}{CH_3COOC_2H_5} + H_2O$$

The reaction is known as reaction of esterification.

Structure of Ethyl acetate (ethyl ethanoate)



ethanoate

3. Acetic Acid reacts with Phosphorus penta chloride and get converted to **acetylchloride**.

$$CH_3COOH + PCl_5 \rightarrow CH_3COCl + POCl_3 + HCl$$

4. It forms **acetic anhydride** on heating with phosphorus pentoxide as, it loses water molecule.

$$2CH_3COOH \xrightarrow[P_2O_5]{\Delta} (CH_3CO)_2O + H_2O$$

5. *Reduction* : A strong reducing agent such as lithum aluminium hydride ($LiAlH_4$) will reduce acetic acid to ethanol.

$$CH_3COOH + 4[H] \rightarrow C_2H_5OH + H_2O$$

12.21.5 Test

1. On adding acetic acid to carbonates and bicarbonates, carbon dioxide is evolved.
2. When warmed with ethyl alcohol and conc. sulphuric acid, a pleasant fruity smell of ethyl acetate is produced.
3. On adding neutral iron (III) chloride, wine red colour is produced.

12.21.6 Acetic acid is used

1. as a solvent for resins, cellulose, *etc*.
2. as a laboratory reagent.
3. as vinegar.
4. in medicines.
5. in the production of dyes, perfumes, esters, etc.
6. For coagulating rubber from latex.
7. For the manufacture of cellulose acetate which is used for making packaging materials, varnishes, rayons, *etc*.

EXERCISE 12F

1. What are carboxylic acids ? Give their general formula.
2. Write the common name, IUPAC name and formula of one monocarboxylic acid and one dicarboxylic acid.
3. Write the names of :
   (a) first three members of carboxylic acid series.
   (b) three compounds which can be oxidised directly, or in stages to produce acetic acid.
4. Vinegar is greyish in colour with a particular taste. Explain.
5. Give the structural formulae and IUPAC name of acetic acid. What is glacial acetic acid ?
6. Complete :
   (a) Vinegar is prepared by the bacterial oxidation of ....
   (b) The organic acid present in vinegar is ....
   (c) The next higher homologue of ethanoic acid is ....
7. How is acetic acid prepared from
   (a) ethanol (b) acetylene ?
8. What do you notice when acetic acid reacts with
   (a) litmus, (b) metals,
   (c) alkalies, (d) alcohol ?
9. Acetic acid is a typical acid. Write one equation in each case for its reaction with
   (a) a metal, (b) a base/alkali,
   (c) a carbonate, (d) a bicarbonate.

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10. Give *two* tests to show that CH_3COOH is acidic in nature.

11. What do you observe when acetic acid is added to :
    (a) sodium bicarbonate,
    (b) ethyl alcohol in the presence of sulphuric acid,
    (c) neutral $FeCl_3$ solution ?

12. Name :
    (a) compound formed when acetic acid and ethanol react together.
    (b) reducing agent used to convert acetic acid into ethanol.
    (c) substance used to change acetic acid to acetic anhydride.

MISCELLANEOUS

1. (a) Write an equation for the laboratory preparation of (i) an unsaturated hydrocarbon from calcium carbide. (ii) an alcohol from ethyl bromide.
   (b) What would you see, when ethyne is bubbled through a solution of bromine in carbon tetrachloride ?
   (c) Name the addition product formed between ethene and water.

2. Ethanol can be converted into ethene which can be changed into ethane. Choose the correct word or phrase from the brackets to complete the following sentences.
   (a) The conversion of ethanol into ethene is an example of _______ (dehydration, dehydrogenation).
   (b) Converting ethanol into ethene requires the use of ______ (conc. HCl, conc. HNO_3, conc. H_2SO_4).
   (c) The conversion of ethene into ethane is an example of ______ (hydration, hydrogenation).
   (d) The catalyst used in the conversion of ethene into ethane is commonly ______ (iron, nickel, cobalt).

3. Give reasons :
   (a) Ethyne is more reactive than ethene.
   (b) Ethene is more reactive than ethane.
   (c) Hydrocarbons are excellent fuels.

4. (a) Write balanced equations
   (i) when butane is burnt in oxygen
   (ii) preparation of ethylene from ethyl alcohol.
   (b) (i) Convert ethane to acetic acid
   (ii) Convert acetylene to ethane
   (iii) Convert acetic acid to ethyl alcohol
   (iv) Convert acetic acid to ethyl acetate.

5. Write the equations for the following lab. preparations:
   (a) Ethane from sodium propionate,
   (b) Ethene from Iodoethane,
   (c) Ethyne from calcium carbide,
   (d) Methanol from Iodomethane.

6. (a) Write the equation for the preparation of carbon tetrachloride from methane.
   (b) Draw the structural formula of ethyne.
   (c) How is the structure of alkynes different from that of alkenes ?

7. Fill in the blanks with the correct words from the brackets :
   Alkenes are the (a) .... (analogous/homologous) series of (b) .... (saturated/unsaturated) hydrocarbons. They differ from alkanes due to the presence of (c) .... (double/single) bonds. Alkenes mainly undergo (d) .... (addition/ substitution) reactions.

8. (a) Draw the structural formulae of the two isomers of Butane. Give the correct IUPAC name of each isomer.
   (b) State one use of acetylene.

9. Copy and complete the following table which relates to three homologous series of hydrocarbons:

General Formula	C_nH_{2n}	C_nH_{2n-2}	C_nH_{2n+2}
IUPAC name of the homologous series			
Characteristic bond type			Single bonds
IUPAC name of the first member of the series			
Type of reaction with chlorine.		Addition	

2008

(a) **Name** the organic compound prepared by each of the following reactions :

(i) $C_2H_5COONa + NaOH \rightarrow$

(ii) $CH_3I + 2H \rightarrow$

(iii) $C_2H_5Br + KOH$ (alcoholic solution) $\rightarrow$

(iv) $CO + 2H_2$ (Zinc oxide catalyst) $\rightarrow$

(v) $CaC_2 + 2H_2O \rightarrow$

(b) Write the equations for the following reactions :

(i) Calcium carbide and water.

(ii) Ethene and water (steam).

(iii) Bromoethane and an aqueous solution of sodium hydroxide.

(c) Distinguish between the saturated hydrocarbon ethane and the unsaturated hydrocarbon ethene by drawing their structural formulae.

(d) Addition reactions and substitution reactions are types of organic reactions. Which type of reaction is shown by :

(i) ethane (ii) ethene ?

(e) (i) Write the equation for the complete combustion of ethane.

(ii) Using appropriate catalysts, ethane can be oxidized to an alcohol, an aldehyde and an acid. Name the alcohol, aldehyde and acid formed when ethane is oxidized.

(f) (i) Why is pure acetic acid known as glacial acetic acid ?

(ii) What type of compound is formed by the reaction between acetic acid and an alcohol ?

2009

(a) Which of the following statements is wrong about alkanes ?

(i) They are all saturated hydrocarbon.

(ii) They can undergo addition as well as substitution reaction.

(iii) They are almost non polar in nature.

(iv) On complete combustion give out carbon dioxide and water.

(b) The organic compound obtained as the end product of the fermentation of sugar solution is :

(i) Methanol (ii) Ethanol

(iii) Ethane (iv) Methanoic acid

(c) Find the odd one out and explain :

$$C_3H_8,\ C_5H_{10},\ C_2H_6,\ CH_4$$

(d) Give chemical equation for :

(i) The laboratory preparation of methane from sodium acetate.

(ii) The industrial preparation fo methanol from water gas.

(iii) The reaction of one mole of ethene with one mole of chlorine gas.

(iv) The preparation of ethyne from 1, 2-dibromoethane.

(e) State how the following conversions can be carried out :

(i) Ethyl chloride to Ethyl alcohol

(ii) Ethyl chloride to Ethene

(iii) Ethene to Ethyl alcohol

(iv) Ethyl alcohol to Ethene

(f) (i) Define isomerism

(ii) Give the IUPAC name of the isomer C_4H_{10} which has a branched chain.

2010

(a) An organic compound undergoes addition reactions and gives a red colour precipitate with ammoniacal cuprous chloride. Therefore, the organic compound could be :

(i) Ethane (ii) Ethene

(iii) Ethyne (iv) Ethanol

(b) An organic weak acid is :

(i) Formic acid (ii) Sulphuric acid

(iii) Nitric acid (iv) Hydrochloric acid

(c) The organic compound mixed with ethanol to make it spurious is :

(i) Methanol (ii) Methanoic acid

(iii) Methanal (iv) Ethanoic acid

(d) Draw the structural formula for each of the following:

(i) Ethanoic acid (ii) But-2-yne

(e) Compound A is bubbled through bromine dissolved in carbon tetrachloride and the product is $CH_2Br - CH_2Br$.

(i) Draw the structural formula of A.

(ii) What type of reaction has A undergone ?

(iii) What is your observation ?

(iv) Name (not formula) the compound formed when steam reacts with A in the presence of phosphoric acid.

(v) What is the procedure for converting the product of (e) (iv) back to A ?

2011

(a) The functional group present in acetic acid is :

(i) Ketonic $>C = O$ (ii) Hydroxyl $- OH$

(iii) Aldehydic $- CHO$ (iv) Carboxyl $- COOH$

(b) The unsaturated hydrocarbons undergo :
   (i) a substitution reaction
   (ii) an oxidation reaction
   (iii) an addition reaction
   (iv) none of the above

(c) The number of C-H bonds in ethane molecule are :
   (i) Four (ii) Six
   (iii) Eight (iv) Ten

(d) Choose the correct word/phrase from within the brackets to complete the following sentences :
   (i) The catalyst used for conversion of ethene to ethane is commonly .... (nickel / iron / cobalt)
   (ii) When acetaldehyde is oxidized with acidified potassium dichromate, it forms .... (ester / ethanol / acetic acid)
   (iii) Ethanoic acid reacts with ethanol in presence of concentrated H_2SO_4, so as to form a compound and water. The chemical reaction which takes place is called .... (dehydration / hydrogenation / esterification)
   (iv) Write the equation for the reaction taking place between 1, 2–dibromoethane and alcoholic potassium hydroxide.
   (v) The product formed when ethene gas reacts with water in the presence of sulphuric acid .... (ethanol /ethanal / ethanoic acid)

(e) Write balanced chemical equations for the following :
   (i) Monochloro ethane is hydrolysed with aqueous KOH.
   (ii) A mixture of sodalime and sodium acetate is heated.
   (iii) Ethanol under high pressure and low temperature is treated with acidified potassium dichromate.
   (iv) Water is added to calcium carbide.
   (v) Ethanol reacts with sodium at room temperature.

2012

(a) Give the structural formula for the following :
   (i) Methanoic acid (ii) Ethanal
   (iii) Ethyne (iv) Acetone
   (iv) 2-methyl propane.

(b) From the following organic compounds given below, choose one compound in each case which relates to the description [i] to [iv] :
[*Ethyne, ethanol, acetic acid, ethene, methane*].
   (i) An unsaturated hydrocarbon used for welding purposes.
   (ii) An organic compound whose functional group is carboxyl.
   (iii) A hydrocarbon which on catalytic hydrogenation gives a saturated hydrocarbon.
   (iv) An organic compound used as a thermometric liquid.

(c) (i) Why is pure acetic acid known as glacial acetic acid ?
   (ii) Give a chemical equation for the reaction between ethyl alcohol and acetic acid.

2013

(a) (i) Give a chemical test to distinguish ethene gas and ethane gas.
   (ii) Identify the statement that is incorrect about alkanes :
      (A) They are hydrocarbons.
      (B) There is a single covalent bond between carbon and hydrogen.
      (C) They can undergo both substitution as well as addition reactions.
      (D) On complete combustion they produce carbon dioxide and water.

(b) Give the structural formulae for the following :
   (i) An isomer of n-butane.
   (ii) 2-propanol.

2014

(a) The I.U.P.A.C. name of acetylene is :
   (i) propane (ii) propyne
   (iii) ethene (iv) ethyne

(b) Name hydrocarbons containing a $-\overset{\overset{\displaystyle O}{\|}}{C}-$ functional group.

(c) Give preparation of ethane from sodium propionate.

(d) Distinguish ethane and ethene (using alkaline potassium permanganate solution).

(e) Give the structural formula of the following :
   (i) ethanol (ii) 1-propanal
   (iii) ethanoic acid (iv) 1, 2, dichloroethane.

(f) Give preparation of ethanol from monochloroethane and aq. sodium hydroxide.