Unit 11

Organic Chemistry

Long Answer Questions

Q.1 Explain the types of formulae of organic compounds.

Ans. There are four types of formulae of organic compounds:

(i) Molecular formula

(ii) Structural formula

(iii) Condensed formula

(iv) Dot and cross formula

(i) Molecular Formula

The formula which represents the actual number of atoms in one molecule of the organic compound is called the molecular formula. For example molecular formula of butane is C_4H_{10}. It shows:

(a) Butane is made up of carbon and hydrogen atoms.

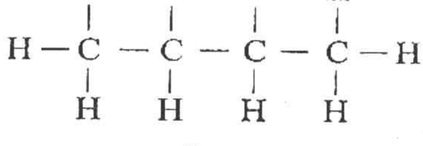
(b) Each molecule of butane consists of 4 carbon atoms and 10 hydrogen atoms.

(ii) Structural Formula

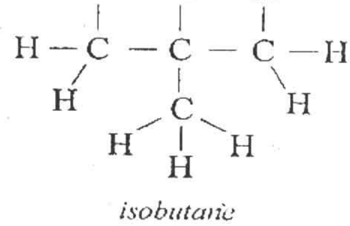
Structural formula of a compound represents the exact arrangement of the different atoms of various elements present in a molecule of a substance.

In a structural formula, single bond is represented by a single line (—), a double bond by two lines (=) and a triple bond by three lines (≡) between the bonded atoms.

Organic compounds may have same molecular formulae but different structural formulae, e.g., structural formulae of butane C_4H_{10} are:



n-Butane



isobutane

(iii) Condensed Formula

The formula that indicate the group of atoms joined together to each carbon atom in a straight chain or a branched chain is called the condensed formula.

$H_3C-(CH_2)_2-CH_3$

n-butane

or

$H_3C-CH_2-CH_2-CH_3$

$H_3C-CH-CH_3$

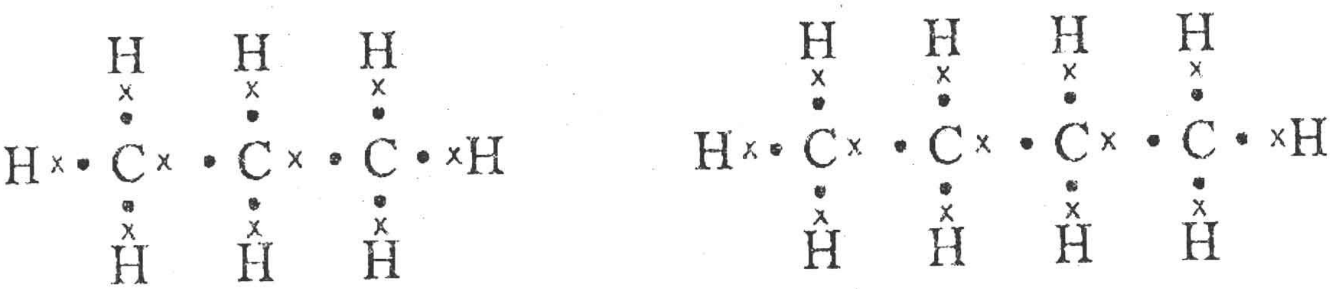
$\quad\quad\quad|$

$\quad\quad CH_3$

isobutane

(iv) Electronic or Dot and Cross Formula

The formula which shows the sharing of electrons between various atoms in one molecule of the organic compound is called dot and cross formula or electronic formula.



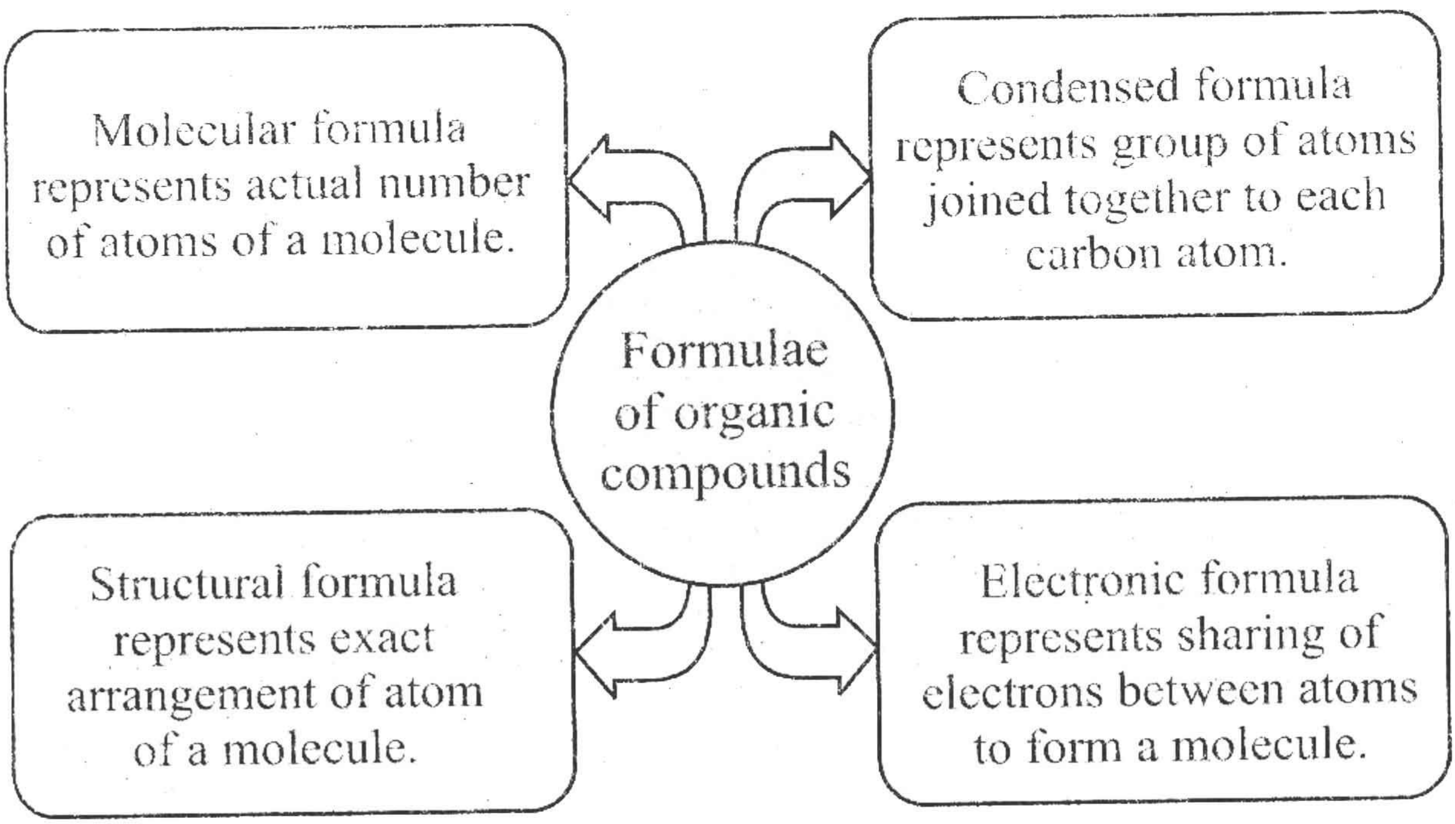


Table: presents the names, molecular formulae, condensed form and structural formulae of the first ten hydrocarbons.

Hydrocarbons

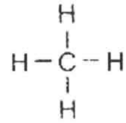
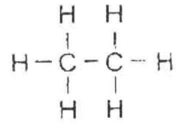
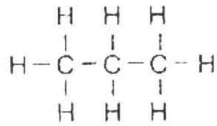
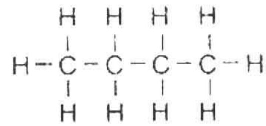
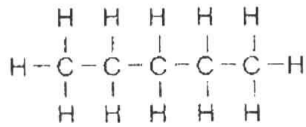
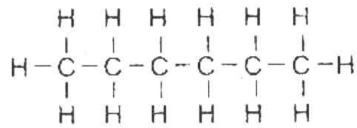
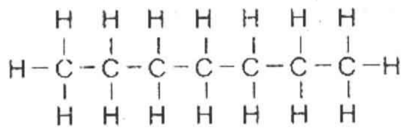
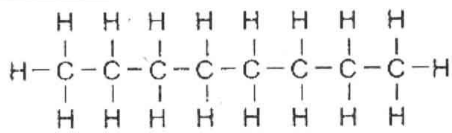
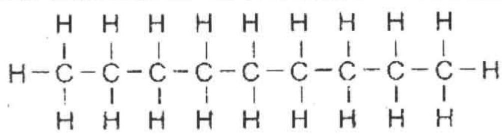
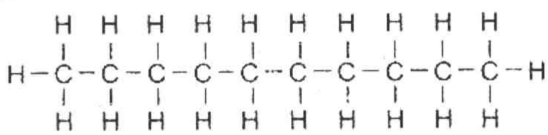
Name	Molecular Formula	Condensed Form	Structural Form
Methane	CH_4	CH_4	
Ethane	C_2H_6	H_3CCH_3	
Propane	C_3H_8	$H_3CCH_2CH_3$	
Butane	C_4H_{10}	$H_3C\ (CH_2)_2CH_3$	
Pentane	C_5H_{12}	$H_3C(CH_2)_3CH_3$	
Hexane	C_6H_{14}	$H_3C(CH_2)_4CH_3$	
Heptane	C_7H_{16}	$H_3C(CH_2)_5CH_3$	
Octane	C_8H_{18}	$H_3C(CH_2)_6CH_3$	
Nonane	C_9H_{20}	$H_3C(CH_2)_7CH_3$	
Decane	$C_{10}H_{22}$	$H_3C(CH_2)_8CH_3$	

Table: Names, Molecular, Condensed and Structural Formulae of Hydrocarbons

Q.2 Explain the Classification of organic compounds.

Ans. Classification of organic compounds

All known organic compounds have been broadly divided into two categories depending upon their carbon skeleton. These are:

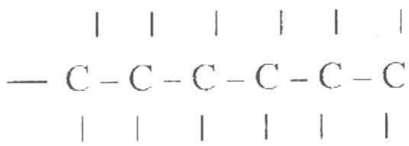
(i) Open chain or acyclic compounds.

(ii) Close chain or cyclic compounds.

(i) Open chain or Acyclic compounds

Open chain compounds are those in which the end carbon atoms are not joined with each other in this way they form a long chain of carbon atoms. These chains may be either straight or branched. For example

(a) Straight chain compounds are those in which carbon atom link with each other through a single, double or triple bonds forming a straight chain, such as

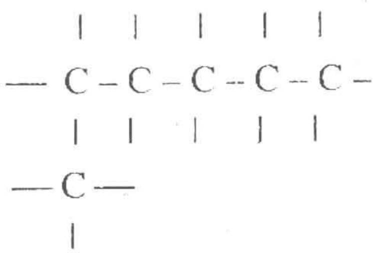


Straight Chain

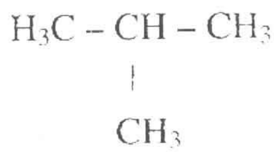
$H_3C - CH_2 - CH_2 - CH_3$

Straight Chain (n-Butane)

(b) Branched chain compounds are those in which there is a branch along a straight chain, such as:



Branched chain



Branched chain (isobutane)

Open chain compounds are also called **aliphatic compounds**.

(ii) Closed chain or Cyclic compounds

Closed chain or cyclic compounds are those in which the carbon atoms at the end of the chain are not free. They are linked to form a ring. They are further divided into two classes:

(a) Homocyclic or carbocyclic compound

(b) Heterocyclic compounds.

(a) Homocyclic or carbocyclic compounds

Homocyclic or carbocyclic compounds contain rings which are made up of only one kind of atoms, i.e., carbon atoms. These are further divided into two classes:

- Aromatic compounds
- Alicyclic compounds

Aromatic compounds

These organic compounds contain at least one benzene ring in their molecule. A benzene ring is made up of six carbon atoms with three alternating double bonds. They are called aromatic because of aroma or smell they have. For example,

Benzene Naphthalene

They are also called **benzenoid compounds.**

Alicyclic or non-benzenoid compounds:

Carbocyclic compounds which do not have benzene ring in their molecules are called alicyclic or non-benzenoid compounds. For examples,

CH_2 CH_2

CH_2 CH_2

Cyclobutane

CH_2

CH_2 CH_2

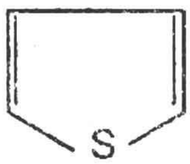
CH_2 CH_2

CH_2

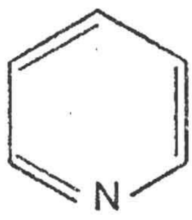
Cyclohexane

(b) Heterocyclic compounds

Cyclic compounds that contains one or more atoms other than that of carbon atoms in their rings are called heterocyclic compounds.

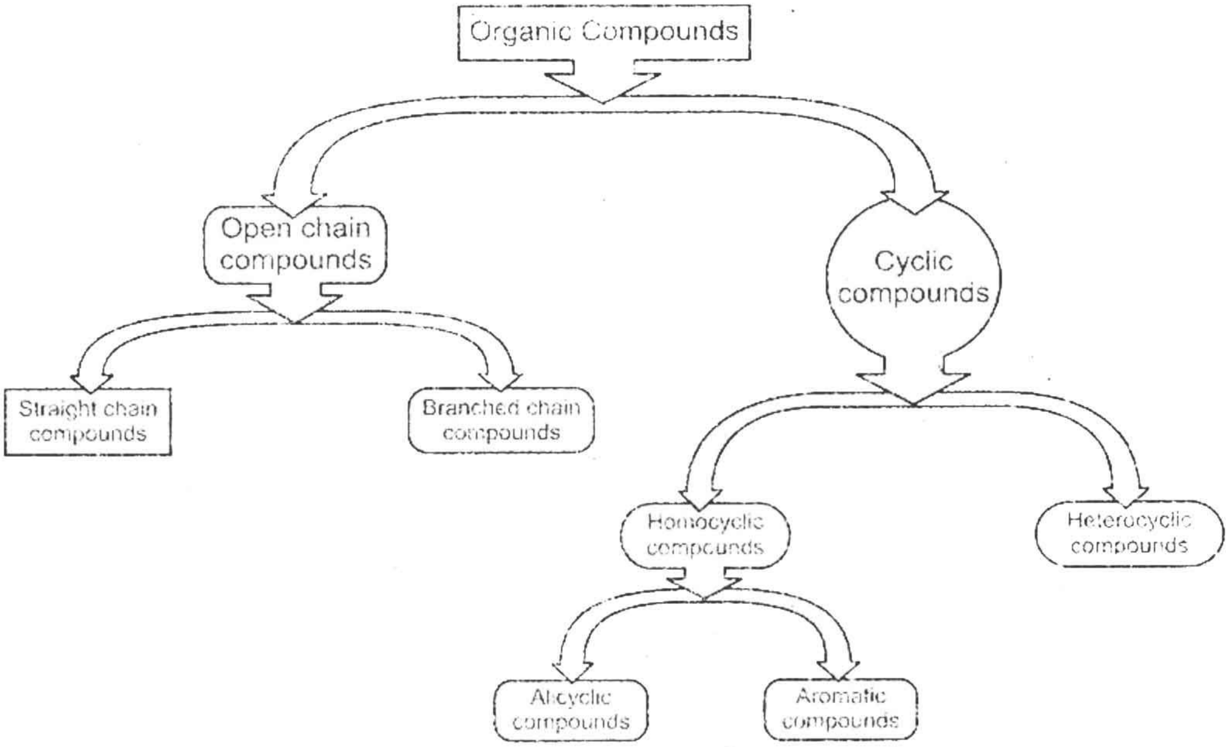


Thiophene



Pyridine

The above classification may be summarized as follows:



Q.3 Explain Diversity and Magnitude of Organic Compounds.

Ans: Diversity and Magnitude of Organic Compounds

There are a total of 118 elements known today. The number of organic compounds (carbon compounds) is more than ten million. This number is far more than the number of compounds of all the remaining elements taken together. The existence of such a large number of organic compounds is due to the following reasons:

(i) Catenation:

The main reason for the existence of a large number of organic compounds is that carbon atoms can link with one another by means of covalent bonds to form long chains or rings of carbon atoms. The chains can be straight or branched. **The ability of carbon atoms to link with other carbon atoms to form long chains and large rings is called catenation**.

Condition for Catenation

Two basic conditions for an element to exhibit catenation are:

(a) Element should have valency two or greater than two.

(b) Bonds made by an element with its own atoms should be stronger than the bonds made by the element with other atoms especially oxygen.

Silicon does not show isomerism's

Both silicon and carbon have similar electronic configurations but carbon shows catenation whereas silicon does not. It is mainly due to the reason that C-C bonds are much stronger (355 kJ mol^{-1}) than Si-Si (200 kJ mol^{-}) bonds. On the other hand, Si – O bonds are much stronger (452 kJ mol^{-1}) than C – O bonds (351 kJ mol^{-1}). Hence silicon occurs in the form of silica and silicates in nature.

(ii) Isomerism

Another reason for the abundance of organic compounds is the phenomenon of isomerism.

Definition

The compounds are said to be isomers if they have the same molecular formula but different arrangement of atoms in molecules or different structural formulae.

Isomerism also adds to the possible number of structure. For example molecular formula of pentane C_5H_{12} can be represented by three different structures. Thus, C_5H_{12} has three isomers, as shown below:

$$H_3C - CH_2 - CH_2 - CH_2 - CH_3$$

n-pentane

$$\begin{array}{c} H_3C - CH - CH_2 - CH_3 \\ \quad\quad\quad\; | \quad\quad\quad\quad\quad\quad\quad\quad \\ \quad\quad\quad CH_3 \quad\quad\quad\quad\quad\quad \end{array}$$

isopentane

$$\begin{array}{c} CH_3 \\ | \\ H_3C - C - CH_3 \\ | \\ CH_3 \end{array}$$

neopentane

Number of isomers increase with the increase in number of carbon atom in the given molecular formula.

iii. Strength of covalent bonds of carbon

Due to its very small size, carbon can form very strong covalent bonds with other carbon atoms, hydrogen, oxygen, nitrogen and halogens. This enables it to form a large number of compounds.

iv. Multiple bonding

In order to satisfy its tetravalency, carbon can make multiple bonds (i.e., double and triple bonds). This further adds to the possible number of structures. For example, two carbons in ethane are linked by a single covalent bond, by a double covalent bond in ethylene and a triple covalent bond in acetylene.

Q.4 Write down the general characteristic of Organic Compounds.

Ans. General characteristic of Organic Compounds

Organic compounds have the following general characteristics.

(i) Origin: Naturally occurring substances are obtained from plants and animals. On the other hand, inorganic compounds are obtained from minerals and rocks.

(ii) Composition: Carbon is an essential constituent of all organic compounds. They are made up of few elements such as carbon, hydrogen, nitrogen, oxygen, halogen, sulphur etc. On the other hand inorganic compounds are made up of almost all the elements of the Periodic Table known so far.

(iii) Covalent linkage: organic compound contain covalent bonds that may be polar or non-polar, while the inorganic compounds mostly contain ionic bonds.

(iv) Solubility: Organic compounds having non-polar linkages are generally soluble in organic solvents like alcohol, ether, benzene, carbon disulphide etc. on the other hand, the inorganic compounds with ionic bonds are soluble in polar solvents like water.

(v)Electrical Conductivity: Due to the presence of covalent bonds, organic compounds are poor conductor of electricity. Whereas inorganic compounds being ionic in nature, are good conductors of electricity.

(vi) Melting and boiling points: Generally organic compounds have low melting and boiling points and are volatile in nature. Inorganic compounds, on the other hand, have comparatively high melting and boiling points.

(vii) Stability: Since organic compounds have low melting and boiling points they are less stable than inorganic compounds.

(viii) Combustibility: Organic compounds with high percentage of carbon are generally combustible. On the other hand, inorganic compounds are mostly non-combustible.

(ix) Isomerism: A main characteristics of organic compounds which differentiate them from inorganic substances is their tendency to exhibit the phenomenon of isomerism. Isomerism is rare in inorganic substance.

(x)Rate of reaction: Due to the presence of covalent linkages, the reactions of organic compounds are molecular in nature. They are often slow and require specific conditions such as temperature, pressure or catalyst.

Q.5 How coal is formed? Explain the different types of coal.

Ans: Coal

Coal is blackish, complex mixture of compounds of carbon, hydrogen and oxygen. It also consists of small amounts of nitrogen and sulphur compounds.

Formation of coal

Coal was formed by the decomposition of dead plants buried under the Earth's crust millions of years ago. **Conversion of wood into coal is called carbonization.** It is a very slow bio-chemical process. It takes place in the absence of air under high pressure and high temperature over a long period of time (about 500 millions of years) as shown in figure. Wood contains about 40% carbon, so depending upon the extent of carbonization process, four types of coal are found. These types differ with respect to carbon content, volatile matter and moisture. Table shows the detail of contents of different types of coals and their uses in daily life and industry.

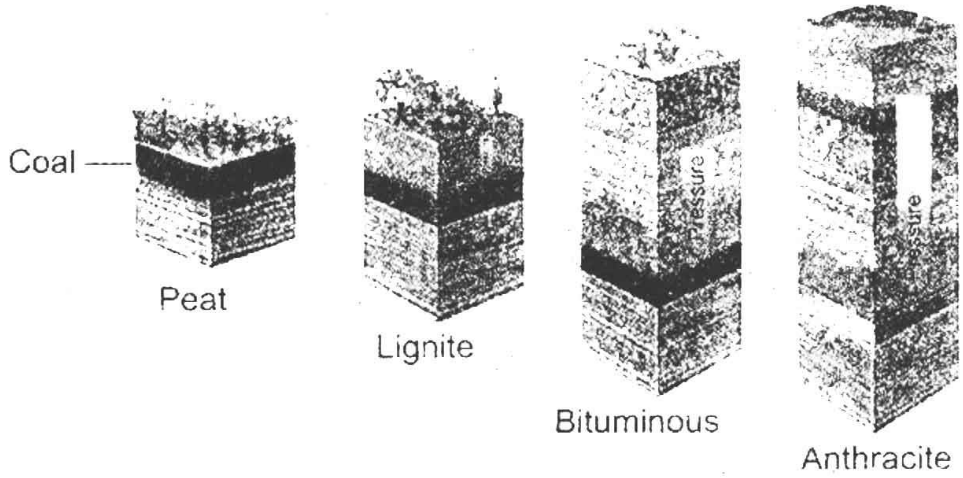


Fig. Formation of coal in different stages with the increase of pressure.

Type of Coal	Carbon contents	Uses
Peat	60%	It is inferior quality coal used in kiln.
Lignite	70%	It is soft coal used in thermal power stations.
Bituminous	80%	It is common variety of coal used as household coal.
Anthracite	90%	It is superior quality hard coal that is used in industry.

Q.6 What is destructive distillation of coal? Explain the different types of the products obtained by the destructive distillation.

Ans. Destructive distillation of Coal

Coal has become a major source of organic compounds because of destructive distillation. **The strong heating of coal in the absence of air is called destructive distillation**. As we know coal contains elements like carbon, hydrogen, oxygen, nitrogen, and sulphur. So destructive distillation of coal provides a large number of organic compounds along with a few inorganic compounds.

Products obtained by the destructive distillation of coal

(i) Coal Gas:

It is mixture of hydrogen, methane and carbon monoxide. It produces heat when burnt in air. Therefore, it is mainly used as a fuel in industry. It is also used to provide an inert or reducing atmosphere in various metallurgical processes.

(ii) Ammonical Liquor:

It is a solution of ammonia gas in water. It is used to prepare nitrogenous fertilizers. For example, when it is treated with sulphuric acid, it produces ammonium sulphate, fertilizer.

(iii) Coal-Tar:

It is a thick black liquid. It is a mixture of more than 200 different organic compounds, mostly aromatic. These compounds are separated by fractional distillation. Some of the important aromatic compounds are benzene, phenol, toluene, aniline, etc. These chemicals are used to synthesize drugs, dyes, explosives, paints, varnishes, plastics, synthetic fiber and pesticides. Besides these valuable chemicals, **the black residue of the coal tar is called pitch.** It is used for surfacing of roads and roofs.

(iv) Coke:

Coke is 98% carbon. It is left behind residue of coal. When coal is subjected to destructive distillation, it loses all its volatile components and leaves behind a solid residue called coke. It is mainly used as a reducing agent in the extraction of metals especially iron. It is also used as fuel.

Q.7 Write down the uses of organic compounds.

Ans: Uses of organic compounds

No doubt, thousands of organic compounds are synthesized naturally by animals and plants. But millions of organic compounds are being prepared in the laboratories by the `chemists. Because these compounds are part of everything from food we eat to the various items we use in daily life to fulfill our needs.

(i) **Uses as Food:** The food we eat daily such as milk, eggs, meat, vegetables, etc., contain carbohydrates proteins, fats, vitamins, etc., are all organic stuff.

(ii) **Uses as Clothing:** All types of clothing (we wear, we use as bed sheets etc.) are made up of natural fibres.

(iii) **Uses as Houses:** Wood is cellulose (naturally synthesized organic compound). It is used for making house and furniture of all kinds.

(iv) **Uses as Fuel:** The fuels we use for automobiles and domestic purposes are coal, petroleum and natural gas. These are called fossil fuels. All of these are organic compounds.

(v) **Uses as medicines:** A large number of organic compounds (naturally synthesized by plants) are used as medicines by us. Most of the life saving medicines and drugs such as antibiotics (inhibit or kill microorganisms which cause infectious diseases) are synthesized in laboratories.

(vi) **Uses as Raw Material:** Organic compounds are used to prepare a variety of material, such as rubber, paper, ink, drugs, dyes, paints, varnishes, pesticides, etc.

Q.8 Define homologous series write down characteristics of homologous series.

Ans: Homologous series

Organic compounds are divided into groups of compounds having similar chemical properties. Each group is known as a homologous series. Organic compounds of the same homologous series have the following properties in common:

Characteristics of homologous series

(i) All members of a series can be represented by a general formula for example general formulae of alkane, alkenes and alkynes are CnH_{2n+2}, CnH_{2n}, and CnH_{2n-2}, respectively.

(ii) Successive members of the series differ by one unit of – CH_2 – and 14 units in their relative molecular mass.

(iii) They have similar chemical properties (because they contain the same functional group).

(iv) There is a regular change in their physical properties; the melting and boiling points increase gradually with the increase of molecular masses.

(v) They can be prepared by similar general methods.

Hydrocarbons are regarded as parent organic compounds. All other compounds are considered to be derived from them by substituting one or more hydrogen atoms of a hydrocarbon by one or more reactive atoms.

Q.9 Write detail note on functional groups.

Ans: Functional Group

An atom or group of atoms or presence of double or triple bound which determines the characteristic properties of an organic compound is known as the functional group. The remaining part of the molecule mainly determines the physical properties such as melting point, boiling point, density etc

Example

- OH group is the functional group of alcohols, which gives characteristics properties of alcohols. The characteristic properties of carboxylic acids are due to the presence of – COOH group in them. Therefore, functional group of carboxylic acids is – COOH group.

Functional groups containing Carbon, Hydrogen and Oxygen

The organic compounds containing carbon, hydrogen and oxygen as functional group are alcohols, ethers, aldehydes, ketones, carboxylic acids and ester. Their class name, functional group, class formula and examples are given below

(i) **Alcoholic Group**

The functional group of alcohols is – OH. Their general formula is ROH. Where R is any alkyl group.

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

(ii) Ether Linkage

The functional group of ether is $C-O-C$. their general formula is

$R\text{-}O\text{-}R'$. where R and R' are alkyl groups

R and R may be same or different, such as

$H_3C\text{-}O\text{-}CH_3$ Dimethyl ether

$C_2H_5\text{-}O\text{-}C_2H_5$ Diethyl ether

$H_3C\text{-}O\text{-}C_2H_5$ Ethyl methyl ether

(iii) Aldehydic Group

Aldehyde family consists of functional group $-\overset{\overset{O}{\|}}{C}-H$

Their general formula is RCHO.

Where R stands for H or some alkyl group, such as:

$$H-\overset{\overset{O}{\|}}{C}-H \qquad\qquad H_3C-\overset{\overset{O}{\|}}{C}-H$$

Formaldehyde Acetaldehyde

(iv) Ketonic Group

Compounds containing the functional group $>C=O$ are called ketones.

They have the general formula $R-\overset{\overset{O}{\|}}{C}-R'$

Where R and R' are alkyl groups. They may be same or different, such as:

$$H_3C-\overset{\overset{O}{\|}}{C}-CH_3 \qquad\qquad H_3C-\overset{\overset{O}{\|}}{C}-CH_2-CH_3$$

Acetone (Dimethyl Ketone) EthylmethylKetone

(v) Carboxyl Group

Compounds containing functional group $-\overset{O}{\overset{||}{C}}-OH$ are called carboxylic acids. their general formula is $R-\overset{O}{\overset{||}{C}}-OH$;

Where R stands for – H or some alkyl group. Such as:

$$\underset{\text{Formic acid}}{H-\overset{O}{\overset{||}{C}}-OH} \qquad \underset{\text{Acetic acid}}{H_3C-\overset{O}{\overset{||}{C}}-OH}$$

vi) Ester Linkage

compound containing functional group $R-\overset{O}{\overset{||}{C}}-OR'$ are called ester linkage and their general formula is $R-\overset{O}{\overset{||}{C}}-OR'$.

Example:

$$\underset{\text{Methyl Acetate}}{H_3C-\overset{O}{\overset{||}{C}}-OCH_3}$$

Q.10 Write the note on the followings (i) Petroleum (ii) Natural gas

Ans. Petroleum

Petroleum is a dark brownish or greenish black coloured viscous liquid. It is a complex mixture of several solid, liquid or gaseous hydrocarbons mixed with water, salt and earth particles.

Petroleum is a main source of organic compounds. It consists of several compounds mainly hydrocarbons. These compounds are separated by

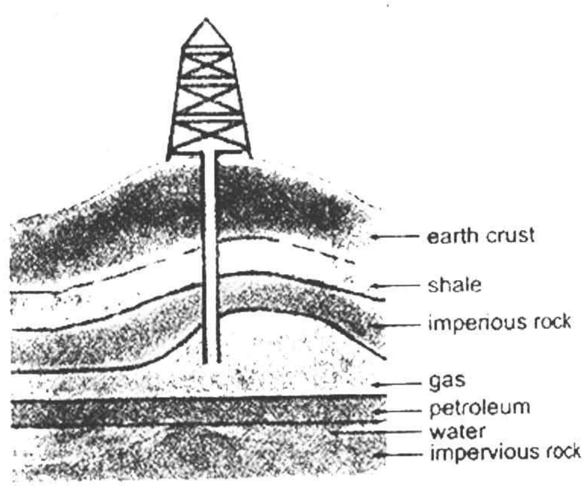


Fig: Occurrence and drilling of gas

fractional distillation (separation of fractions or components depending upon their boiling point ranges). Each fraction is not a single compound; rather each of it consists of different organic compounds.

Natural Gas

It is a mixture of low molecular mass hydrocarbons. The main component about 85% is methane, along with other gases ethane, propane and butane. Its origin is similar to that of coal and petroleum. Therefore, it is found with their deposits as shown in figure. Natural gas is used as fuel in homes as well as in industries. It is used as fuel in auto-mobiles as compressed natural gas (CNG). Natural gas is also used to make carbon black and fertilizer.

Q.11 Explain the formation of Alkyl radical.

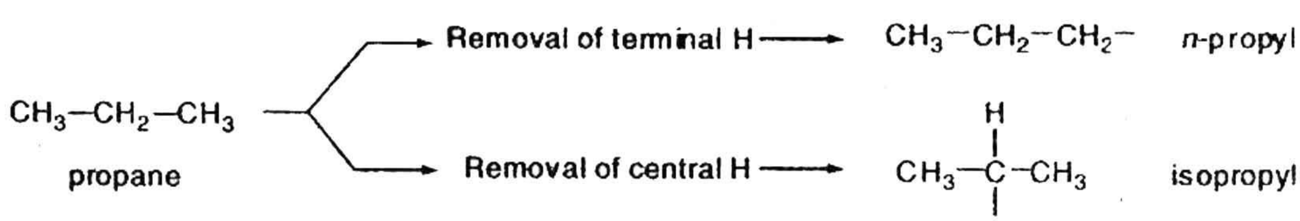
Ans: Formation of Alkyl Radicals

Alkyl radicals are derivatives of alkanes. They are formed by the removal of one of the hydrogen atom of an alkane and are represented by a letter 'R'. their name is written by replacing 'ane' of alkane with 'yl'. Table represents first ten alkanes and their alkyl radicals. Their general formula is C_nH_{2n+1}.

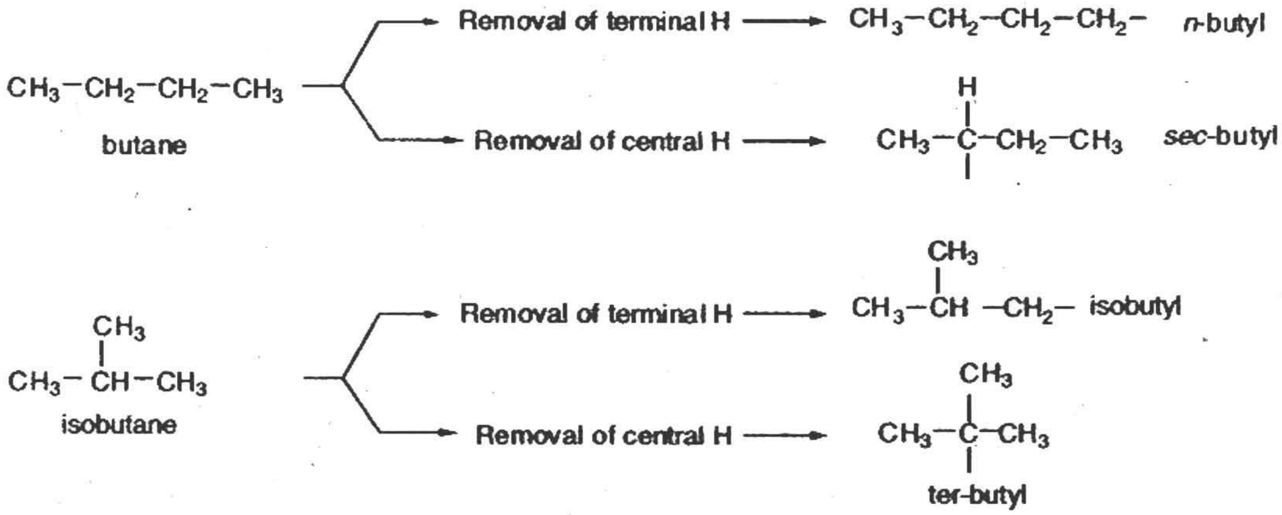
Table: Names and Molecular Formulae of Alkanes and their Alkyl Radicals

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

It is better to explain the type of radicals of propane and butane. Propane has a straight chain structure. When terminal H is removed it is called ***n* – *propyl***. When hydrogen from central carbon is removed it is called ***isopropyl,*** as explained below:



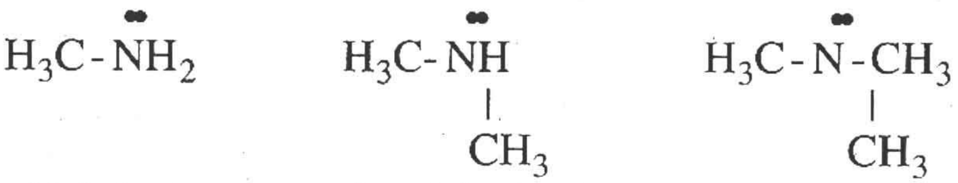
Similarly, different structures of butyl radicals are explained:



Q.12 Explain functional group containing carbon, hydrogen and Nitrogen.

Ans: Functional Group Containing Carbon, Hydrogen and Nitrogen:

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



Methylamine Dimethylamine Trimethylamine

Functional Group Containing Carbon, Hydrogen and Halogens:

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

Table Functional group containing carbon, hydrogen and halogens

Class Name	Functional Group	Class Formula	Examples
Alkyl Halides a. Primary	$-CH_2-X$	$R-CH_2-X$	H_3C-CH_2-X Ethyl halide
b. Secondary	$>CH-X$	R_2CH-X	$(H_3C)_2CH-X$ *sec*-Propyl halide
c. Tertiary	$-\overset{\mid}{\underset{\mid}{C}}-X$	R_3C-X	$(CH_3)_3C-X$ *ter*-Butyl halide

Double and Triple Bond:

Organic compounds consisting of double bonds in their molecules are called as alkenes, such as:

$$H_2C = CH_2 \qquad\qquad H_3C - CH = CH_2$$

Ethene — Propene

Organic compounds consisting of triple bonds in their molecules are called as alkynes, such as:

$$HC \equiv CH \qquad\qquad H_3C - C \equiv CH$$

Ethyne — Propyne

Q. 13 Explain the tests of functional groups?

Ans: Tests of functional groups

Test for Unsaturation $>C = C<$ **or** $-C \equiv C-$

i. **Bromine water test:**

Dissolve a pinch of the given organic compound in 2.0 cm^3 of carbon tetrachloride(CCl_4). Add 2 cm^3 of bromine water in it and shake.

Result: Bromine will be decolourised.

ii. **Baeyer's test:**

Dissolve about 0.2 g of the organic compound in water. Add to it 2-3 drops of alkaline $KMnO_4$ solution and shake.

Result: Pink colour will disappear.

Test for Alcoholic Group - OH

i. **Sodium metal test:**

Take about 2-3 cm^3 of the given organic liquid in a dry test tube and add a piece of sodium metal.

Result: Hydrogen gas will evolve.

ii. **Ester formation test**

Heat about 1.0 cm^3 of the organic compound with 1.0 cm^3 of acetic acid and 1 – 2 drops of concentrated sulphuric acid.

Result: Fruity smell will be given out

Test for Carboxylic Group $-\overset{\overset{\large O}{\|}}{C}-OH$

i. **Litmus test:**

Shake a pinch of the given compound with water and add a drop of blue litmus solution.

Result: Litmus paper will turn red.

ii. $NaHCO_3$ solution test:

Take about 2.0 cm^3 of 5% $NaHCO_3$ solution and add a pinch of given compound.

Result: CO_2 gas with effervescence evolves.

Detection of Aldehydic Group $-\overset{\overset{\displaystyle O}{\|}}{C}-H$

i. Sodium bisulphite test

Shake about 0.2 g or 0.5 cm^3 of the given compound with 1-2 cm^3 of saturated solution of sodium bisulphate.

Result: A crystalline white precipitate will be formed.

ii. Fehling's solution test:

Mix equal volumes of Fehling's solution A and B in a test tube. Add a pinch of organic compound and boil for five minutes.

Result: Red precipitate will be formed.

Test for ketonic Group

i. Phenyl hydrazine test:

Shake a pinch of the given organic compound with about 2.0 cm^3 of phenyl hydrazine solution.

Result: Orange red precipitate will be formed.

ii. Sodium nitroprusside test:

Take about 2.0 cm^3 of sodium nitroprusside solution in a test tube and add 2-3 drops of NaOH solution. Now add a pinch of the given compound and shake.

Result: Red colour will be formed.

iii. With Fehling's solution:

No reaction

Test for Primary Amino Group ($-NH_2$)

Carbyl amine test:

Heat about 0.2 g of the given compound and add 0.5 cm^3 of chloroform and add 2-3 cm^3 of alcoholic KOH.

Result: Extremely unpleasant odour will be given out.

Test of Ester:

They are recognized by their fruity smell.