
CHAPTER



Fundamental Principles of Organic Chemistry

Animation 7.1 : Organic Chemistry
Source and credit : Stackexchange

In This Chapter You Will Learn:

1. The special features of carbon chemistry with reference to its ability to form chains, rings and isomers.
2. The importance of organic chemistry in daily life.
3. About the sources of carbon and its compounds like coal, petroleum and natural gas with reference to their availability in Pakistan.
4. Refining, reforming and cracking of petroleum and to enlist products in a tabular form.
5. How can petroleum serve as a source of different type of fuels.
6. About the classification of organic compounds based on the carbon skeleton.
7. About functional groups and the dependence of chemical properties on functional groups.
8. About the structural isomerism in organic compounds.
9. That cis-trans isomerism arises due to restricted rotation around a carbon-carbon double bond.
10. How the hybridization theory can help us understand the type of bonding and the shapes of organic compounds.

7.1 INTRODUCTION

More than 200 years ago, early chemists recognized organic compounds distinct from inorganic compounds because of the differences in their origin and properties. Organic compounds were considered as those obtained from living things, plants or animals, and inorganic compounds were those obtained from non-living or mineral sources.

The early chemists never succeeded in synthesizing organic compounds and their failure led them to believe that organic compounds could be manufactured only by and within living things and these compounds could never be synthesized from inorganic materials. This theory was referred to as vital force theory. This theory was rejected by Friedrich Wohler when he obtained urea ($(\text{NH}_2)_2\text{CO}$), an organic compound in the urine of mammals, from ammonium cyanate, NH_4CNO , a substance of known mineral origin.



7.1.1 Modern Definition of Organic Chemistry.

Since the synthesis of urea from ammonium cyanate, millions of organic compounds have been prepared and analyzed. All these compounds contain carbon as an essential element. Apart from carbon, most of the organic compounds also contain hydrogen. Other elements which may also be present include oxygen, nitrogen, sulphur, etc. For historical and conventional reasons a few of the carbon compounds such as CO , CO_2 , carbonates, bicarbonates, etc are studied as inorganic compounds. It also has been recognized that the chemical forces in organic compounds are similar to those, which exist, in inorganic compounds. Thus it was felt that organic chemistry should be redefined. According to the modern definition, **organic chemistry is that branch of chemistry which deals with the study of compounds of carbon and hydrogen (hydrocarbons) and their derivatives.**

7.2 SOME FEATURES OF ORGANIC COMPOUNDS

Following are some features of organic compounds.

(1) Peculiar Nature of Carbon

Carbon forms a large number of compounds. There are millions of organic compounds known at present. The main reason for such a large number of compounds is its unique property of linking with other carbon atoms to form long chains or rings. This selflinking property of carbon is called catenation. Carbon also forms stable single and multiple bonds with other atoms like oxygen, nitrogen and sulphur, etc. It can thus form numerous compounds of various sizes, shapes and structures.

(2) Non-ionic Character of Organic Compounds

Organic compounds are generally covalent compounds, therefore, do not give ionic reactions.

(3) Similarity in Behaviour

There exists a close relationship between different organic compounds. This is exemplified by the existence of homologous series.

This similarity in behaviour has reduced the study of millions of compounds to only a few homologous series.

(4) Complexity of Organic Compounds

Organic molecules are usually large and structurally more complex. For example, starch has the formula $(C_6H_{10}O_5)_n$ where n may be several thousands. Proteins are very complex molecules having molecular masses ranging from a few thousands to a million.

(5) Isomerism

Isomerism is a very common phenomenon in organic compounds. Very often more than one compounds are represented by the same molecular formula. However, they have different structural formulas.

(6) Rates of Organic Reactions

The reactions involving organic compounds are slow and in general the yields are low. The slow rate of the organic reactions is due to the molecular nature of organic compounds.

(7) Solubility

Most organic compounds are insoluble in water and dissolve readily in non-polar organic solvents, such as, benzene, petroleum ether, etc.

7.3 IMPORTANCE OF ORGANIC CHEMISTRY

The importance of organic chemistry can hardly be over emphasized. Almost all the chemical reactions that take place in living systems, including our own bodies, are organic in nature because they involve such life molecules like proteins, enzymes, carbohydrates, lipids, vitamins and nucleic acids, all contain thousand of carbon atoms.

We have become dependent upon organic compounds that occur in nature for our food, medicines and clothing. Over the years, the chemists have learned to synthesize plastics, synthetic rubber, medicines, preservatives, paints, varnishes, textile fibres, fertilizers, pesticides, detergents, cosmetics, dyes, etc. Many of these synthetic compounds prevent the shortages of naturally occurring products.

7.4 SOURCES OF ORGANIC COMPOUNDS

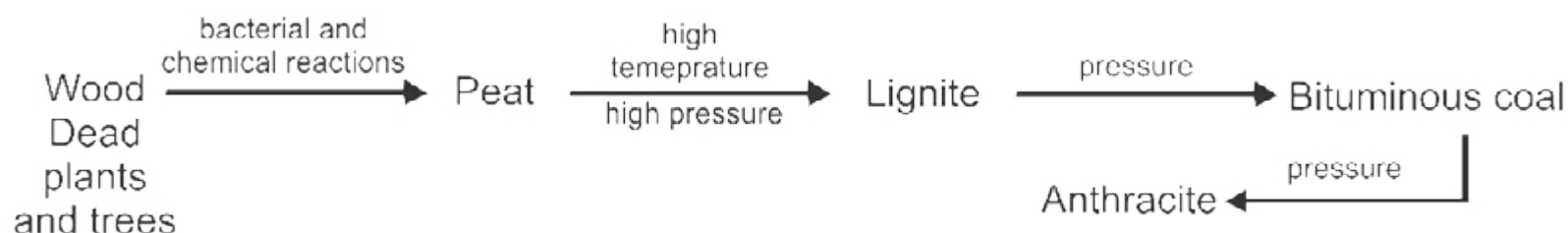
Petroleum, coal and natural gas are vast reservoirs from which many organic compounds are obtained. These are called fossil fuels and are formed, over long period of time, from the decay of plants and animals.

Coal

It is believed that coal in nature was formed from the remains of the trees buried inside the earth crust some 500 millions years ago. Due to the bacterial and chemical reactions on wood it got converted into peat. Then, as a result of high temperature and high pressure inside the earth crust, peat got transformed into coal.

Coal is an important solid fuel and becomes a source of organic compounds when subjected to carbonization or destructive distillation. When coal is heated in the absence of air (temperature ranging from 500-1000°C); it is converted into coke, coal gas and coal tar. Coal tar contains a large number of organic compounds, which separate out on fractional distillation.

The total coal resources of Pakistan are estimated by the geological survey of Pakistan to be 184 billion tonnes. About 80% of this coal is used to bake bricks in lime kilns; besides, some quantity is used for domestic purposes. Conscious efforts are being made by the government to induct coal into industry by setting up coal based power units. The Sindh Coal Authority and the directorates of Mineral Developments of the Punjab, Baluchistan and Khyber Pakhtunkhwa are all keen to expand coal utilization in power generation for which many incentives have been made available.



Animation 7.2 : What is coal seam gas
Source and credit: Aplng

Natural Gas

Natural Gas is an important means of energy especially for countries like Pakistan, which are deficient in the production of mineral oil and coal. It is a mixture of low boiling hydrocarbons. Major portion of the natural gas is methane. It is also formed by the decomposition of organic matter. In Pakistan the gas, being cheaper, is used for power generation, in cement and fertilizer industries; as a fuel in general industries and for domestic purposes.

Animation 7.3 : Coal fired power station
Source and credit: Gif2fly

Petroleum

Mineral oil is called petroleum when it is in the refined form. It is thought to have been formed by slow chemical and biochemical decomposition of the remains of organic matters found between the sedimentary rocks. When extracted from rocks it appears like a liquid of blackish colour known as 'crude oil'.

Table 7.1 Principal Fractions Obtained from Petroleum

Fraction	Boiling Point Rang (°C)	Composition	Uses
Natural gas	< 20	$\text{CH}_4 - \text{C}_4\text{H}_{10}$	Fuel, petrochemicals
Petroleum Ether	20 - 60	$\text{C}_5\text{H}_{12}, \text{C}_6\text{H}_{14}$	Solvent
Ligroin, or naphtha	60 - 100	$\text{C}_6\text{H}_{14}, \text{C}_7\text{H}_{16}$	Solvent, raw material
Gasoline	40- 220	$\text{C}_4\text{H}_{10} - \text{C}_{13}\text{H}_{28}$ mostly $\text{C}_6\text{H}_{14} - \text{C}_8\text{H}_{18}$	Motor fuel
Kerosene	175 - 325	$\text{C}_8\text{H}_{18} \cdot \text{C}_{14}\text{H}_{30}$	Heating fuel
Gas oil	> 275	$\text{C}_{12}\text{H}_{26} \cdot \text{C}_{18}\text{H}_{38}$	Diesel and heating fuel
Lubricating oils and greases	Viscous liquids	$> \text{C}_{18}\text{H}_{38}$	Lubrication
Paraffin	M.p. 50 - 60	$\text{C}_{23}\text{H}_{48} - \text{C}_{29}\text{H}_{60}$	Wax products
Asphalt, or petroleum coke	Solids	Residue	Roofing, paving, fuel reducing agent

It is refined to get different petroleum fractions. At present four oil refineries are in operation in our country. One oil refinery known as Attock Oil Refinery is located at Morgah near Rawalpindi. It has about 1.25 million tonnes oil refining capacity. Similarly, two oil refineries have been established at Karachi which have about 2.13 million tonnes of oil refining capacity. Another refinery known as Pak-Arab refinery is located at Mahmud Kot near Multan.

The crude petroleum is separated by fractional distillation into a number of fractions each corresponding to a particular boiling range, Table 7.1.

7.5 CRACKING OF PETROLEUM

The fractional distillation of petroleum yields only about 20% gasoline. Due to its high demand this supply is augmented by converting surplus supplies of less desirable petroleum fractions such as kerosene oil and gas oil into gasoline by a process called cracking. It is defined as breaking of higher hydrocarbons having high boiling points into a variety of lower hydrocarbons, which are more volatile (low boiling). For example, a higher hydrocarbons $C_{16}H_{34}$ splits according to the following reaction.



This is the process in which C-C bonds in long chain alkane molecules are broken, producing smaller molecules of both alkanes and alkenes. The composition of the products depends on the condition under which the cracking takes place. Cracking is generally carried out in the following ways.

(1) Thermal Cracking

Breaking down of large molecules by heating at high temperature and pressure is called Thermal Cracking. It is particularly useful in the production of unsaturated hydrocarbons such as ethene and propene.

(2) Catalytic Cracking

Higher hydrocarbons can be cracked at lower temperature (500°C) and lower pressure (2 atm), in the presence of a suitable catalyst. A typical catalyst used for this purpose is a mixture of silica (SiO_2) and alumina (Al_2O_3). Catalytic cracking produces gasoline of higher octane number and, therefore, this method is used for obtaining better quality gasoline.

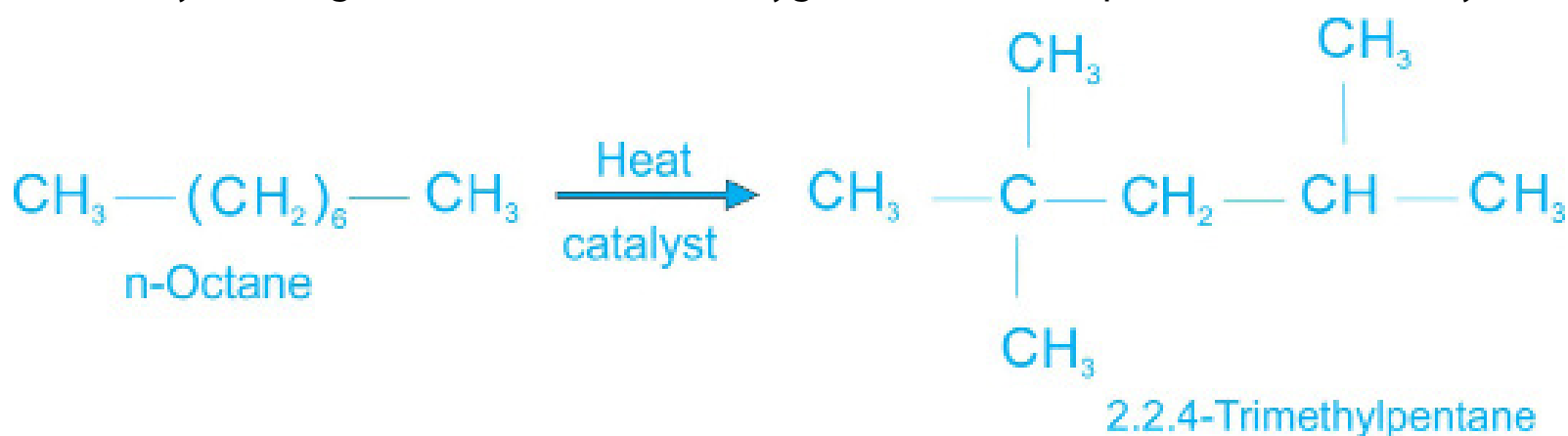
(3) Steam Cracking

In this process, higher hydrocarbons in the vapour phase are mixed with steam, heated for a short duration to about 900°C and cooled rapidly. The process is suitable for obtaining lower unsaturated hydrocarbons.

Besides increasing the yield of gasoline, cracking has also produced large amounts of useful by-products, such as ethene, propene, butene and benzene. These are used for manufacturing drugs, plastics, detergents, synthetic fibres, fertilizers, weed killers and important chemicals like ethanol, phenol and acetone.

7.6 REFORMING

The gasoline fraction present in petroleum is generally not of good quality. When it burns in an automobile engine, combustion can be initiated before the spark plug fires. This produces a sharp metallic sound called knocking which greatly reduces the efficiency of an engine. The quality of a fuel is indicated by its octane number. As the octane number increases, the engine is less likely to produce knocking. Straight-chain hydrocarbons have low octane numbers and make poor fuels. Experiments have shown that isooctane or 2,2,4-trimethyl pentane burns very smoothly in an engine and has been arbitrarily given an octane number of 100. The octane number of gasoline is improved by a process called reforming. It involves the conversion of straight chain hydrocarbons into branched chain by heating in the absence of oxygen and in the presence of a catalyst.



The octane number of a poor fuel can also be improved by blending it with a small amount of additive like tetraethyl lead (TEL). Tetraethyl lead $(C_2H_5)_4Pb$, is an efficient antiknock agent but has one serious disadvantage; its combustion product, lead oxide, is reduced to metallic lead which is discharged into the air through the exhaust pipe and causes air pollution.

7.7 CLASSIFICATIONS OF ORGANIC COMPOUNDS

There are millions of organic compounds. It is practically not possible to study each individual compound. To facilitate their study, organic compounds are classified into various groups and sub-groups. They may be broadly classified into the following classes.

1. Open chain or Acyclic compounds.
2. Closed chain or Cyclic (or ring) compounds.

(1) Open Chain or Acyclic Compounds

This type of compounds contain an open chain of carbon atoms. The chains may be branched or non-branched (straight chain). The open chain compounds are also called aliphatic compounds.

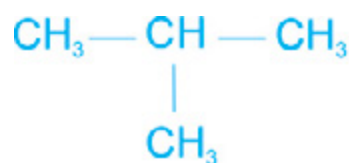
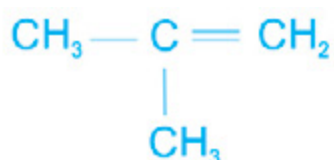
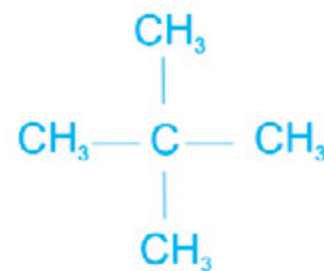
Straight Chain (or non- branched) Compounds

Those organic compounds in which the carbon atoms are connected in series from one to the other.



Branched chain compounds

Those organic compounds in which the carbon atoms are attached on the sides of chain.

2-Methylpropane
Isobutane2-Methylpropene
(Isobutylene)

2,2-Dimethylpropane (neo-Pentane)

(2) Closed Chain Compounds or Cyclic Compounds

These compounds contain closed chains or rings of atoms and are known as cyclic or ring compounds. These are of two types;

- (a) Homocyclic or carbocyclic compounds
- (b) Heterocyclic compounds

The classification of organic compounds into various classes is shown in Fig. 7.1.

(a) Homocyclic or Carbocyclic Compounds

The compounds in which the ring consists of only carbon atoms, Homocyclic or carbocyclic compounds.

Homocyclic compounds are further classified as :

1. Alicyclic compounds
2. Aromatic compounds

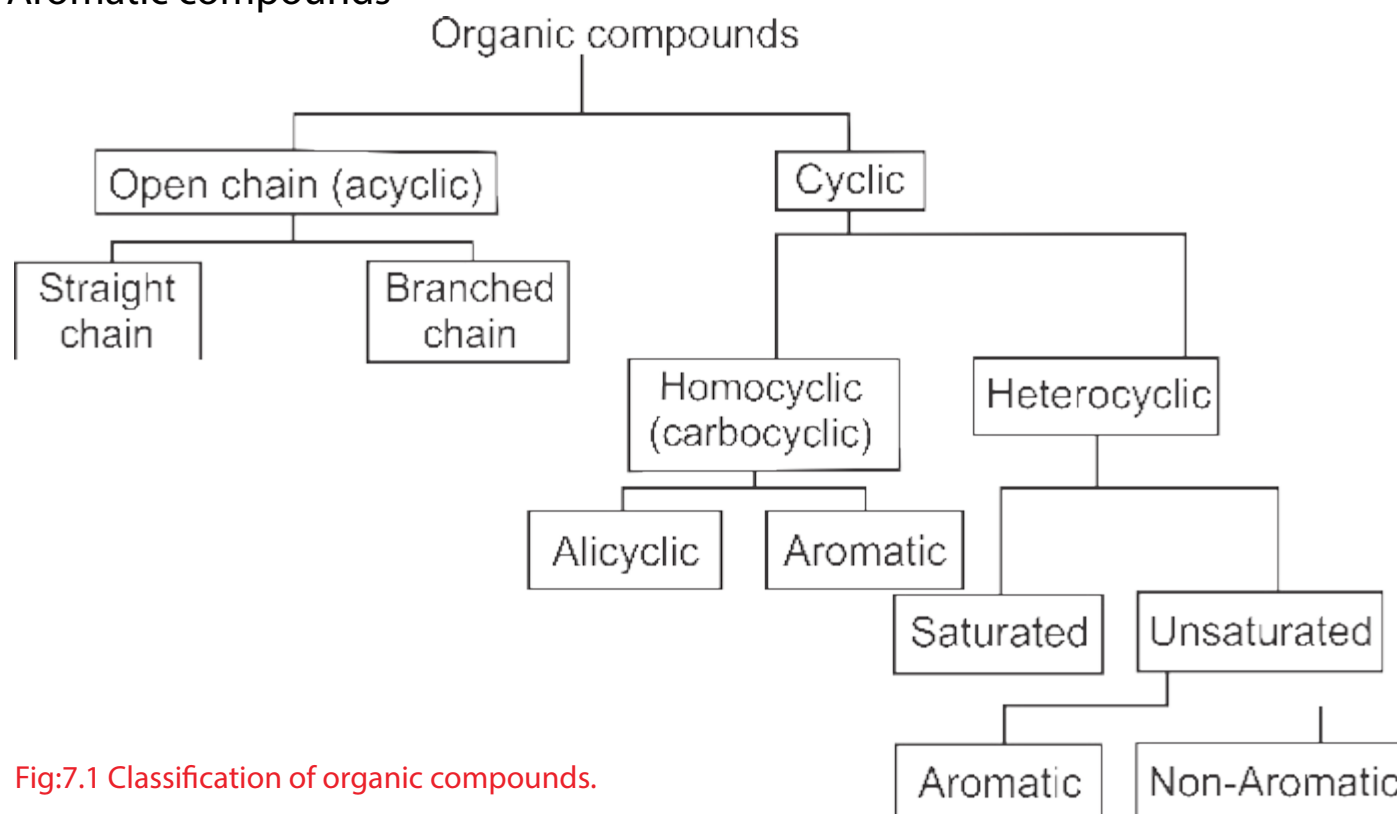
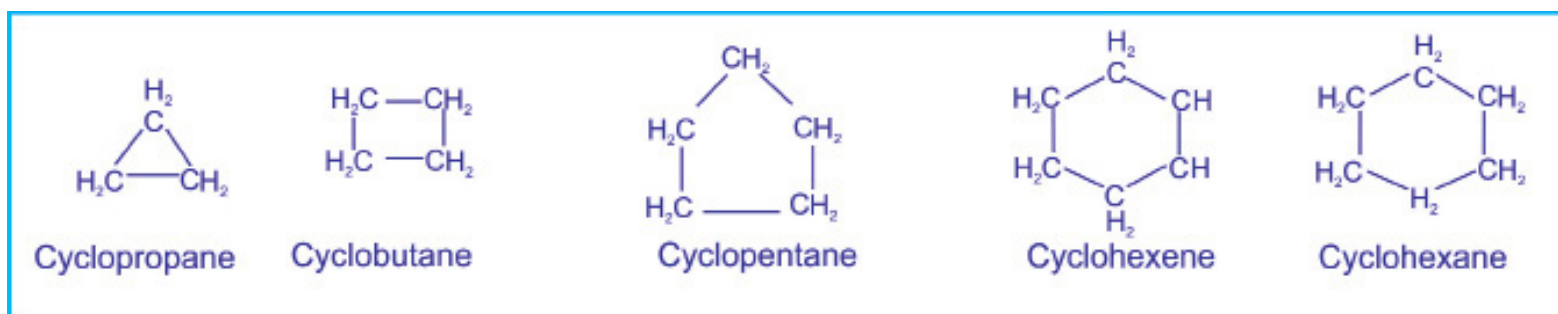


Fig:7.1 Classification of organic compounds.

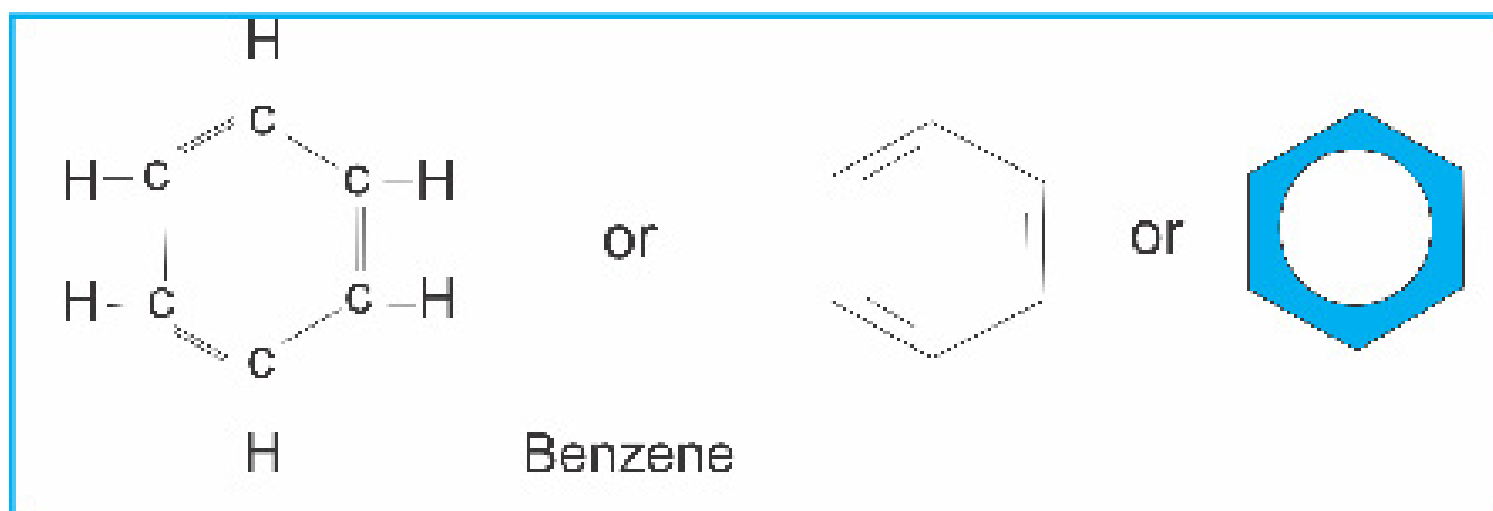
(1) Alicyclic Compounds

The homocyclic compounds which contain a ring of three or more carbon atoms and resembling aliphatic compounds are called alicyclic compounds. The saturated alicyclic hydrocarbons have the general formula C_nH_{2n} . Typical examples of alicyclic compounds are given below. One or more hydrogen atoms present in these compounds may be substituted by other group or groups.

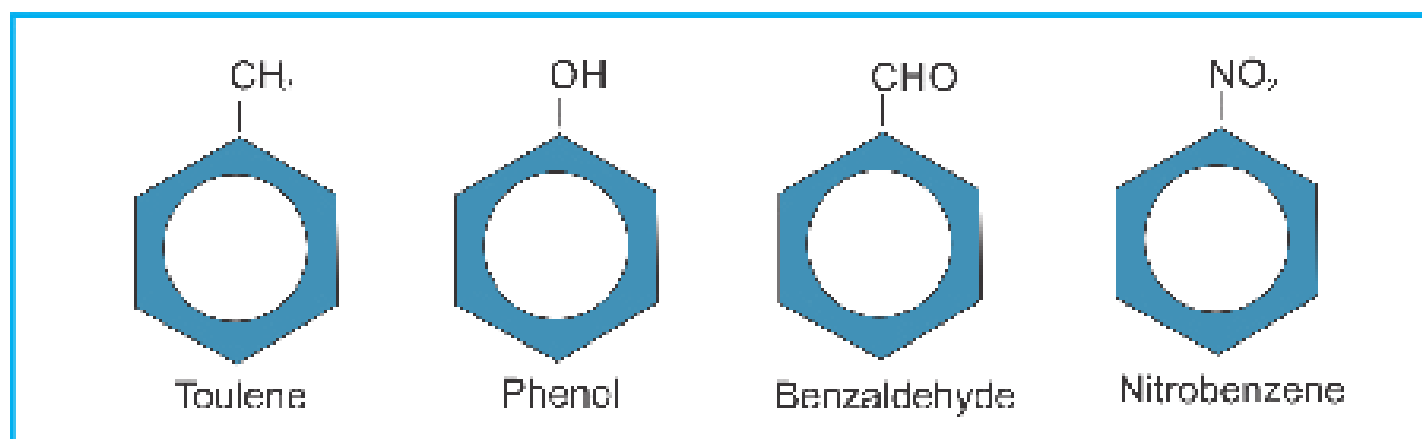


(2) Aromatic Compounds

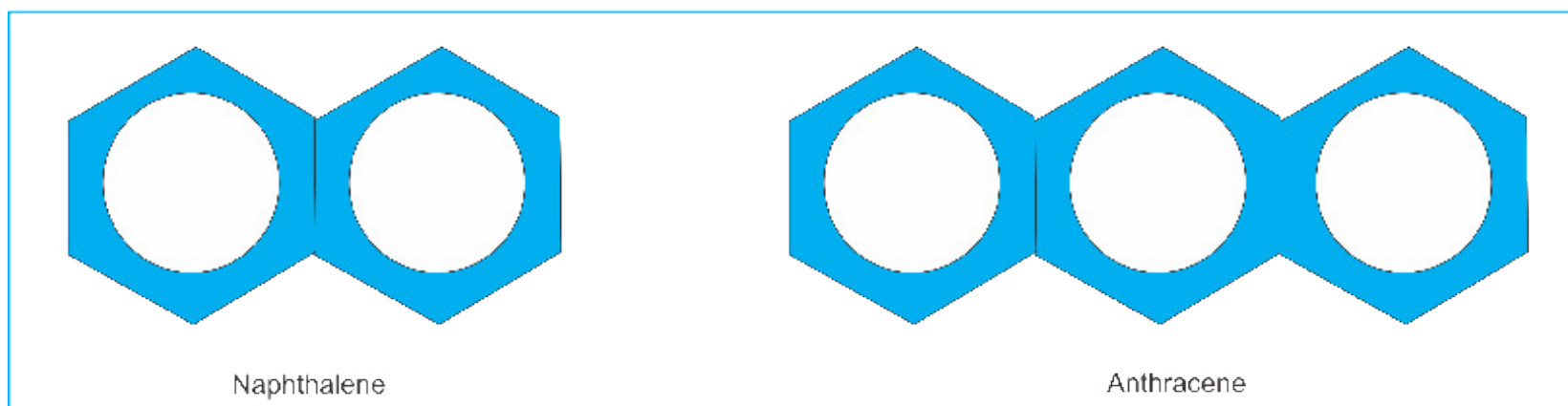
These carbocyclic compounds contain at least one benzene ring, six carbon atoms with three alternate double and single bonds. These bonds are usually shown in the form of a circle. Typical examples of aromatic compounds are given below.



The aromatic compounds may have a side-chain or a functional group attached to the ring. For example:

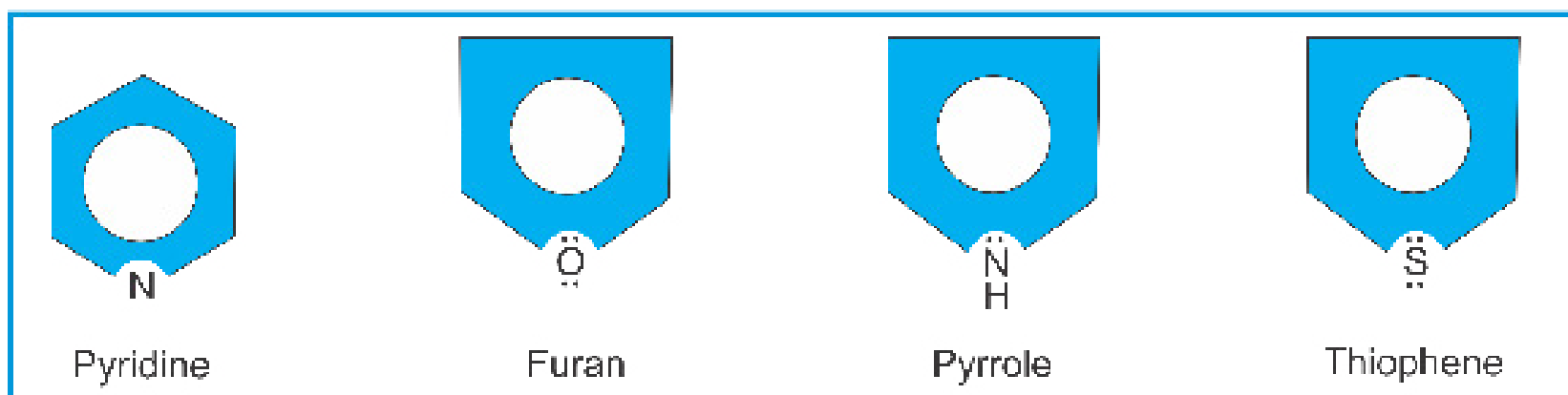


The aromatic compounds may also contain more than one benzene rings fused together.



(b) Heterocyclic Compounds

The compounds in which the ring consists of atoms of more than one kind are called heterocyclic compounds or heterocycles. In heterocyclic compounds generally one or more atoms of elements such as nitrogen (N), oxygen (O) or sulphur (S) are present. The atom other than carbon viz, N, O, or S, present in the ring is called a hetero atom.



7.8 FUNCTIONAL GROUP

An atom or a group of atoms or a double bond or a triple bond whose presence imparts specific properties to organic compounds is called a functional group, because they are the chemically functional parts of molecules.

The study of organic chemistry is organized around functional groups. Each functional group defines an organic family. Although over six million organic compounds are known, there are only a handful of functional groups, and each one serves to define a family of organic compounds. The examples of functional groups are outlined in Table 7.2.

TABLE 7.2 FUNCTIONAL GROUPS

Functional group		Class of compounds	Example
Formula	Name		
	None	Alkane	CH ₃ -CH ₃
	Double bond	Alkene	H ₂ C=CH ₂
	Triple bond	Alkyne	HC≡CH
-X(X=F,Cl,Br,I)	Halo (fluoro, chloro, bromo, iodo)	Alkyl halide	CH ₃ -CH ₂ -Cl
-OH	Hydroxyl group	Alcohol or alkanol	CH ₃ -CH ₂ -OH
-NH ₂	Amino group	Amine	CH ₃ -CH ₂ -NH ₂
	Imino group	Imine	CH ₂ =NH
	Ether linkage	Ether	CH ₃ -CH ₂ -O-CH ₂ -CH ₃
	Formyl group	Aldehyde or alkanal	
	Carbonyl	Ketone or alkanone	

	Carboxyl group	Carboxylic acid (or alkanoid acid)	
	Acid halide	Acid halide	
	Acid amide	Acid amide	
	Ester group	Ester	
	Mercapto	Thioalcohol or Thiol	
	Cyano	Alkyl cyanide or alkane nitrile	
	Nitro	Nitro compounds	

7.9 HYBRIDIZATION OF ORBITALS AND THE SHAPES OF MOLECULES

Although the most stable electronic configuration of a carbon atom (having two partially filled 2p orbitals) requires it to be divalent, carbon is tetravalent in the majority of its compounds. In order to explain this apparent anomaly, it is assumed that an electron from the 2s orbital is promoted to an empty 2p_z orbital, giving the electronic configuration:

Ground state electronic configuration of carbon = $1s^2 2s^2 2p_x^1 2p_y^1 2p_z^0$

Excited state electronic configuration of carbon = $1s^2 2s^1 2p_x^1 2p_y^1 2p_z^1$

The excited state configuration can explain the tetravalency of carbon but these four valencies will not be equivalent. Orbital hybridization theory has been developed to explain the equivalent tetravalency of carbon.

According to this theory the four atomic orbitals of carbon belonging to valence shell may be mixed in different ways to explain the bonding and shapes of molecules formed by carbon atoms.

sp^3 Hybridization

In order to explain the bonding and shapes of molecules in which carbon is attached with four atoms, all these four atomic orbitals are mixed together to give rise to four new equivalent hybrid atomic orbitals having same shape and energy. This mode of hybridization is called tetrahedral or sp^3 hybridization.

All these four sp^3 hybrid orbitals are degenerate (having equal energy) and are directed at an angle of 109.5° in space to give a tetrahedral geometry.

When a carbon atom forms single bonds with other atoms, these hybrid orbitals overlap with the orbitals of these atoms to form four sigma bonds. This type of hybridization explains the bonding and shapes of all those compounds in which carbon atom is saturated.

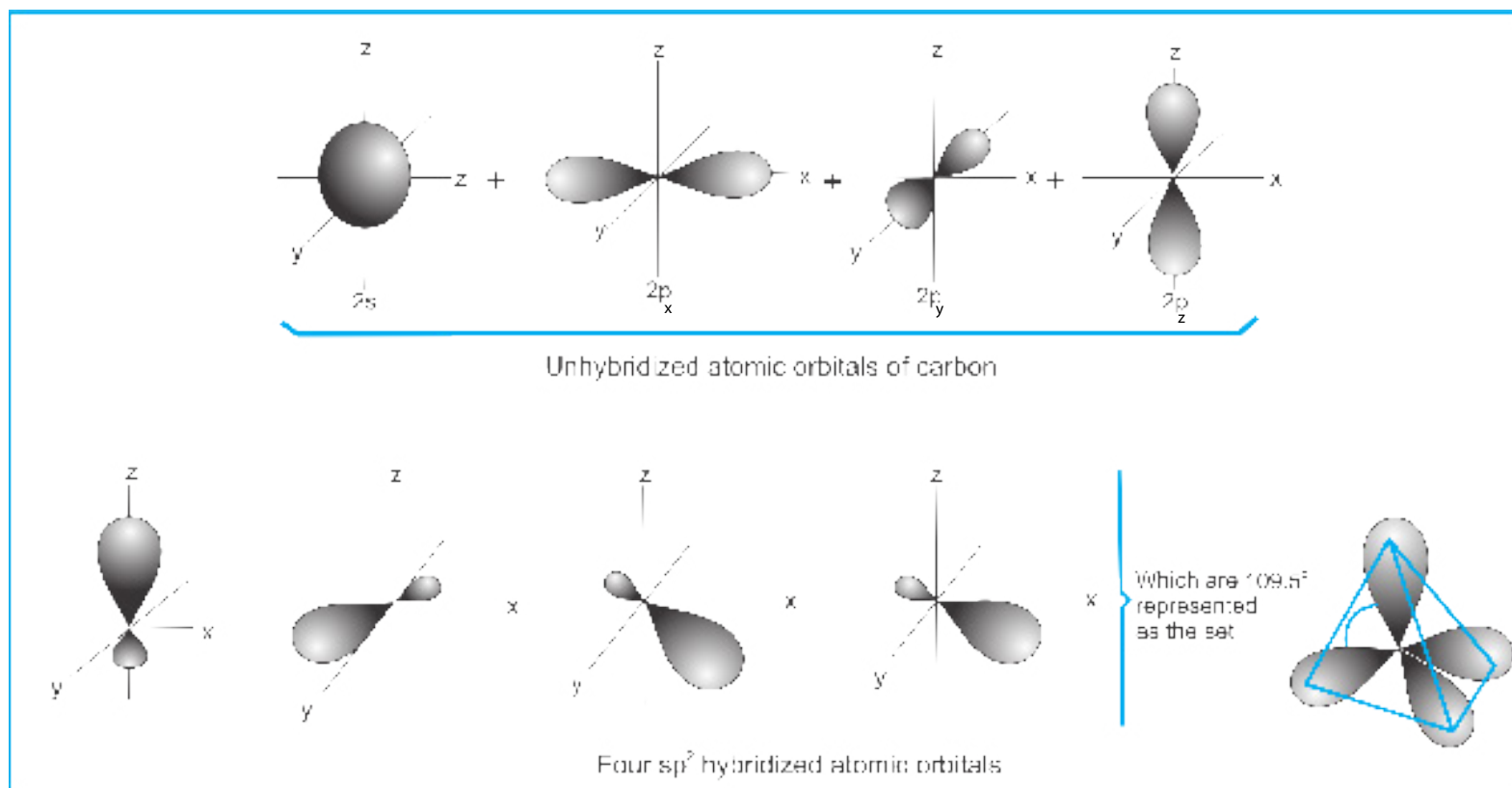
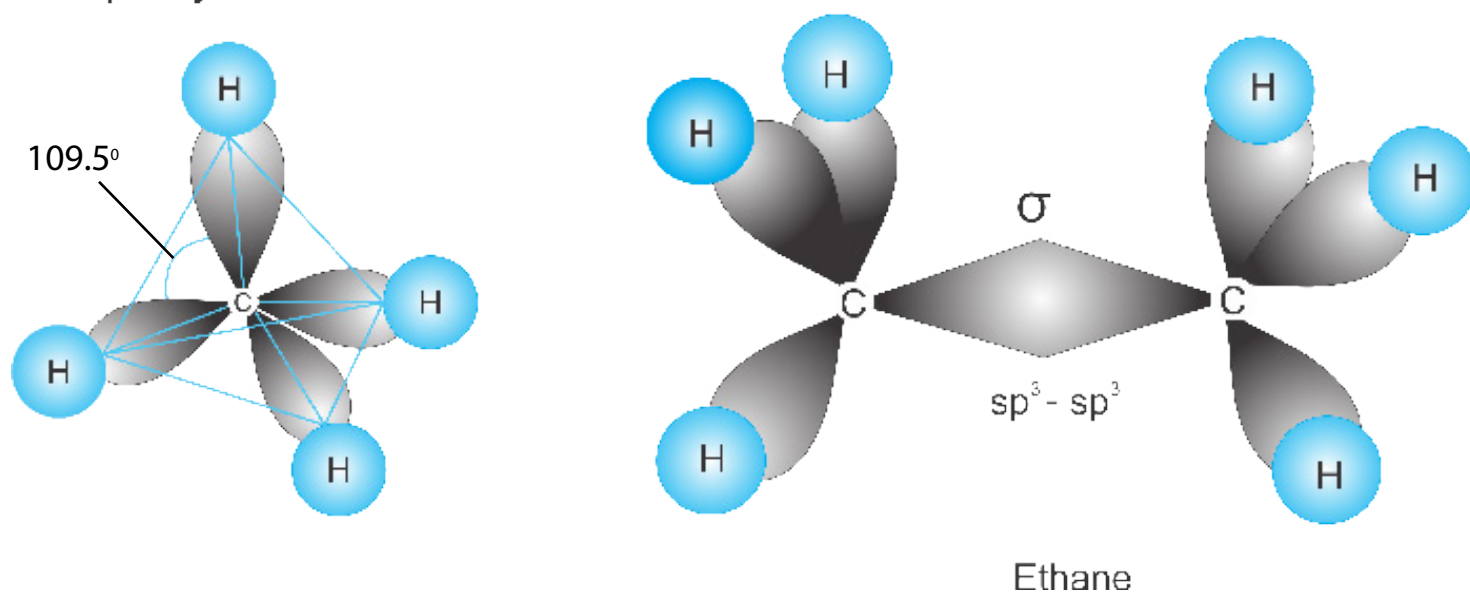


Fig. 7.2 sp^3 hybridization of carbon to give methane (CH_4)

In the formation of methane, the four hybrid atomic orbitals of carbon overlap separately with four 1s atomic orbitals of hydrogen to form four equivalent C-H bonds. The shape of methane thus formed is very similar to the actual methane molecule. All the four hydrogen atoms do not lie in the same plane.

sp^3 -hybridization in ethane



In ethane, $CH_3 - CH_3$, the two tetrahedrons of each carbon are joined together as shown in the above figure. Further addition of a carbon atom with ethane will mean the attachment of another tetrahedron. At this stage, it is necessary to answer an important question. From where does the energy come to excite the carbon atom?

The answer to this question is simple. Before excitation the carbon should make two covalent bonds releasing an adequate amount of energy. After excitation, however, it will form four covalent bonds releasing almost double the amount of energy. This excess energy is more than that needed to excite the carbon atom. So a tetravalent carbon atom is expected to be more stable than a divalent carbon atom.

sp^2 Hybridization

In order to explain the bonding in unsaturated compounds, two more modes of hybridization have been developed.

The structure of alkenes can be explained by sp^2 mode of hybridization. In this type one $2s$ and two $2p$ orbitals of carbon are mixed together to give three equivalent and coplanar sp^2 hybridized orbitals, Fig. 7.3.

Each sp^2 hybrid orbital is directed from the centre of an equilateral triangle to its three corners. The bond angle between any two sp^2 hybrid orbitals is 120° . The unhybridized $2p_z$ orbital will remain perpendicular to the triangle thus formed.

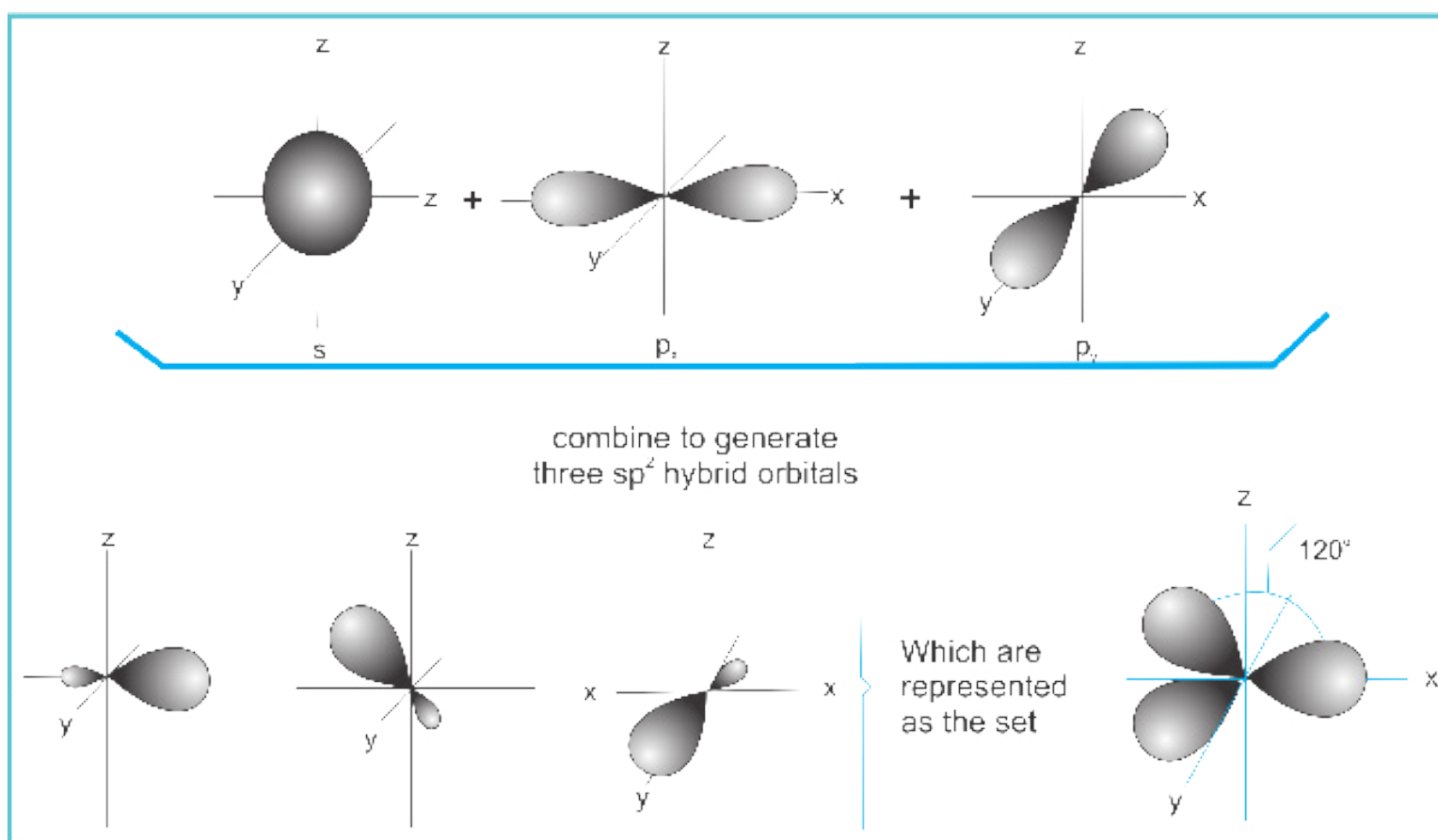


Fig. 7.3 sp^2 -hybridization of carbon.

In the formation of ethene molecule, three sp^2 orbitals of each carbon atom overlap separately with sp^2 orbital of another carbon and $1s$ orbitals of two hydrogen atoms to form three σ bonds. This gives rise to what is called the σ -frame work of ethene molecule. The unhybridized orbitals of each carbon atom will then overlap in a parallel fashion to form a π -bond, Fig. 7.4

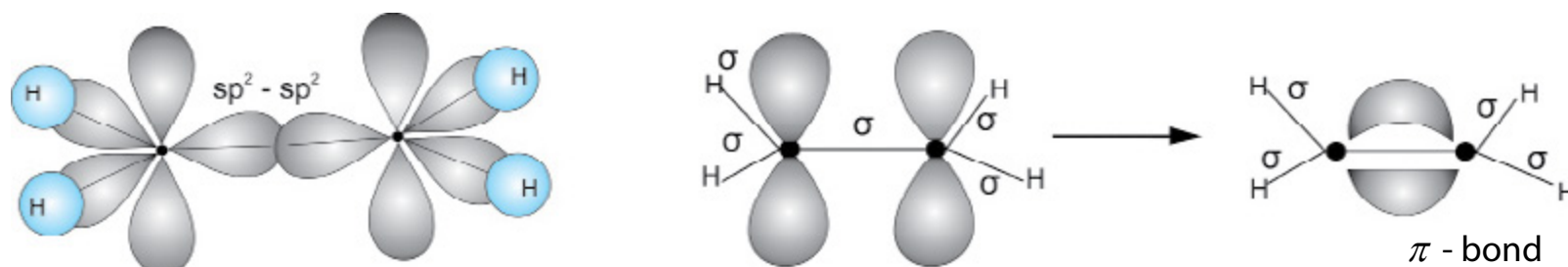
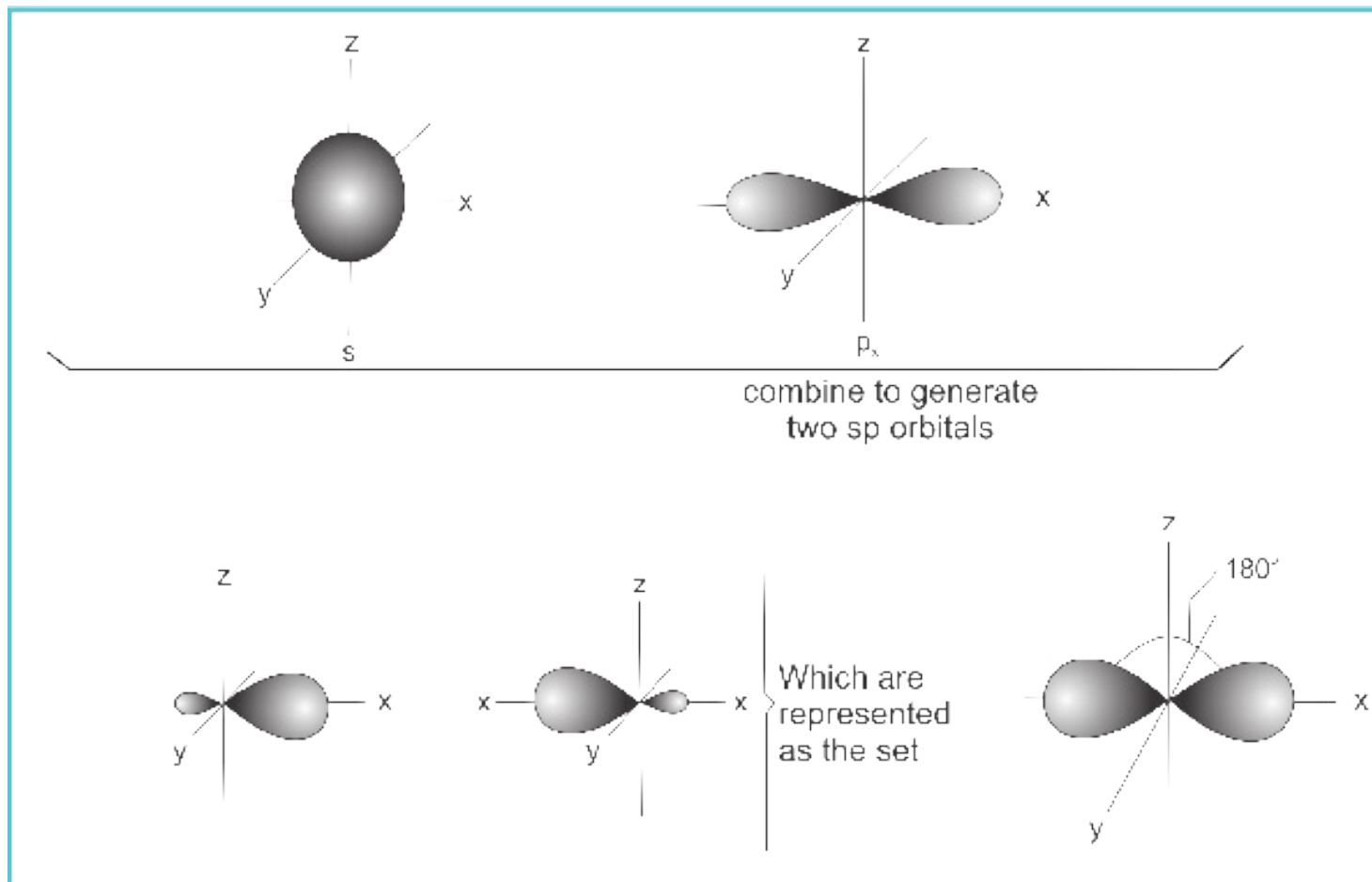


Fig. 7.4 Formation of ethene.

sp-Hybridization

The structure of alkynes can be explained by yet another mode of hybridization called sp hybridization. In this type one 2s and one 2p orbitals of the carbon atom mix together to give rise to two degenerate sp hybridized atomic orbitals. These orbitals have a linear shape with a bond angle 180° .



The two unhybridized atomic orbitals, $2p_y$ and $2p_z$ are perpendicular to these sp hybridized orbitals.

Ethyne molecule is formed when two sp hybridized carbon atoms join together to form a σ -bond by sp-sp overlap. The other sp orbital is utilized to form a σ -bond with 1s orbital of hydrogen atom.

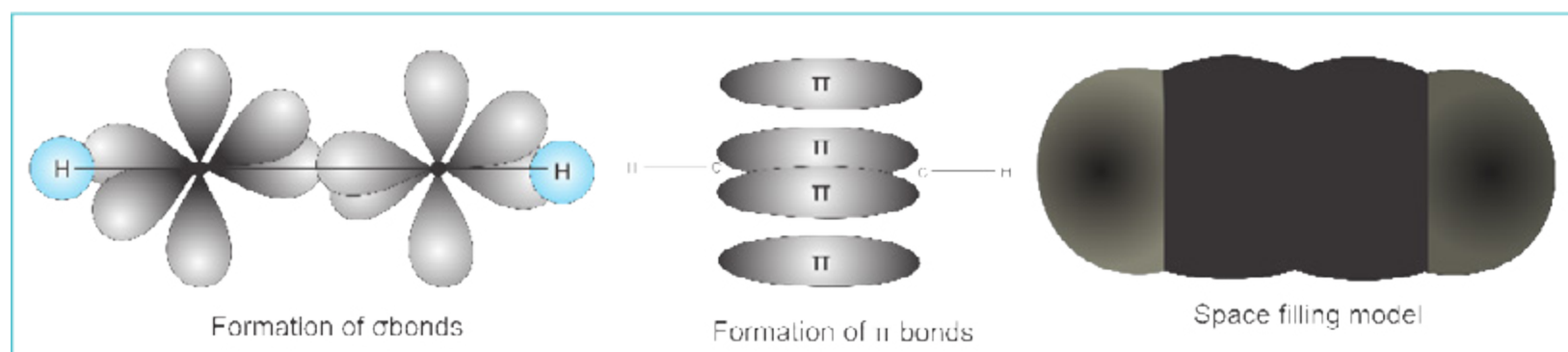


Fig. 7.6 Formation of ethyne

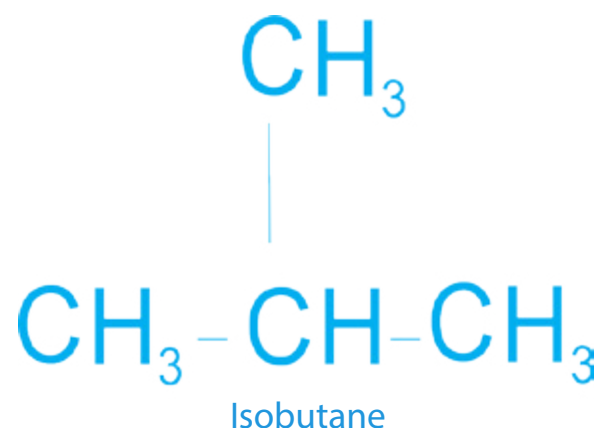
The two unhybridized p orbitals on a carbon atom will overlap separately with the p orbitals of the other carbon atom to give two π -bonds both perpendicular to the σ -framework of ethyne. The presence of a σ and two π bonds between two carbon atoms is responsible for shortening the bond distance.

7.10 ISOMERISM

The concept of isomerism is an important feature of organic compounds. **Two or more compounds having the same molecular formula but different structural formulas and properties are said to be isomers and the phenomenon is called isomerism.** The structural formula of a compound shows the arrangement of atoms and bonds present in it.

The simplest hydrocarbon to have structural isomers is butane (C_4H_{10}). The alkanes, methane, ethane and propane do not show the phenomenon of isomerism because each exists in one structural form only. If we study the structural formula of butane or other higher hydrocarbons of the alkane family, we will observe that it is possible to arrange the atoms present in the molecule in more than one way to satisfy all valencies.

This means that it is possible to have two or more different arrangements for the same molecular formula. For example, butane molecule can have two different arrangements as represented by the following structural formulas:



This fact has been supported by an experimental evidence that there are two compounds with different physical properties but with the same molecular formula of C_4H_{10} .

Isomerism is not only possible but common if the compound contains more than three carbon atoms. As the number of carbon atoms in a hydrocarbon increases, the number of possible isomers increase very rapidly. The five carbon compound, pentane, has three isomers. When the number of carbon atoms increases to thirty, the number of isomers amount to over four billions.

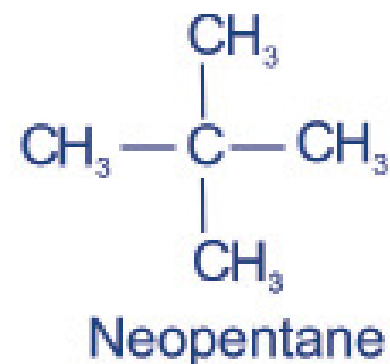
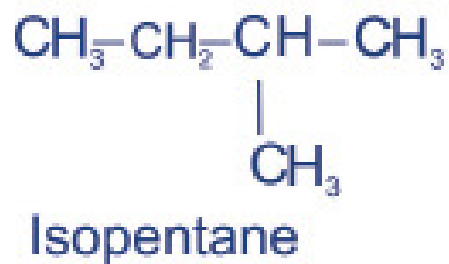
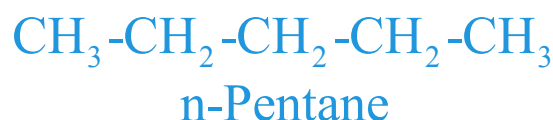
7.10.1 Types of Isomerism

(1) Structural Isomerism

The structural isomerism is not confined to hydrocarbons only. In fact, all classes of organic compounds and their derivatives show the phenomenon of structural isomerism. The structural isomerism arises due to the difference in the arrangement of atoms within the molecule. The structural isomerism can be exhibited in five different ways. These are :

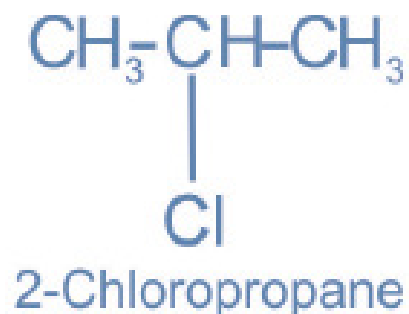
(i) The Chain Isomerism.

This type of isomerism arises due to the difference in the nature of the carbon chain. For example, for pentane (C_5H_{12}), the following arrangements are possible.

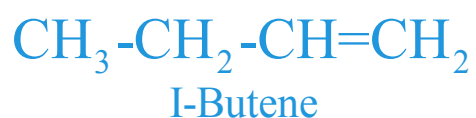
**(ii) Position Isomerism.**

This type of isomerism arises due to the difference in the position of the same functional group on the carbon chain. The arrangement of carbon atoms remains the same. For example,

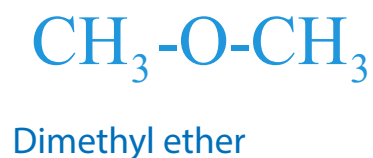
(a) Chloropropane can have two positional isomers given below.



(b) Butene (C_4H_8) can have two positional isomers.

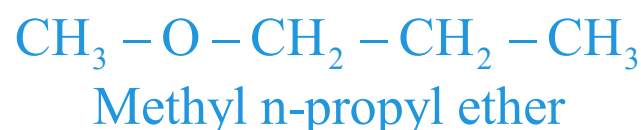
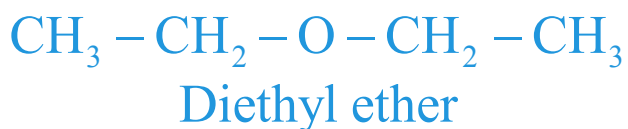
**(iii) Functional Group Isomerism**

The compounds having the same molecular formula but different functional groups are said to exhibit functional group isomerism. For example, there are two compounds having the same molecular formula $\text{C}_2\text{H}_6\text{O}$, but different arrangement of atoms.

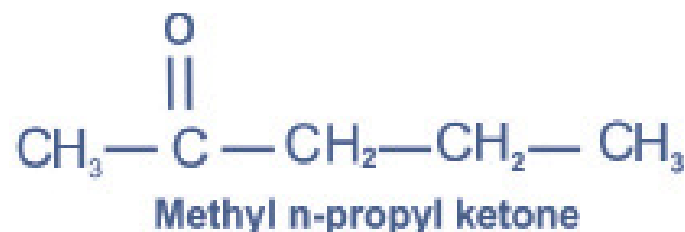
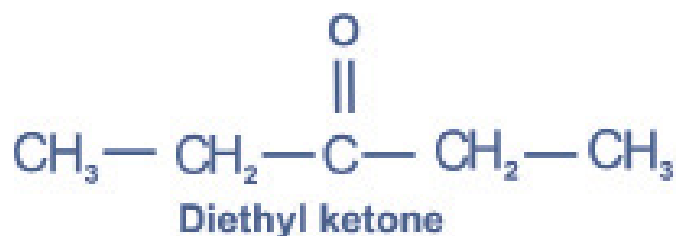


(iv) Metamerism

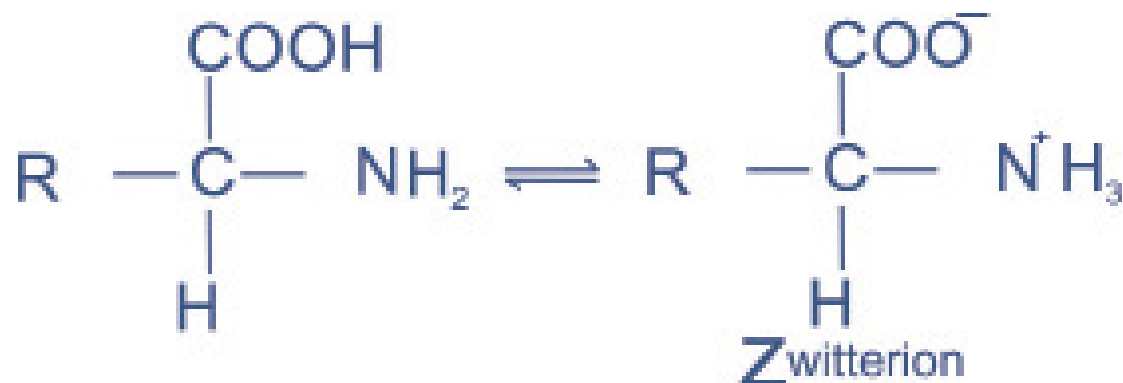
This type of isomerism arises due to the unequal distribution of carbon atoms on either side of the functional group. Such compounds belong to the same homologous series. For example, diethyl ether and methyl n-propyl ether are metamers.



For a ketonic compound having the molecular formula $\text{C}_5\text{H}_{10}\text{O}$, the following two metamers are possible.

**(v) Tautomerism**

This type of isomerism arises due to shifting of proton from one atom to other in the same molecule.

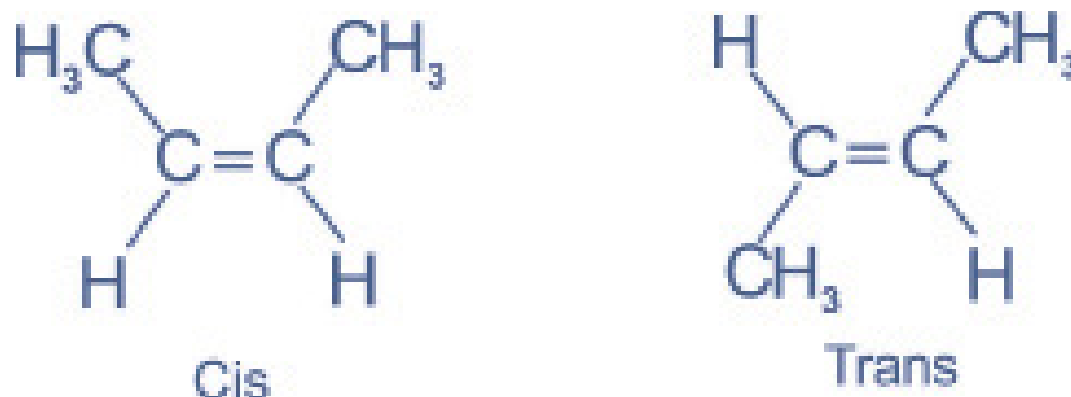
**(2) Cis-trans Isomerism or Geometric Isomerism**

Two carbon atoms joined by a single bond are capable of free rotation about it. However, when two carbon atoms are joined by a double bond, they cannot rotate freely. As a result, the relative positions of the various groups attached to these carbon atoms get fixed and gives rise to cis- trans isomers.

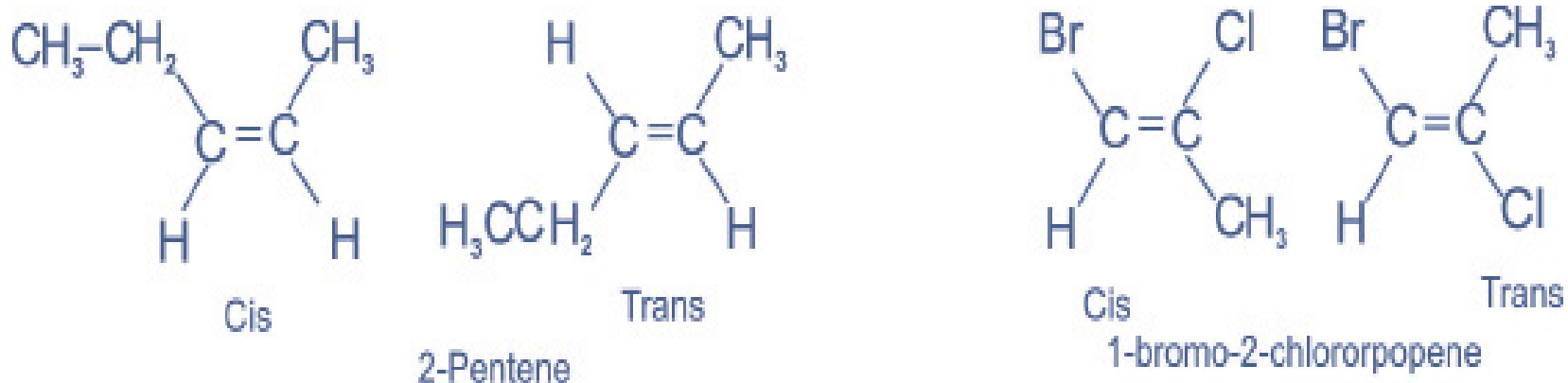
Such compounds which possess the same structural formula, but differ with respect to the positions of the identical groups in space are called cis-trans isomers and the phenomenon is known as the cis-trans or geometric isomerism.

The necessary and sufficient condition for a compound to exhibit geometric isomerism is that the two groups attached to the same carbon must be different.

2-Butene can exist in the form of cis and trans isomers.



Similarly 2-pentene and 1-bromo-2-chloropropene also show cis-trans isomerism.



In the cis-form, the similar groups lie on the same side of the double bond whereas in the trans-form, the similar groups lie on the opposite sides of the double bond.

The rotation of two carbon atoms joined by a double bond could happen only if the π bond breaks. This ordinarily costs too much energy, making geometric isomers possible.

KEY POINTS

1. Chemical compounds were classified as organic and inorganic compounds based upon their origin. Organic compounds are obtained from living things whereas inorganic compounds are obtained from mineral sources.
2. It was thought that organic compounds could not be synthesized in the laboratory from inorganic sources.
3. Organic chemistry is now-a-days defined as the chemistry of carbon compounds.
4. Most of the commercially important compounds we use everyday are organic in nature.
5. Coal, petroleum and natural gas are important sources of organic compounds.
6. The process of cracking is developed to increase the yield of lower hydrocarbons which serve as important fuels commercially.
7. Organic compounds are classified into acyclic and cyclic compounds.
8. The study of organic chemistry is organized around functional groups. Each functional group defines an organic family.
9. The type of bonding and the shapes of different type of compounds formed by carbon can be explained by sp^3 , sp^2 and sp modes of hybridization.
10. Compounds having the same molecular formula but different structural formulas are called isomers. There are four different type of structural isomers.
11. Isomerism arises due to restricted rotation around a carbon-carbon double bond is called cis-trans isomerism.

EXERCISE

Q I. Fill in the blanks

- i) Organic compounds having same molecular formula but different _____ are called isomers.
- ii) The state of hybridization of carbon atom in _____ is sp^2 .
- iii) Alkenes show _____ due to restricted rotation around a carbon-carbon double bond.
- iv) Heating an organic compound in the absence of oxygen and in the presence of _____ as a catalyst is called cracking.

- v) A group of atoms which confers characteristic properties to an organic compound is called _____ .
- vi) 2-Butene is _____ of 1-butene.
- vii) Carbonyl functional group is present in both _____ and ketones.
- viii) A heterocyclic compound contains an atom other than _____ in its ring.
- ix) The quality of gasoline can be checked by finding out its _____ .
- x) A carboxylic acid contains _____ as a functional group.

Q.2 Indicate true or false.

- (i) There are three possible isomers for pentane.
- (ii) Alkynes do not show the phenomenon of cis-trans isomerism.
- (iii) Organic compounds can not be synthesized from inorganic compounds.
- (iv) All close chain compounds are aromatic in nature.
- (v) The functional group present in amides is called an amino group.
- (vi) Government of Pakistan is trying to use coal for power generation.
- (vii) Crude petroleum is subjected to fractional sublimation in order to separate it into different fractions,
- (viii) A bond between carbon and hydrogen serves as a functional group for alkanes.
- (ix) o-Nitrotoluene and p-nitrotoluene are the examples of functional group isomerism.
- (x) Almost all the chemical reactions taking place in our body are inorganic in nature.

Q 3. Multiple choice questions. Encircle the correct answer.

- (i) The state of hybridization of carbon atom in methane is:
(a) sp^3 (b) sp^2 (c) sp (d) dsp^2
- (ii) In t-butyl alcohol, the tertiary carbon is bonded to:
(a) two hydrogen atoms (b) three hydrogen atoms
(c) one hydrogen atom (d) no hydrogen atom
- (iii) Which set of hybrid orbitals has planar triangular shape.
(a) sp^3 (b) sp (c) sp^2 (d) dsp^2
- (iv) The chemist who synthesized urea from ammonium cyanate was:
(a) Berzelius (b) Kolbe (c) Wholer (d) Lavoisier

(v) Linear shape is associated with which set of hybrid orbitals?

- (a) sp (b) sp^2 (c) sp^3 (d) dsp^2

(vi) A double bond consists of:

- (a) two sigma bonds (b) one sigma and one pi bond
(c) one sigma and two pi bonds (d) two pi bond

(vii) Ethers show the phenonenom of:

- (a) position isomerism (b) functional group isomerism
(c) metamerism (d) cis-trans isomerism

(viii) Select From the following the one which is alcohol:

- (a) CH_3-CH_2-OH (b) CH_3-O-CH_3
(c) CH_3COOH (d) CH_3-CH_2-Br

Q 4. How organic compounds are classified? Give suitable example of each type.

Q 5. What are homocyclic and heterocyclic compounds? Give one example of each.

Q 6. Write the structural formulas of the two possible isomers of C_4H_{10} .

Q 7. Why is ethene an important industrial chemical?

Q 8. What is meant by a functional group? Name typical functional groups containing oxygen.

Q 9. What is an organic compound? Explain the importance of Wohler's work in the developrnt of organic chemistry.

Q 10. Write a short note on cracking of hydrocarbons.

Q 11. Explain reforming of petroleum with the help of suitable example.

Q 12. Describe important sources of organic compounds.

Q13. What is orbital hybridization? Explain sp^3 sp^2 and sp modes of hybridization of carbon.

Q14. Explain the type of bonds and shapes of the following molecules using hybridization approach.

$CH_3 - CH_3$, $CH_2 = CH_2$, $CH = CH$, $HCHO$, CH_3Cl

Q 15. Why there is no free rotation around a double bond and a free rotation around a single bond ? Discuss cis-trans isomerism.