

## CHAPTER

## 15

## Organic Compounds

Organic Chemistry:

Definition: "The branch of chemistry which deals with the scientific study of the structure, composition, properties, reactions and preparation of carbon based compounds i.e. hydrocarbons and their derivatives is called organic chemistry."

Hydrocarbons:

"Compounds containing carbon and hydrogen elements only are called hydrocarbons."

Organic Compounds (Old Concept):

Carbon containing compounds are called organic compounds. There are some exceptions like simple compounds of carbon like;

Carbon monoxide  $\text{CO}$ , Carbon dioxide,  $\text{CO}_2$

Metal carbonates  $\text{CaCO}_3$ , Metal bicarbonates  $\text{NaHCO}_3$

Metal carbides  $\text{Al}_4\text{C}_3$  and  $\text{CaC}_2$

Metal cyanides  $\text{NaCN}$  and  $\text{KCN}$

Ammonium cyanate  $\text{NH}_4\text{CNO}$

Organic Compounds (Modern Concept):

"Hydrocarbons and their derivatives are called organic compounds."

Beside Carbon and Hydrogen, organic compounds also contain Oxygen, Nitrogen, Sulphur and Halogens. Sometimes organic compounds also contain metallic elements like Si, Pb, Fe, Mg etc and such compounds are called organometallic compounds.

Idea about Organic Compounds:

The word organic means life. Similarly, the word "organic" is derived from organism.

Berzelius in 1807, classified organic and inorganic compounds on the basis of its source from which these are obtained.

Compounds obtained from living organisms (plants, animals) like sugar (plant source) and urea (animal source) were named as organic compounds.

Compounds obtained from mineral sources were named as inorganic compounds. The word "inorganic" means "lifeless".

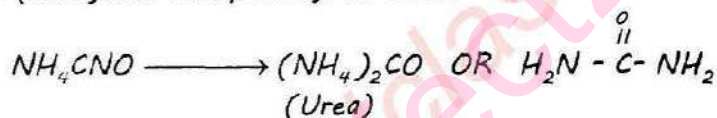
### Vital Force Theory:

According to this theory:

1. Organic compounds are prepared only inside the bodies of living organism by a super natural force called vital force.
2. It is impossible to synthesize organic compounds in the laboratory.

### Rejection of Vital Force Theory:

Vital force theory was rejected by a German chemist Fredrik Wohler. He prepared urea an organic compound by heating Ammonium cyanate (inorganic compound) in 1828.



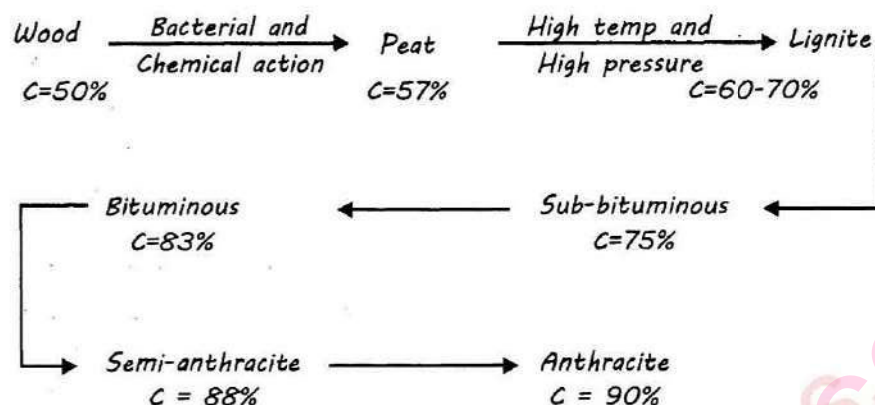
So urea was the first organic compound which was prepared in the laboratory.

**Q1: What are the main sources of organic compounds?**

**Ans:** The main sources of organic compounds are fossil fuels (3%). The old remains of plants and animals are called fossil fuels. Fossil fuels include coal, petroleum and natural gas.

#### 1) Coal:

Coal is a black mineral of plant's origin. It is black or brownish black colour mineral, normally occurring in rock strata in the form of layers called coal beds. Coal is mainly composed of carbon along with other elements like Hydrogen, Oxygen, Sulphur and Nitrogen. Coal is formed naturally from the decay of plants matter buried under the soil over millions of years ago. Due to bacterial and chemical action, the bodies of plants got converted into peat. Then as a result of high temperature and pressure inside the earth crust, peat got converted into coal, through several stages.



### Uses of Coal:

1. Coal is suitable for power generation to minimize the use of petroleum and natural gas for heating purpose.
2. Coal is used as a fuel to produce electricity and heat through combustion.
3. It is the largest source of energy for the generation of electricity world wide.
4. It is the major source of aromatic organic compounds.

### 2) Petroleum:

The word "petroleum" is the combination of two Greek words "petra" means "rock" and "oleum" means "oil". So, the word "petroleum" means rock oil (پتھائی تیل). It is also called mineral oil. It is also called crude oil (خام تیل) and liquid gold. Petroleum is naturally occurring brown or greenish black viscous (لچکدار) liquid obtained from the earth crust. It has strong unpleasant smell due to the presence of Sulphur. Petroleum is formed by the burial and decay of animals inside the earth crust after long time.

### Composition:

Petroleum is a mixture of hydrocarbons. These hydrocarbons are mostly alkanes, cycloalkanes and aromatic hydrocarbons. Some other organic compounds in trace (small) amounts are also found, which contain Nitrogen, Oxygen, Sulphur and even metals like Nickel, Copper and Vanadium.

### 3) Natural Gas:

Natural gas is found in porous rocks. It is a mixture of hydrocarbons. It occurs along with petroleum. It is a mixture of methane, ethane, propane and butane. In Pakistan it is called sui gas because the first biggest deposit of natural gas was discovered at sui in Baluchistan in 1952. It is formed by the dead decay of animal's matter. It is usually formed above the underground deposits of petroleum. Natural gas and petroleum deposits are found in association with each other. The only difference is that natural gas is composed of lower hydrocarbons while petroleum is composed of higher hydrocarbons.

**Q2: (a) Define natural products and natural product chemistry.  
(b) Difference between Partial and Total Synthesis:**

#### Ans: Natural Products:

Compounds produced inside the bodies of living things naturally are called natural products. For example: carbohydrates, fats, vitamins, urea, nucleic acids (DNA, RNA) etc.

#### Natural Product Chemistry:

The scientific study of the naturally occurring compounds (natural products) is called natural products chemistry / biochemistry.

Plants are the main sources of large number of organic compounds. Natural products may be extracted (✓) from tissues of plants. Natural products are of medicinal importance. These can be used in pharmaceutical drug discovery and drug designs.

Large number of organic compounds are isolated from plants. Some of the useful drugs include:

1. Anticancer agent palliate (texol) from the yew tree and
2. Antimalarial agent artemisinin from artemisia annual.

**Yew Tree:** Its botanical name is *taxus baccata*. It is an evergreen tree. Its height ranges from 33 - 66 feet. It belongs to conifer family. It is native to Europe, North-West Africa, South-West Asia and Northern Iran.

#### **Artemisia Annual:**

Its common name is sweet worm wood. This plant is cultivated for ornamental purpose in Indonesia. Its oil is used in cosmetics.

**(b) Partial and Total Synthesis:****Synthetic Organic Chemistry:**

"The study of various process by which organic compounds can be synthesized from a living or non-living source in the laboratory is called synthetic organic chemistry."

**Synthetic Organic Compounds:**

"Organic compounds which are synthesized from a living or non-living source in the laboratory are called synthetic organic compounds."

Organic compounds can be synthesized either through partial synthesis or through total synthesis.

**Partial Synthesis:**

Most organic reactions occur in many steps. Sometimes an intermediate product of a reaction is used to synthesize a targeted product. The process in which the intermediate product or compounds, isolated from natural sources (e.g. coal, petroleum, natural gas, plants, animals, or microorganism etc.) are used as a starting material to produce other organic molecules is called partial synthesis. For example, for the preparation of soap we use oil or fat from plants or animals and is reacted with the sodium or potassium hydroxide to get our target product. Another example of partial synthesis is the production of alcohol from sugar (a compound obtained from plant) by fermentation using yeast.

**Total Synthesis:**

The process in which organic molecule is synthesized from small, cheap, and readily available molecules is called total synthesis. In this synthesis the desired product is obtained by converting the starting material through many steps. For example, we can produce urea from cheap and easily available material by chemical reaction through a number of chemical steps. For example, hydrogen is obtained from natural gas methane.

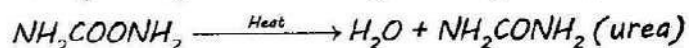
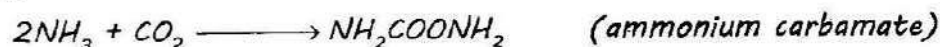


Nitrogen is obtained from air and reacted with  $\text{H}_2$  to produce ammonia



Ammonia and  $\text{CO}_2$  are then reacted to produce urea in further two

steps:



### Products of Biotechnology:

"The use of microorganisms for the welfare of human being is called biotechnology." (OR)

"The field of applied biology that deals with the study of the uses of living organisms and bio-processes in medicine, technology and engineering is called biotechnology. Biotechnology is the use of living organisms to develop useful synthetic products in industries. Most of the products of biotechnology are organic compounds. Biotechnology has applications in four major areas i.e.

- (i) Health care
  - (ii) Crops production
  - (iii) Agriculture and
  - (iv) Industry
1. One application of biotechnology is the direct use of organisms for the manufacturing of organic products. For example: beer and milk products.
  2. Chemicals which have been made by using biotechnology are:
    - a) Benzyl penicillin (an antibiotic)
    - b) Insulin (a hormone secreted by pancreas)
    - c) Ethanol and ethylene glycol ( $\text{OH}-\text{CH}_2-\text{CH}_2-\text{OH}$ ).
    - d) Polyhydroxy butyrate (a biodegradable plastic)
    - e) Renin (an enzyme, plays role in blood pressure)
    - f) Chemosensory protein (CSP).

### Branches of Biotechnology:

#### 1) Blue Biotechnology:

It deals with marine and aquatic applications of biotechnology.

#### 2) Green Biotechnology:

It deals with the selection and demonstration of plants.

#### 3) Red Biotechnology:

It deals with medical processes, the designing of organisms to produce antibiotics and the engineering of genetic cures.

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#### **4) White Biotechnology:**

It is applied to industrial process i.e. the designing of an organism to produce useful chemicals.

**Q3: Explain the different fractions obtained by the destructive distillation of coal.**

**Ans: Destructive Distillation of Coal:**

Strong heating of coal in the absence of air/oxygen is called destructive distillation of coal. The main products obtained by the destructive distillation of coal are:

1. Coke
2. Coal tar
3. Coal gas
4. Ammoniacal liquor

#### **1) Coke:**

Coke is a fuel used in homes, and factories. It is also used in industry as reducing agent for the extraction of metals from their ores.



#### **2) Coal Tar:**

Coal tar is a mixture of more than 200 organic compounds which can be isolated by fractional distillation. Some of these are benzene, toluene, xylene, phenol, cresol, naphthalene and anthracene. These compounds can be separated from one and others by fractional distillation process. The various compounds obtained from coal tar are used in making soap, fats, dyes, plastics, perfumes, drugs, pesticides and explosives.

#### **3) Coal Gas:**

Coal gas is also called town gas. It is a mixture of hydrogen and carbon monoxide gases. Coal gas is combustible because it contains combustible materials like carbon and hydrogen. Coal gas is an excellent fuel.

#### **4) Ammoniacal Liquor:**

Ammonia solution in water ( $\text{NH}_4\text{OH}$ ) is called ammoniacal solution. Ammonia solution is called ammoniacal liquor. Ammoniacal liquor consists of ammonium chloride, ammonium sulphide, ammonium

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bisulphide, ammonium carbonate, ammonium nitrate and ammonium sulphate etc. Ammoniacal liquor is used for the preparation of fertilizers (گول).

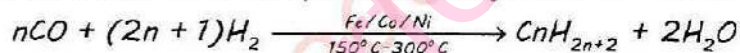
**Q4: Explain conversion of coal into petroleum.**

**Ans- Conversion of Coal into Petroleum: (ETEA 2016)**

First destructive distillation of coal is carried out, which produces coal gas and other fractions like coal tar, coke and ammoniacal liquor.

Coal gas is converted into petroleum by Fischer - Tropsch process (FT-process). This process was first developed and introduced by Franz Fischer and Hans Tropsch in 1925 in Germany.

Fischer - Tropsch process is a set of chemical reactions during which coal gas [ $H_2 + CO$ ] is converted into liquid petroleum i.e. hydrocarbons mainly alkanes. The conversion of carbon monoxide (CO) in the presence of hydrogen involves the breaking of carbon - oxygen double bond and the formation of new carbon-carbon single covalent bonds and carbon-hydrogen single covalent bonds. This is called hydrogenolysis. The catalysts used during this process are: iron, cobalt, nickel and ruthenium at a temperature range  $150^\circ C - 300^\circ C$ .



In the above reaction "n" ranges from 10-20. Coal based F-T plants can produce a petroleum substitute, that is used as synthetic fuel and synthetic lubricating oil.

The conversion of solid coal into gaseous substances ( $CO + H_2$ ) is called coal gasification.

The process of conversion of solid coal into liquid synthetic fuel is called coal liquification.

Coal is converted into petroleum because:

1. Coal reservoirs (گاز) are 100 times more than petroleum reservoirs.
2. Storage and transportation of liquid petroleum is easy as compared to solid coal.
3. Less environmental pollution is associated with petroleum.

**Q5: Write down the characteristic properties of organic compounds.**

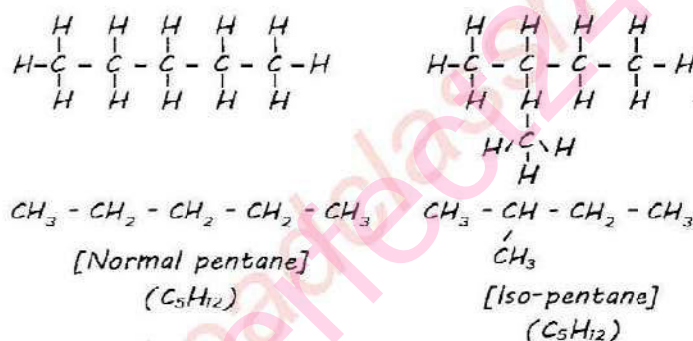
**Ans-** Some of the characteristic properties of organic compounds are:

**1) Unique Character of Carbon (Catenation):**

The self linkage of carbon atoms to form chains and rings compounds is called catenation. Carbon has the property of self linkage. It can link with hundreds and thousands of other carbon atoms to form long carbon-carbon chains or rings. Carbon can also form stable single covalent and multiple covalent bonds with each other and other different atoms like hydrogen, oxygen, nitrogen, Sulphur and halogens  $C-C$ ,  $C=C$ ,  $C \equiv C$ ,  $C \equiv N$ ,  $C=O$ ,  $C=S$ ,  $C-H$ ,  $C-X$ .

**2) Isomerism:**

Two or more than two organic compounds having the same molecular formula, different structural formula, different physical and chemical properties are called isomers and this phenomenon is called isomerism. "iso" means "same" and "mers" means "parts/units".

**3) Non-Ionic Characters [Covalent Nature]:**

As majority of organic compounds are composed of non-metals [C, H, O, N, S, P, X]. As non-metals share electrons among themselves and form covalent bonds so organic compounds are covalent in nature. Due to covalent nature, most of them are non-polar and have non-ionic characters.

**4) Solubility:**

There is a general rule for solubility that "like dissolve like". It means ionic solutes are soluble in polar solvents. Polar solutes are soluble in polar solvents. Non-polar solute are soluble in non-polar solvents. Organic solutes are soluble in organic solvents. Most of the organic compounds are non-polar so these are soluble in non-polar solvents like ether, benzene and carbon tetrachloride.

**5) Rates of Organic Reactions:**

The rates of organic reactions are much slower than ionic compounds.

because these involve breaking of old bonds and formation of new bonds.

**6) Similar Structural Features and Behaviors:**

Mostly organic compounds have similar structural features and similar physical and chemical properties. So, they show similar behavior to various reactants. This similarity in behavior has reduced the study of millions of organic compounds to a few homologous series.

**7) Combustion:**

All organic compounds are combustible. In excess amount of oxygen organic compounds burn, form carbon dioxide, water and heat is evolved.

**8) Composition:**

Organic compounds are made up of a few elements i.e. C, H, O, N, S, P and halogens while inorganic compounds are made up of approximately 109 elements.

**9) Thermal Instability or Action of Heat:**

Organic compounds are thermally unstable.

**10) High Molecular Masses:**

Most of the organic compounds have high molecular masses.

11) Organic compounds burn with flames, which are associated with smoke and soot.

**12) Polymerization:**

Some organic compounds exhibit the phenomenon of polymerization. Ethylene polymerizes to polyethylene.

**Q6: Enlist the uses of organic compounds.**

**Ans:** Life is a practical version of organic chemistry. Organic chemistry is very closely related to our daily life. Most of the things that we come across in our daily life are organic.

1. The food we eat (carbohydrates, proteins, vitamins, fats etc.) are organic materials.
2. The clothes we wear like cotton, silk, nylon are organic in nature.
3. Various materials, we use in our daily life like paper, rubber, ink, plastics, leather, fibres, fertilizers, shoe polishes, pesticides, cosmetics, paint, dyes, preservatives, detergents and medicines are organic in nature.

4. Our body is made up of thousands of complex organic molecules like proteins, nucleic acids, enzymes, fats etc. are organic and these are called life molecules.
5. The chemical reactions taking place inside our bodies (biochemical reactions) are organic.
6. Fuels like petroleum products, petrol, diesel, oil, compressed natural gas (CNG), coal gas, as well as natural gas are also mixtures of organic compounds, that run our cars and industries.

**Q7: Write a note on Bucky Balls.**

**Ans: Bucky Balls:**

"Substances composed of an even number of carbon atoms, which form a cage-like fused ring polycyclic system with twelve five membered rings (pentagone) and the rest six membered rings (hexagons) are called Buckyballs." (ETEA 2018)

Buckyball is the allotropic form of carbon. Buckyball is a member of class of structures called carbon fullerenes. Fullerenes are a family of carbon allotropes, molecules composed entirely (کامل) of carbon in the form of a hollow (خالی) sphere, ellipsoid, tube or plane. Carbon atoms are arranged in a series of interlocking pentagons and hexagons, forming a structure that looks similar to a soccer ball. The most stable and roundest molecule is called Buckyball or fullerene. The most common of fullerene is  $C_{60}$ .  $C_{60}$  contains 20-hexagons and 12-pentagons of carbon atoms fused with one another, resulting in a spherical football like geometry.

**Discovery:**

The first fullerene molecule was discovered in 1985 by Richard Smalley, Robert Curl, James Heath, Sean O'Brien and Herald Croto at Rice University. This discovery expanded the total number of allotropes of carbon. The previous known allotropes of carbon were, diamond, graphite, soot and charcoal. Croto, Curl and Smalley were awarded 1996 noble prize in chemistry for their role in the discovery of buckyballs.

**Structure:**

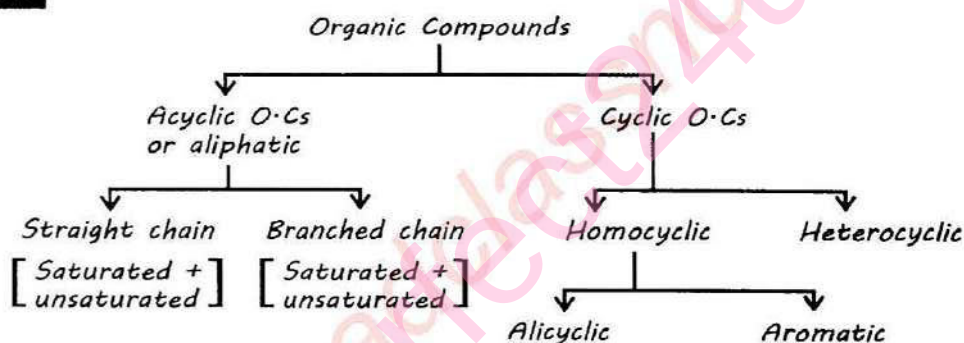
$C_{60}$  fullerene is also called buckminsterfullerene after the name of Richard Buckminster fuller (a known architect), who popularized

geodesic domes and the shape of  $C_{60}$  is similar to these domes. In buckyballs pentagonal and hexagonal rings are arranged in alternating manner/fashion. Each five membered ring (pentagon) is surrounded by five six membered rings (hexagons). No two pentagons share an edge.

Among the buckyballs the smallest member is  $C_{20}$  (dodecahedron) which is made up of 20 carbon atoms. Negligible amounts of  $C_{70}$ ,  $C_{72}$ ,  $C_{74}$ ,  $C_{76}$ ,  $C_{80}$ ,  $C_{82}$  and  $C_{84}$  are found in nature.  $C_{60}$  = molecular weight is 720 amu.

**Q8: Explain classification of organic compounds on the basis of arrangement of carbon atoms in the molecule.**

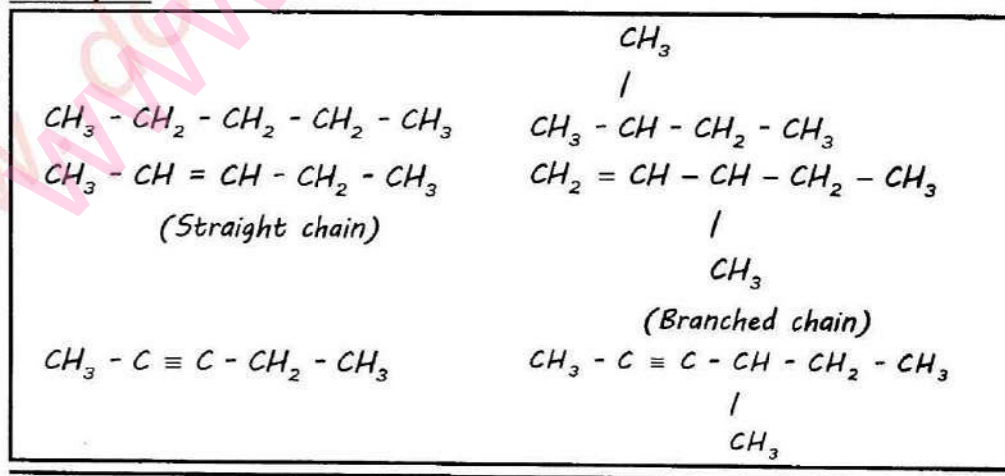
**Ans:**



### 1) Acyclic/Open Chain Organic Compounds:

"Organic compounds having open chain of carbon atoms are called acyclic organic compounds." These compounds may be straight chain and also can have branches. These can be saturated and unsaturated.

Examples:



## 2) Cyclic Organic Compounds:

"Organic compounds having closed rings of carbon atoms are called cyclic organic compounds."

These compounds are further classified into:

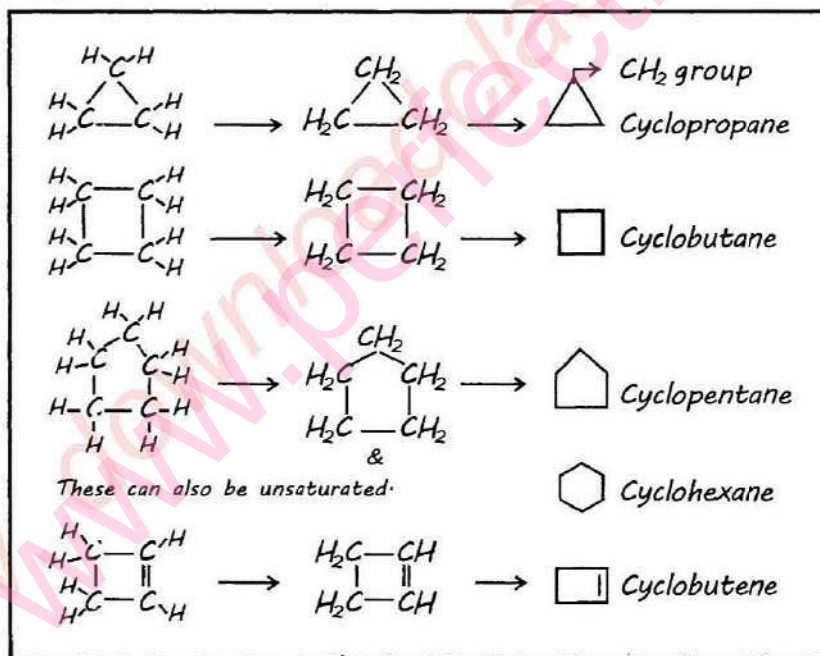
- a. Homocyclic organic compounds
- b. Heterocyclic organic compounds

### a. Homocyclic Organic Compounds (Homo = Same):

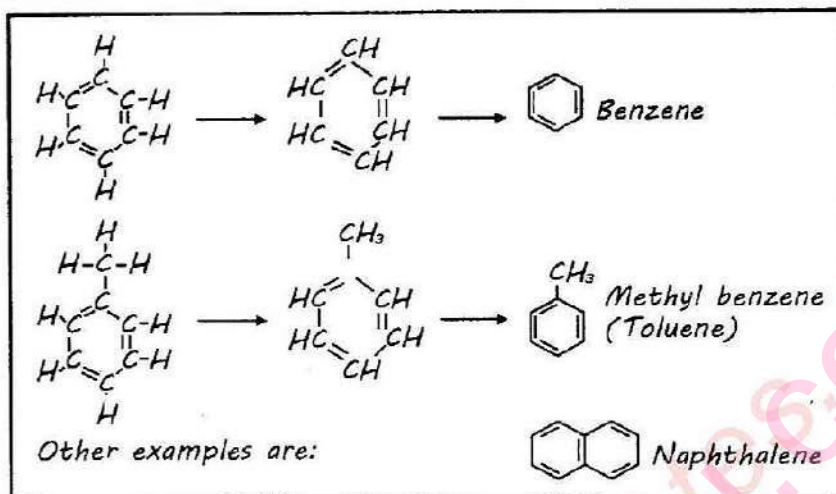
These are also called carbocyclic compounds. Compounds that contain only carbon atoms in their ring structure are called homocyclic or carbocyclic compounds. These are of two types i.e.

- (i) Alicyclic compounds
- (ii) Aromatic compounds

**(i) Alicyclic Compounds:** In alicyclic compounds all the members of the ring are carbon atoms and resemble in properties with open chain compounds.

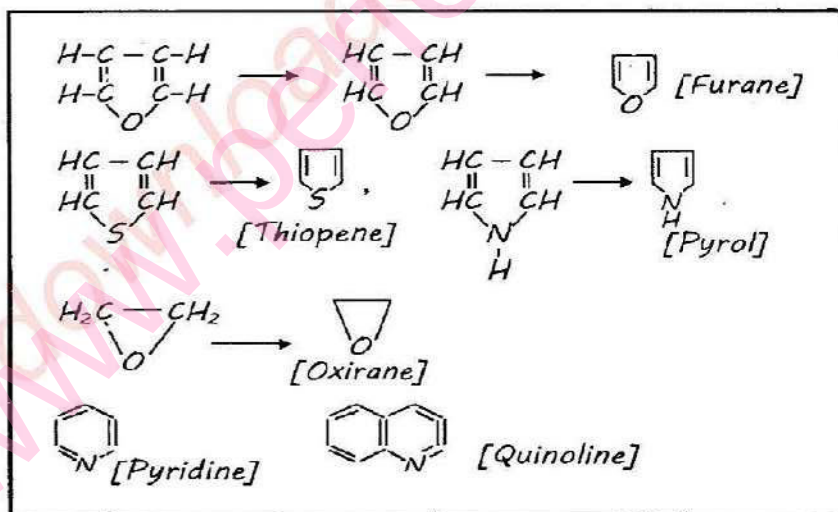


**(ii) Aromatic Compounds:** Compounds which contain one benzene ring in their structures are called aromatic compounds. These are cyclic compounds, having alternate single and double bonds. Benzene and derivatives of benzene are aromatic organic compounds.



**b. Heterocyclic Organic Compounds (Hetero = Different):**

Organic compounds which contain one heteroatom [different atom] in the rings of carbon atoms are called heterocyclic organic compounds. The atoms other than carbon can be Sulphur, Oxygen and Nitrogen. These may be acyclic and aromatic. Thiophene, furane, oxirane and pyrrol are the examples of alicyclic and pyridine is the example of aromatic heterocyclic.



**Q9: Define functional group. How organic compounds are classified on the basis of functional group.**

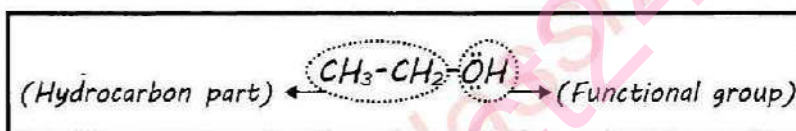
**Ans: Functional Group**

"The active part / functional part of an organic compound is called

functional group."

"An atom, group of atoms or a bond [ $C-C$ ,  $C=C$ ,  $C \equiv C$ ] which give certain characteristic properties to an organic compound is called a functional group."

- Functional group helps in nomenclature of organic compounds.
- Functional group specify chemical reactivity of organic compounds.
- Functional group helps in classification of organic compounds/
- Each functional group represent a different class of an organic compound.
- Millions of organic compounds have been divided into homologous series on the basis of functional groups. An organic compound has mainly two parts i.e.
  - a. A hydrocarbon part
  - b. A functional group part



| Class of Compound | General Formula                                                                      | Functional Group                                                          | Example                                                                  |
|-------------------|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------|--------------------------------------------------------------------------|
| Alkane            | $\begin{array}{c}   &   \\ -C- & -C- \\   &   \end{array}$                           | Single bond                                                               | $H_3C - CH_3$ (ethane)                                                   |
| Alkene            | $\begin{array}{c} \diagdown & \diagup \\ C & = C \\ \diagup & \diagdown \end{array}$ | Double bond                                                               | $H_2C = CH_2$ (ethene)                                                   |
| Alkyne            | $-C \equiv C-$                                                                       | Triple bond                                                               | $HC \equiv CH$ (ethyne)                                                  |
| Alkyl halides     | $R-X$<br>$X(F, Cl, Br, I)$                                                           | -x (halo)                                                                 | $H_3C - Cl$<br>(methyl chloride)                                         |
| Alcohols          | $R-OH$                                                                               | -OH (hydroxyl)                                                            | $H_3C - OH$ (methyl alcohol/methanol)                                    |
| Amine             | $R-NH_2$                                                                             | $-NH_2$ (amino)<br>(oxa)                                                  | $H_3C - NH_2$ (methyl amine)                                             |
| Ether             | $R-O-R$                                                                              | -O- (oxygen)                                                              | $H_3C - O - CH_3$<br>(dimethyl ether)                                    |
| Ketone            | $R-CO-R$                                                                             | $-CO-$ (keto)<br>OR $\begin{array}{c} O \\    \\ -C- \end{array}$         | $\begin{array}{c} O \\    \\ H_3C - C - CH_3 \end{array}$<br>(Acetone)   |
| Aldehyde          | $R-CHO$                                                                              | $-CHO$<br>OR $\begin{array}{c} O \\    \\ -C - H \end{array}$<br>(Formyl) | $\begin{array}{c} O \\    \\ H_3C - C - H \end{array}$<br>(Acetaldehyde) |

|                            |                                                                                       |                                                                                                                                    |                                                                                                                       |
|----------------------------|---------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|
| Carboxylic acid            | $R-\text{COOH}$<br>-                                                                  | $-\text{COOH}$ (carboxyl)<br>$-\text{CO}_2\text{H}$<br>$\begin{array}{c} \text{O} \\ \parallel \\ -\text{C}-\text{OH} \end{array}$ | $\begin{array}{c} \text{O} \\ \parallel \\ \text{H}_3\text{C}-\text{C}-\text{OH} \end{array}$<br>(Acetic acid)        |
| Acid halides               | $\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{X} \end{array}$    | $\begin{array}{c} \text{O} \\ \parallel \\ -\text{C}-\text{X} \end{array}$ (Acyl)                                                  | $\begin{array}{c} \text{O} \\ \parallel \\ \text{H}_3\text{C}-\text{C}-\text{Cl} \end{array}$<br>(Acetyl chloride)    |
| Acid amides)               | $\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{NH}_2 \end{array}$ | $\begin{array}{c} \text{O} \\ \parallel \\ -\text{C}-\text{NH}_2 \end{array}$ (Amide)<br>$-\text{CONH}_2$                          | $\begin{array}{c} \text{O} \\ \parallel \\ \text{CH}_3-\text{C}-\text{NH}_2 \end{array}$<br>(Acetamide)               |
| Ester                      | $\text{R}-\text{CO}-\text{O}-\text{R}$<br>(ETEA 2018)                                 | $\begin{array}{c} \text{O} \\ \parallel \\ -\text{C}-\text{O}- \end{array}$<br>OR $-\text{COOR}$                                   | $\begin{array}{c} \text{O} \\ \parallel \\ \text{CH}_3-\text{C}-\text{O}-\text{CH}_3 \end{array}$<br>(Methyl acetate) |
| Alkyl cyanides or nitriles | $\text{R}-\text{CN}$                                                                  | $-\text{CN}$ (cyano)<br>OR $-\text{C} \equiv \text{N}$                                                                             | $\text{CH}_3-\text{CN}$<br>(methyl cyanide)                                                                           |

**Q10:** Define homologous series. Write down characteristic properties of homologous series.

**Ans:** Homologous Series: (Homo = same), logos = properties)

"A series of organic compounds in which two adjacent members differ from each other by a methylene ( $-\text{CH}_2$ ) group is called homologous series."

Each member of the homologous series is called a homologue. Each class of organic compounds has its own homologous series which can be represented by a general formula. For example alkane has the general formula  $\text{C}_n\text{H}_{2n+2}$ .

|      |                |                           |                                                                                                                                                    |                                                                                                                                     |
|------|----------------|---------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|
| When | $\text{C} = 1$ | $\text{CH}_4$             | $\left. \begin{array}{l} \text{CH}_2 \\ \text{CH}_2 \\ \text{CH}_2 \\ \text{CH}_2 \\ \text{CH}_2 \\ \text{CH}_2 \text{ etc.} \end{array} \right\}$ | In this series there is a common difference of $-\text{CH}_2$ group between two consecutive members. So, it is a homologous series. |
|      | $\text{C} = 2$ | $\text{C}_2\text{H}_6$    |                                                                                                                                                    |                                                                                                                                     |
|      | $\text{C} = 3$ | $\text{C}_3\text{H}_8$    |                                                                                                                                                    |                                                                                                                                     |
|      | $\text{C} = 4$ | $\text{C}_4\text{H}_{10}$ |                                                                                                                                                    |                                                                                                                                     |
|      | $\text{C} = 5$ | $\text{C}_5\text{H}_{12}$ |                                                                                                                                                    |                                                                                                                                     |
|      | $\text{C} = 6$ | $\text{C}_6\text{H}_{14}$ |                                                                                                                                                    |                                                                                                                                     |

**Characteristics of Homologous Series:**

**1:** All members of the homologous series are represented by the

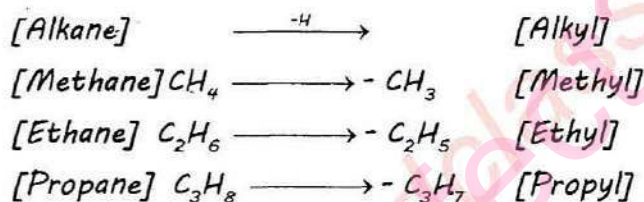
same general formula.

2. All members of the homologous series have the same functional group.
3. All members of the homologous series have same chemical properties.
4. All members of the homologous series have same method of preparation.
5. Physical properties changes gradually down the series.

**Q11: Explain alkyl group. Explain various types of carbon and hydrogen atoms.**

**Ans: Alkyl Group:**

"A group obtained after the removal of one hydrogen atom from alkanes is called an alkyl group / alkyl radical." It is represented by "R".

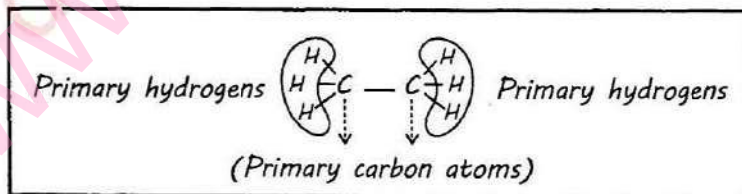


Alkyl group can be normal alkyl, iso-alkyl and neo-alkyl.

**Types of Carbon and Hydrogen Atoms:**

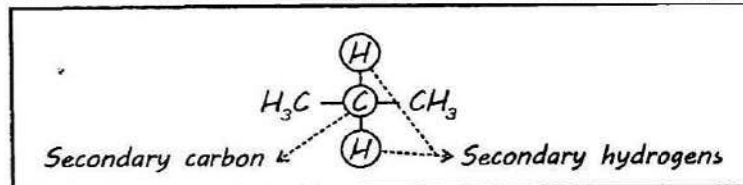
**Primary Carbon and Primary Hydrogens:**

"The carbon atom which is further attached to only one carbon atom or not attached to carbon atom is called primary carbon and the hydrogens attached to primary carbon are called primary hydrogens."



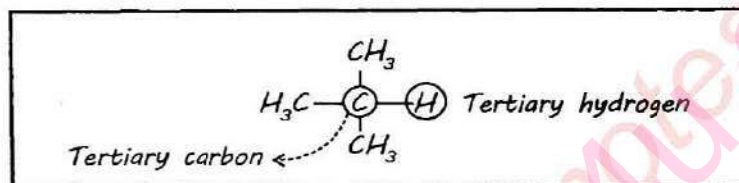
**Secondary Carbon and secondary Hydrogens:**

"The carbon which is attached to two carbon atoms is called secondary carbon and the hydrogens attached to secondary carbon atom are called secondary hydrogens."



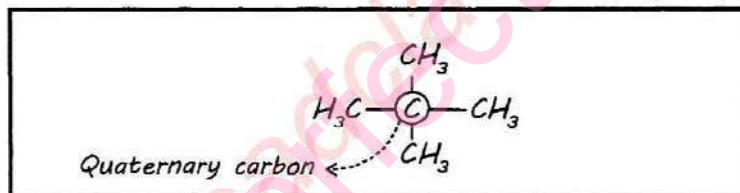
### Tertiary Carbon and Tertiary Hydrogens:

"The carbon atom which is further connected to three carbons is called tertiary carbon and the hydrogen atom attached to tertiary carbon is called tertiary hydrogen."



### Quaternary Carbon:

"The carbon atom which is further connected to four carbons is called quaternary carbon and there is no quaternary hydrogen atom."



**Q12: Elaborate the detection of various elements in organic compounds.**

**Ans:** The main elements present in organic compounds are carbon, hydrogen as well as oxygen, nitrogen, Sulphur and halogens. The following methods are used to detect these elements in the organic compounds.

### Detection of Carbon:

As carbon is the essential element of all organic compounds and present in all organic compounds so there is no need to do any test for it. The test is performed only to know whether the given compound is organic or not.

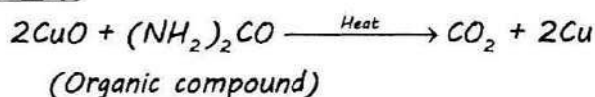
### Procedure:

1. Mix the given organic compound / given compound (one part) with dry cupric oxide (3 parts).

2. Heat the mixture in a test tube fitted with a delivery tube.
3. Pass the gas through lime water taken in another test tube. If lime water turn milky it confirms the presence of carbon in the given organic compound.

By heating carbon oxidizes to carbon dioxide which reacts with lime water, turn it milky due to the formation of calcium carbonate.

**Reaction:**

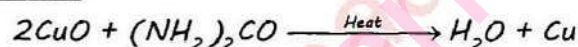


**Detection of Hydrogen: (ETEA 2017)**

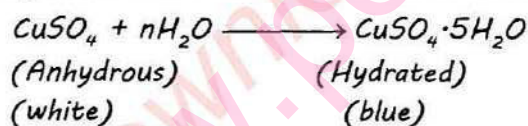
**Procedure:**

1. Heat the mixture of organic compound and CuO in a test tube.
2. Pass the issuing gases through a test tube containing anhydrous copper sulphate (colourless).
3. The change of colour from white to blue confirms the presence of hydrogen in the given compound.

**Reaction:**



Hydrogen of urea will be converted into water



**Detection of Nitrogen, Sulphur and Halogens:**

Lassaigne's solution or sodium fusion extract should be prepared to detect nitrogen, Sulphur and halogens in the given organic compound.

**Preparation of Lassaigne's Solution:**

**Procedure:**

Take a small piece of sodium metal in a fusion tube. Heat it gently to melt. Remove it from the flame. Put a small amount of organic compound. Heat it strongly till the test tube becomes red hot. Now put it into distilled water (10mL) taken in a china dish while still red hot. The fusion tube will break. Dissolve the contents by

stirring with a glass rod. Boil and filter the solution. The filtrate is called Lassaing solution.

### Explanation:

Due to the fusion of organic compound with sodium metal, the covalent bonds are converted into ionic bonds. Thus the elements like nitrogen, Sulphur and halogens are converted into their respective ions. For example:

If "N" is present =  $\text{Na} + (\text{C} + \text{N}) \longrightarrow \text{Na}^+ \bar{\text{C}}\text{N}$

If "S" is present =  $2\text{Na} + \text{S} \longrightarrow \text{Na}_2^+ \text{S}^{2-}$

If "X" is present =  $\text{Na} + \text{X} \longrightarrow \text{Na}^+ \bar{\text{X}}$

### Test for Nitrogen:

#### Procedure:

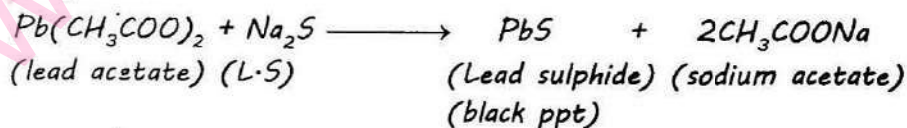
1. Take about 2mL of Lassaing solution in a test tube and add few drops of sodium hydroxide solution to it.
2. Add a few mL of freshly prepared  $\text{FeSO}_4$  solution.
3. Warm, cool and then add few drops of ferric chloride ( $\text{FeCl}_3$ ) solution.
4. Finally acidify it with  $\text{H}_2\text{SO}_4$  or  $\text{HCl}$ .

Appearance of Prussian blue (dark blue / deep blue) or green precipitate/ solution indicate the presence of nitrogen.

Prussian blue ppt =  $\text{Fe}_4[\text{Fe}(\text{CN})_6]_3 \rightarrow$  ferric ferrocyanide

### Test for Sulphur:

1. Acidify about 2mL of Lassaing's solution with few drops of acetic acid.
2. Add lead acetate salt solution. Formation of black precipitate of lead sulphide confirm the presence of Sulphur in the given compound.



### Test for Halogens:

Take Lassaing solution in a china dish, and add few drops of concentrated  $\text{HNO}_3$  and boil it, to remove any  $\bar{\text{C}}\text{N}$  (cyanide) and " $\text{S}^{2-}$ "

(sulphide) ions in the form of  $\text{HCN}$  and  $\text{H}_2\text{S}$ . Then add silver nitrate solution.

(A) Formation of white precipitate, soluble in  $\text{NH}_4\text{OH}$ , indicates the presence of chloride ions.



(B) Formation of pale yellow precipitate, partially soluble in ammonium hydroxide  $[\text{NH}_4\text{OH}]$  indicate the presence of bromide ions.



(C) Formation of deep yellow precipitate, insoluble in  $\text{NH}_4\text{OH}$  indicate the presence of iodide ions ( $\text{I}^-$ ).



### Detection of Oxygen:

Oxygen cannot be detected by any direct method but for its detection some indirect methods are used:

1. The given organic compound is heated alone in dry test tube usually in nitrogen atmosphere. Formation of water droplets on the cooler part of the test tube clearly shows the presence of oxygen.
2. Various tests are carried out for oxygen containing functional groups. If anyone of oxygen containing functional group is detected then it shows that oxygen is present in the given organic compound. Oxygen containing functional groups are: Ketone  $[-\text{CO}-]$ , aldehyde  $[-\text{CHO}]$ , alcohol  $[-\text{OH}]$ , ether  $[-\text{O}-]$ , ester  $[-\text{COOR}]$  and carboxylic acid  $[-\text{COOH}]$ .
3. The most important test for the presence of oxygen is combustion analysis in which the percentage of carbon and hydrogen are determined. If the sum of the percentages of carbon and hydrogen is less than 100, the remaining percentage will be that of oxygen.

$$\% \text{ of oxygen} = 100 - [\% \text{ C} + \% \text{ H}]$$

**Exercise**1: Choose the correct option:

1. The first organic compound prepared in the laboratory was:  
(a) Peat (b) Urea✓  
(c) Sugar (d) Alcohol
2. All the substances are organic except:  
(a) Graphite✓ (b) Urea  
(c) Methane (d) Acetic acid
3. The final stage of conversion of decaying plants into coal is:  
(a) Anthracite✓ (b) Lignite  
(c) Peat (d) Bituminous
4. Petroleum is mainly a mixture of:  
(a) Heterocyclic compounds  
(b) Aromatic hydrocarbons  
(c) Saturated hydrocarbons✓  
(d) Unsaturated hydrocarbons
5. The major component of natural gas is:  
(a) Butane (b) Ethane  
(c) Propane (d) Methane✓
6. All of the following fractions are obtained by destructive distillation of coal except:  
(a) Coal tar (b) Refinery gas✓  
(c) Coal gas (d) Coke
7. Coal can be converted to petroleum by:  
(a) Haber process (b) Destructive distillation  
(c) Fischer-Tropsch process✓  
(d) Fractional distillation
8. Pyridine belongs to which class of organic compounds.  
(a) Heterocyclic✓ (b) Hydrocarbon  
(c) Alicyclic (d) Homocyclic
9. Which of the following represents the functional group of amides?  
(a)  $-COOR$  (b)  $-NH_2$   
(c)  $-C \equiv N$  (d)  $-CONH_2$ ✓
10. Which of the following elements cannot be detected in a given organic compound, directly?

- =====
- (a) Chlorine (b) Phosphorus  
(c) Nitrogen (d) Oxygen✓
11. Lassaigne's solution is used to test presence of:  
(a) Nitrogen (b) Halogen  
(c) Sulphur (d) All of these✓
12. Lassaigne's solution plus silver nitrate gives yellow precipitate which is insoluble in ammonium hydroxide. This shows the presence of:  
(a) Nitrogen (b) Sulphur  
(c) Iodine✓ (d) Carbon
13. Fischer-Tropsch synthesis involve the formation of alkanes by the combination of:  
(a) CO and H<sub>2</sub>✓ (b) CO<sub>2</sub> and H<sub>2</sub>  
(c) C and H<sub>2</sub> (d) All of these
14. Bucky Balls consists of.....carbon rings.  
(a) Tetragonal (b) Pentagonal  
(c) Hexagonal✓ (d) "b" & "c" both
15. Pyridine:  
(a) is homocyclic compound  
(b) contains nitrogen  
(c) is heterocyclic compound  
(d) both "b" & "c"✓

### Short Questions

**2. Briefly answer the following questions:**

**Q1: What is meant by organic compounds and organic chemistry?**

**Ans: Organic Compounds**

"Hydrocarbons and their derivatives are called organic compounds."

**Organic Chemistry:**

The branch of chemistry which deals with the study of structure, composition, properties, reactions and preparation of carbon based compounds i.e. hydrocarbons and their derivatives is called organic chemistry.

**Q2:** Write down the procedure for the test of presence of nitrogen in organic compound.

**Ans:** Please see question number 12.

**Q3:** What is homologous series? Give the characteristics of homologous series.

**Ans:** Please see question number 10.

**Q4:** Although Buckyball is an allotropic form of carbon but it is included in organic chemistry.

**Ans:** Although Buckyball is an allotropic form of carbon but still it has been included in organic chemistry due to its similarities in properties with organic compounds like: buckyballs are covalent in nature, less reactive, can be hydrogenated and possess catenation property.

**Q5:** Mention those compounds which although contain carbon but are not considered organic?

**Ans:** Some compounds contain carbon but do not possess all the properties of organic compounds so these are inorganic in nature.

**Examples:**

Simple compounds of carbon like CO and CO<sub>2</sub>

Metal carbonates and bicarbonates, Na<sub>2</sub>CO<sub>3</sub> and NaHCO<sub>3</sub>

Metal carbides like CaC<sub>2</sub> and Al<sub>4</sub>C<sub>3</sub>

Metal cyanides like NaCN and some cyanates like NH<sub>4</sub>CNO

**Q6:** Differentiate between partial and total synthesis.

**Ans:** Please see question number 2.

**Q7:** How coal can be converted into petroleum?

**Ans:** Please see question number 4.

**Q8:** Discuss the reasons for the presence of large number of organic compounds.

**Ans:**

1. We know that the main sources of organic compounds are plants and animals and these are abundant in nature so large number of organic compounds can be isolated from their bodies.
2. Reservoirs of coal and petroleum are large and they contain organic compounds so large number of organic compounds can be

obtained from them by fractional distillation process.

3. Due to isomerism properties one compound can exist in many structural forms i.e. butane has 2 isomers and pentane has 3 isomeric structures. Hexane has 5 isomers and heptane has 9 isomers.
4. Carbon has tetravalent nature.
5. Carbon has a unique mode of bonding like it can form single, double and triple covalent bonds with other carbons and also with different elements.

**Q9: Differentiate between acyclic and cyclic organic compounds.**

**Ans:** Differences between cyclic and acyclic organic compounds are:

1. Cyclic compounds have closed chain of carbon atoms and acyclic have open chain of carbon atoms.
2. Cyclic organic compounds contain less number of hydrogen atoms than the corresponding open chain organic compounds.
3. Cyclic compounds having angle strain, are more reactive than acyclic organic compounds.
4. Cyclo alkanes have the general formula of  $C_nH_{2n}$  while that of acyclic alkanes is  $C_nH_{2n+2}$ .

### Long Questions

**Q1: What are fossil fuels? Discuss different types of fossil fuels.**

**Ans:** Please see question # 1.

**Q2: Elaborate the detection of various elements in organic compound.**

**Ans:** Please see question # 12.

**Q3: What are the different fraction obtained by the destructive distillation of coal? Give their importance.**

**Ans:** Please see question # 3.

**Q4: Explain some of the important characteristics of organic compound.**

**Ans:** Please see question # 5.

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**Q5:** Define functional group. How organic compounds are classified in the basis of functional group?

**Ans:** Please see question # 9.

**Q6:** Give old classification of organic compounds based on arrangement of carbon atoms in the molecule.

**Ans:** Please see question # 8.

