Chapter#7
Fundamental Principles of Organic Chemistry

1. ***What is vital force theory?***

Ans: 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.

2. ***Who rejected vital force theory? OR Name the organic compound first of all prepared in the laboratory and how?***

Ans: This theory was rejected by Friedrick Wohler when he obtained urea $(NH_2)_2CO$, an organic compound in the urine of mammals, from ammonium cyanate, NH_4CNO.

$$NH_4CNO \longrightarrow (NH_2)_2CO$$

3. ***Define organic chemistry.***

Ans: Organic chemistry is that branch of chemistry which deals with the study of compounds of carbon with hydrogen (hydrocarbons) and their derivatives.

4. ***What is cracking?***

Ans: 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.

$$\underset{\text{Alkane}}{C_{16}H_{34}} \xrightarrow[700\ ^0C]{\text{Heat}} C_7H_{16} + 3CH_2{=}CH_2 + CH_3\text{-}CH{=}CH_2$$

5. ***What is thermal cracking?***

Ans: 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.

$$\underset{\text{Alkane}}{C_{16}H_{34}} \xrightarrow[700\ ^{0}C]{\text{Heat}} C_7H_{16} + 3CH_2{=}CH_2 + CH_3\text{-}CH{=}CH_2$$

6. ***What is catalytic cracking?***

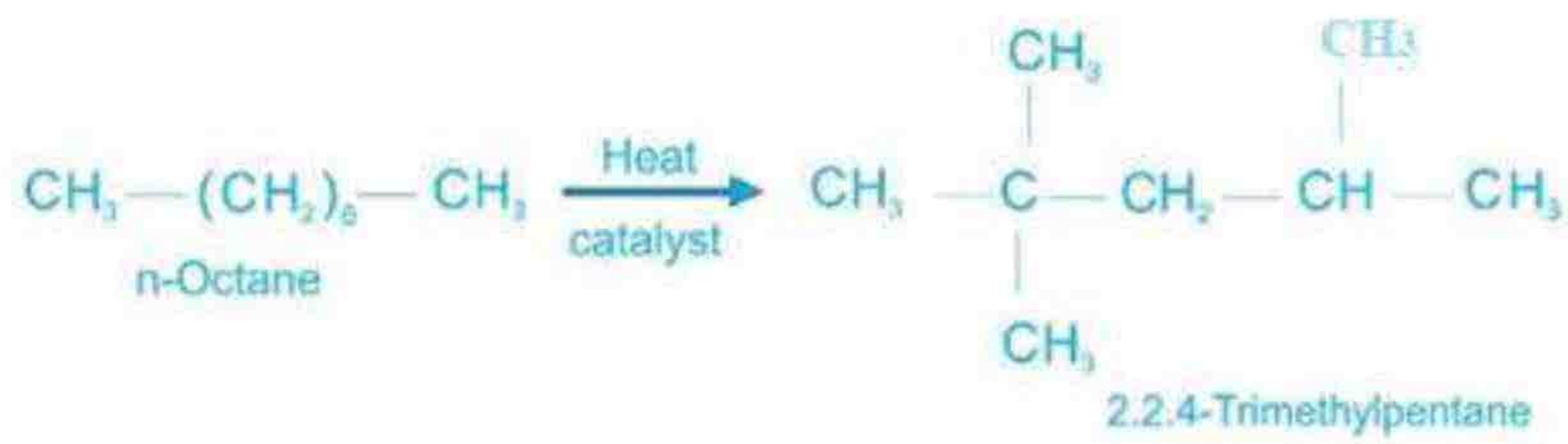
Ans: Higher hydrocarbons can be cracked at lower temperature (500°C) and lower pressure (2 atm), in the presence of a suitable catalyst. A typical catalyst used for this purpose is a mixture of silica (SiO_2) and alumina (AI_2O_3). Catalytic cracking produces gasoline of higher octane number and, therefore, this method is used for obtaining better quality gasoline.

7. ***What is steam cracking?***

Ans: 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.

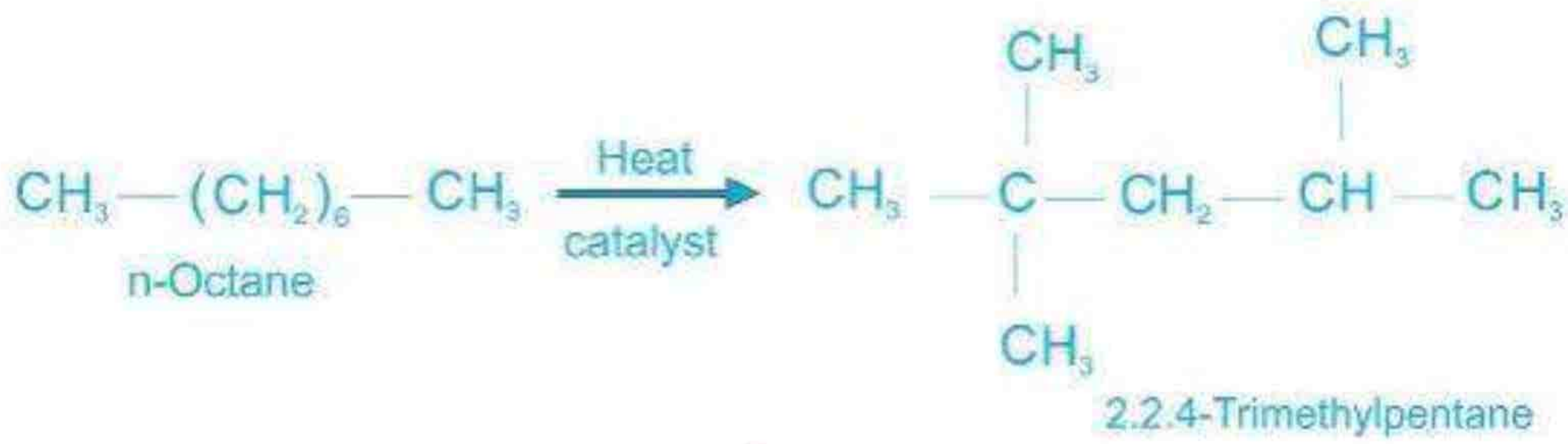
8. ***Explain reforming.***

Ans: 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.



9. ***What is octane number and how it can be improved?***

Ans: Percentage by volume of isooctane relative to that of n-heptane in a fuel is called octane number. Octane number is improved by making Isooctane through the process of reforming and adding it to a low octane number fuel.



10. Branched hydrocarbons are better as a fuel as compared to straight chain. Explain.

Ans: Straight chain hydrocarbons e.g., n-Octane have low octane number and burn rapidly in internal combustion engine producing sharp metallic sound called knocking. Branched chain hydrocarbons e.g., Isooctane, on the other hand, are a good quality fuel as they do not cause knocking. This is because branched chain hydrocarbons have a higher octane number and burn smoothly.

11. What is meant by knocking?

Ans: Straight chain hydrocarbons e.g., n-Heptane have low octane number and burn rapidly in internal combustion engine producing sharp metallic sound called knocking.

12. How does cracking and reforming differ from each other?

Ans:

	Cracking	Reforming
1.	Conversion of long chain hydrocarbons having higher boiling points to lower hydrocarbons which are more volatile	Conversion of straight chain hydrocarbons which are low quality fuel to branched chain hydrocarbons which are good quality fuel
2.	It is used to increase the amount of hydrocarbons suitable for making gasoline	It is used to improve the octane number of fuel
3.	It is done using heat, steam or heating hydrocarbons in presence of a catalyst	It is done by heating hydrocarbons in presence of a catalyst.

13. What are open chain or acyclic compounds?

Ans: 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. They are further divided into:

1. Straight chain compounds
2. Branched chain compounds

14. What are straight chain (or non-branched) compounds?

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

$CH_3\text{-}CH_2\text{-}CH_2\text{-}CH_3$ (n-Butane) $H_2C{=}CH\text{-}CH_2\text{-}CH_3$ (1-Butene) $CH_3\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}OH$ (1-Butanol)

15. What are branched chain compounds?

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

16. What are closed chain compounds?

Ans: 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

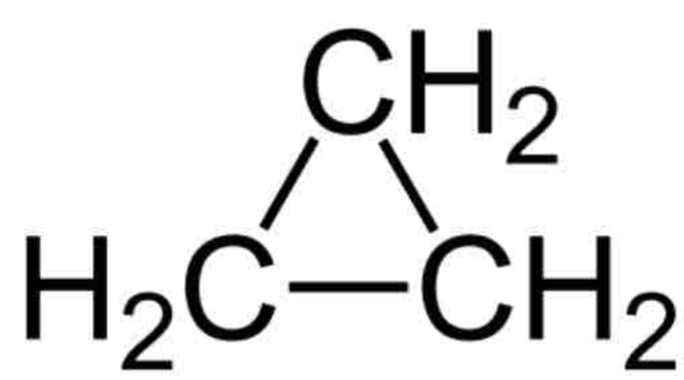
(b) Heterocyclic compounds

17. What are homocyclic or carbocyclic compounds?

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

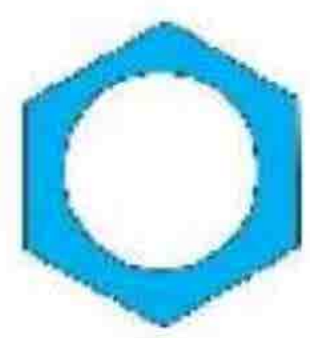
Homocyclic compounds are further classified as:

1. Alicyclic compounds



Cyclopropane

2. Aromatic compounds



Benzene

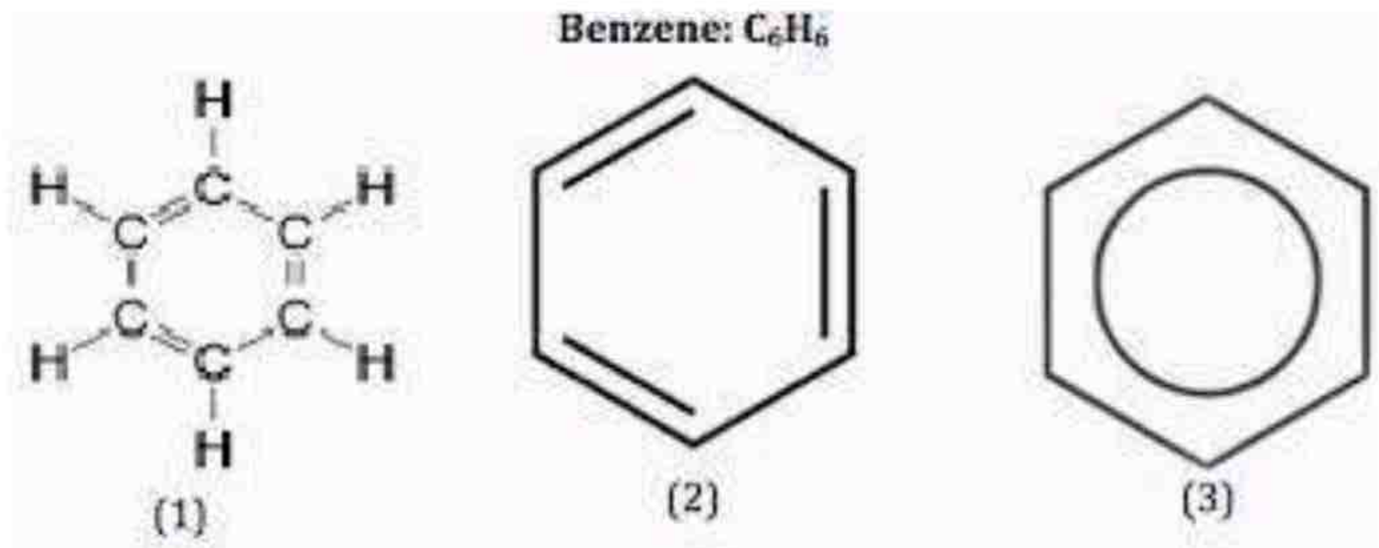
18. What are alicyclic compounds?

Ans: 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.

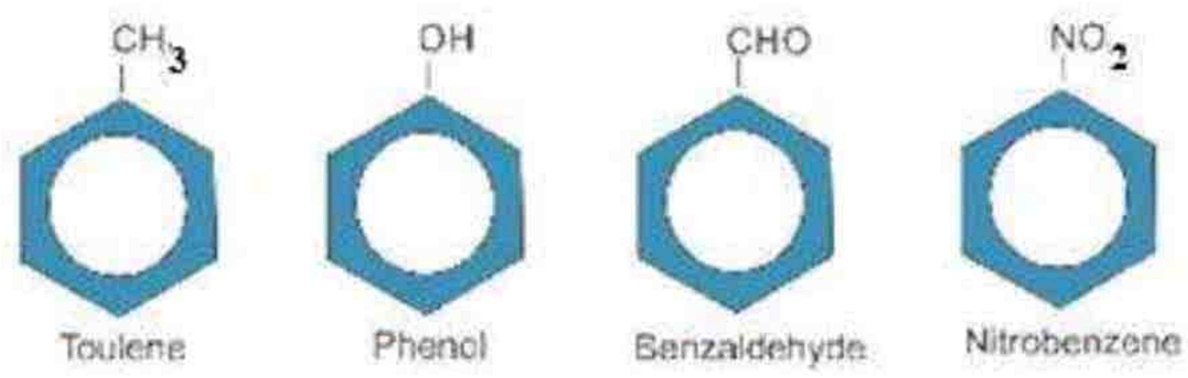
Cyclopropane Cyclobutane Cyclopentane Cyclohexene Cyclohexane

19. What are aromatic compounds?

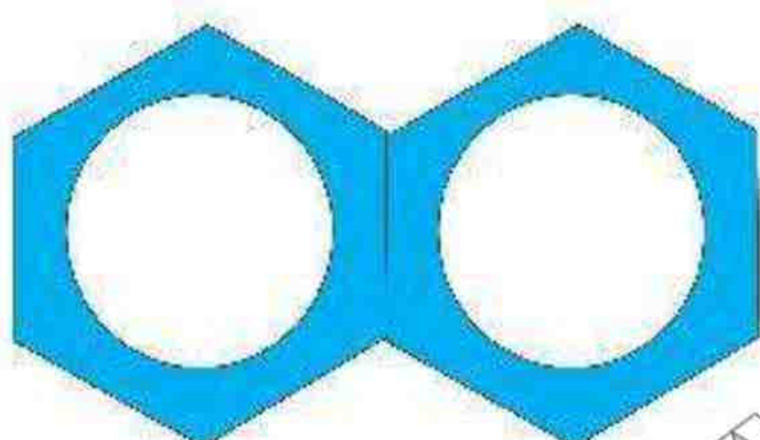
Ans: These carbocyclic compounds contain at least one benzene ring, six carbon atoms with three alternate double and single bonds. These bonds are usually shown in the form of a circle. Typical examples of aromatic compounds are given below. For example

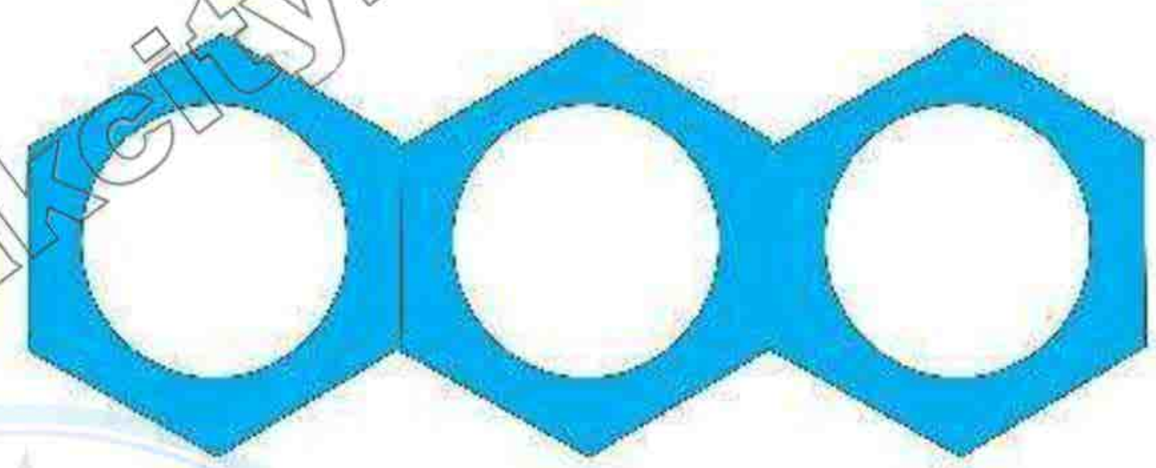


The aromatic compounds may have a side-chain or a functional group attached to the ring. For example:



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

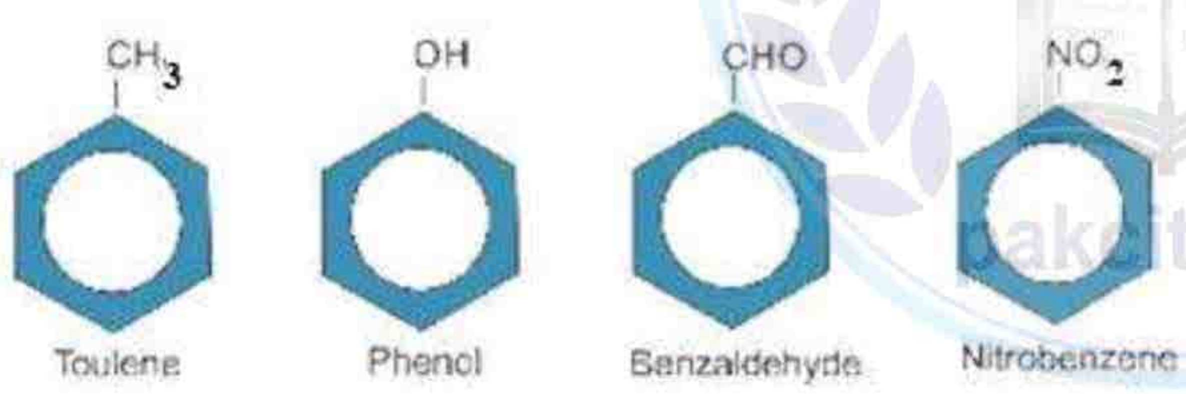


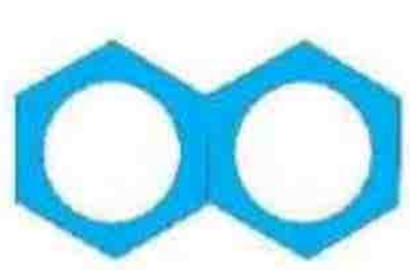


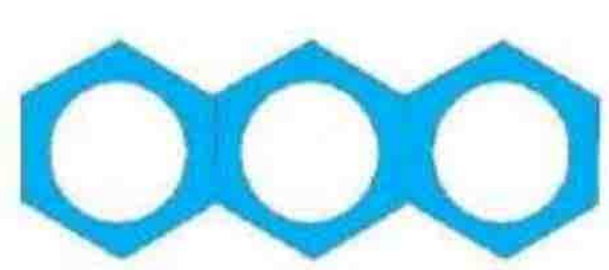
Naphthalene Anthracene

20. Give structures of toluene, phenol, benzaldehyde, nitrobenzene, naphthalene, anthracene.

Ans:



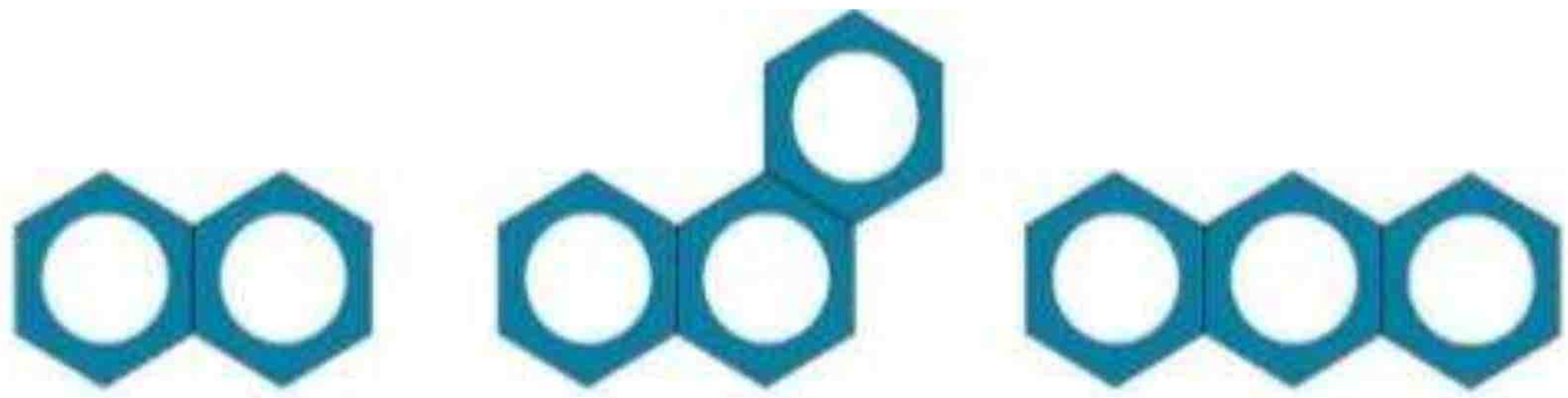




Naphthalene Anthracene

21. What are fused ring aromatic compounds?

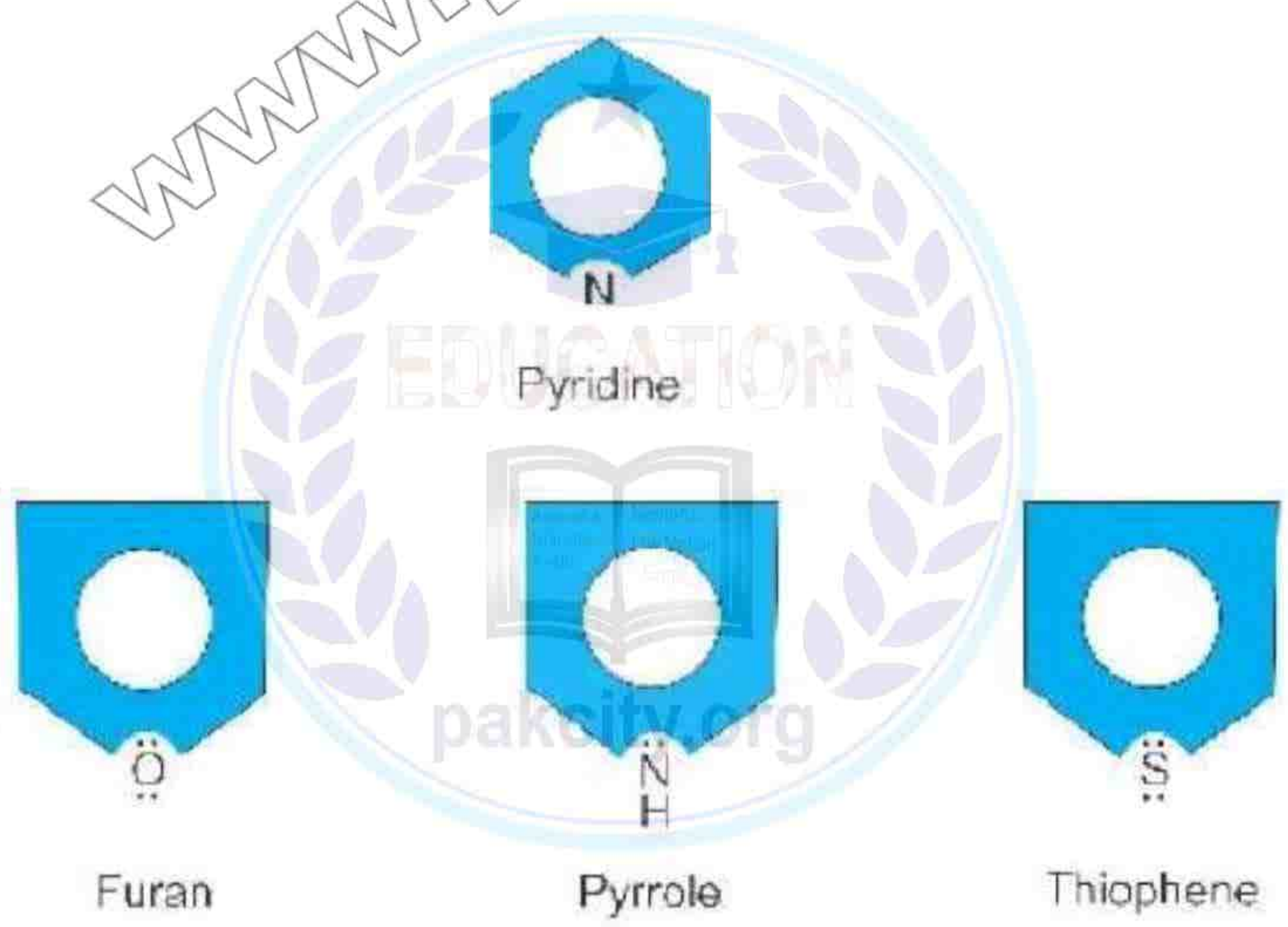
Ans: Those in which the benzene rings are fused together at ortho positions so that the adjacentrings have a common carbon to carbon bonds, e.g. naphthalene, phenanthrene and anthracene.



Naphthalene Phenanthrene Anthracene

22. What are heterocyclic compounds?

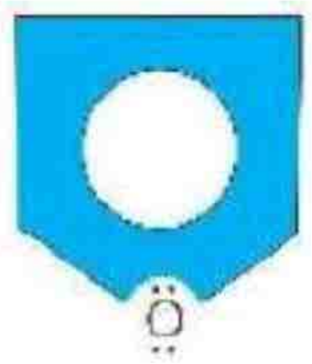
Ans: The compounds in which the ring consists of atoms of more than one kind are called heterocyclic compounds or heterocycles. In heterocyclic compounds generally one or more atoms of elements such as nitrogen (N), oxygen (O) or sulphur (S) are present. The atom other than carbon viz, N, O, or S, present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



23. Give structures of pyridine, furan, pyrrole, thiophene.

Ans:

Pyridine



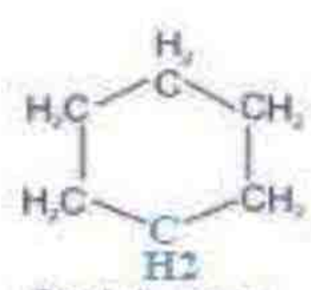
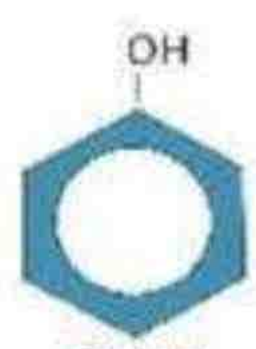
Furan

Pyrrole

Thiophene

24. Differentiate between homocyclic and heterocyclic compounds.

Ans: Following are the differences between homocyclic and heterocyclic compounds:

	Homocyclic Compounds	Heterocyclic Compounds
1.	The compounds in which the ring consists of only one type of atoms	The compounds in which the ring consists of atoms of more than one kind
2.	Organic homocyclic compounds have ring made of carbon atoms only.	Generally one or more atoms of elements such as nitrogen (N), oxygen (O) or sulphur (S) are present in the ring.
3.	 Cyclohexane  Phenol	 Pyridine

25. Define homologous series.

Ans: A series of chemically similar organic compounds having same general formula is called a homologous.

Homologous Series	General Formula
Alkanes	C_nH_{2n+2}
Alkenes	C_nH_{2n}
Alkynes	C_nH_{2n-2}

26. Define functional group. Give examples.

Ans: 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.

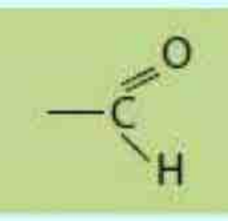
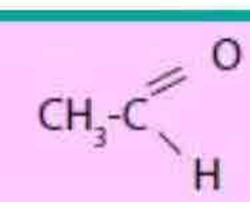
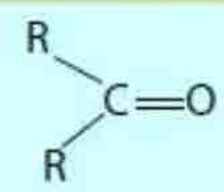
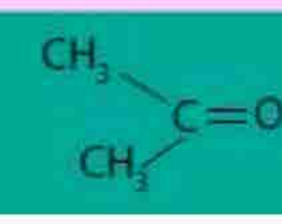
Example

COOH carboxyl group carboxylic acid CH_3COOH Acetic acid

-SH mercapto thioalcohol or thiol CH_3CH_2SH Ethyl thiol

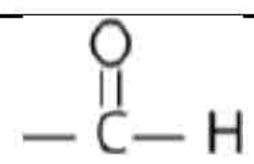
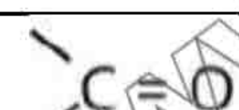
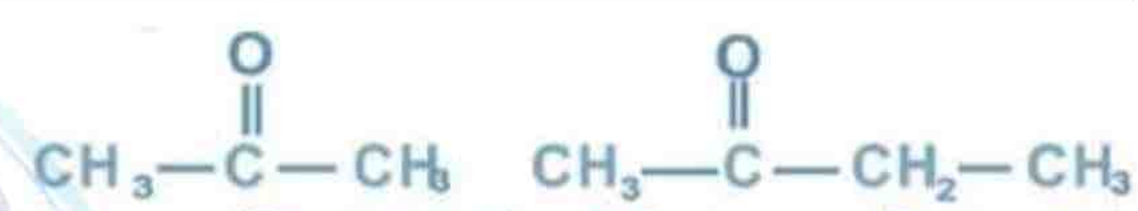
27. Give names of any two functional groups containing oxygen.

Ans:

	Formyl group	Aldehyde or alkanal	
	Carbonyl	Ketone or alkanohe	

28. Write the functional group of aldehyde and ketone. Give one example.

Ans:

	Functional Group	Example
Aldehyde	 Formyl	 Formaldehyde Acetaldehyde
Ketone	 Carbonyl	 2-Propanone (Propanone) 2-Butanone (Butanone)

29. Define hybridization.

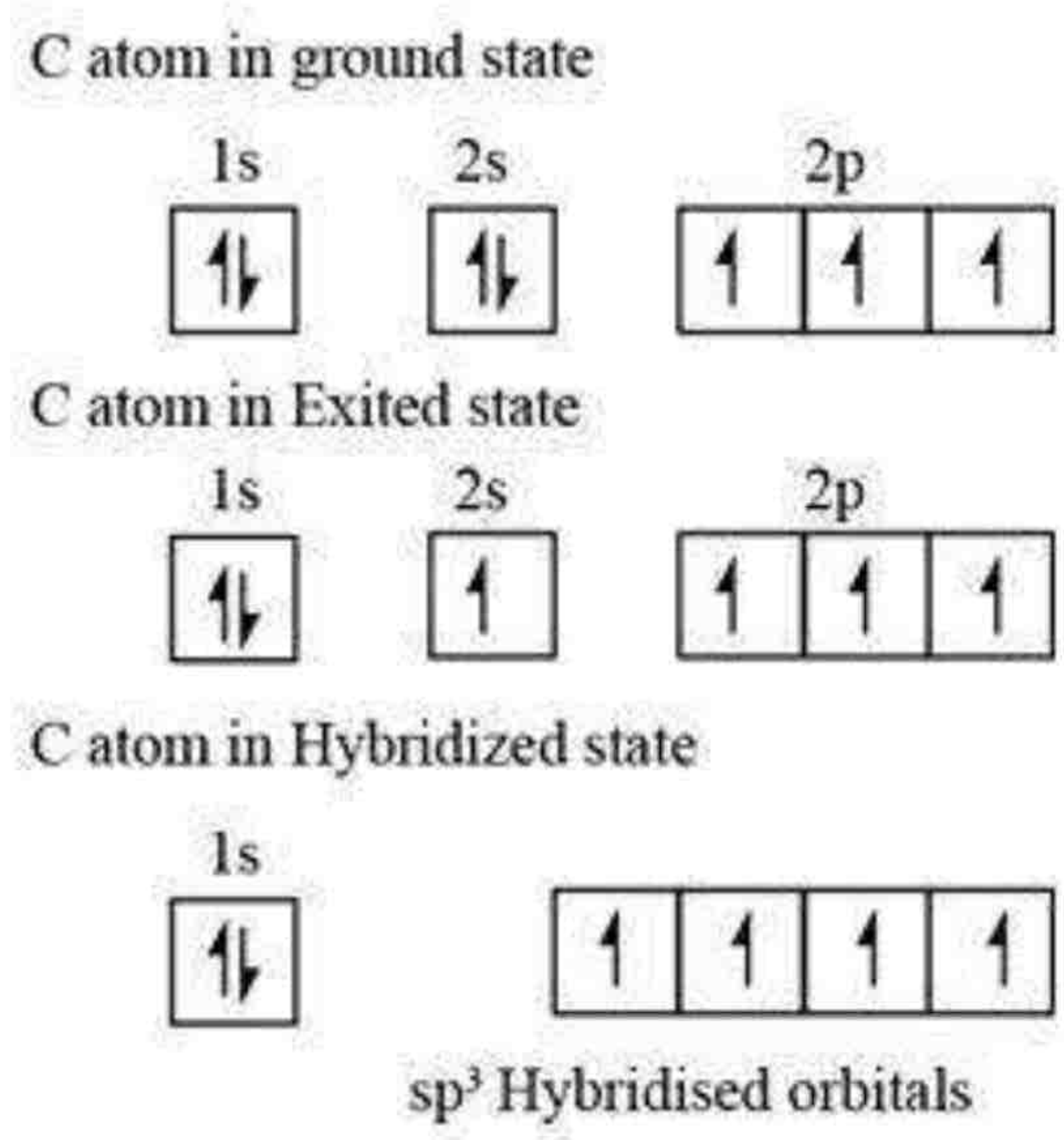
Ans: When atomic orbitals of different energy and shape intermix to form a new set of orbitals of same shape and energy then it is called hybridization.

30. Define sp^3 hybridization.

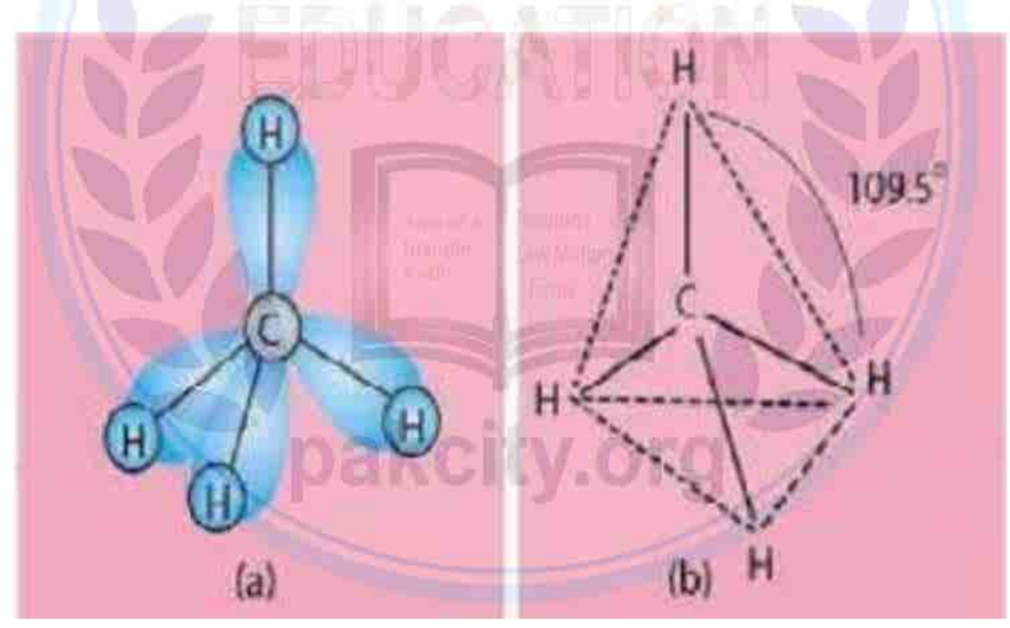
Ans: In sp^3 hybridization, one s and three p atomic orbitals intermix to form four equivalent orbitals called sp^3 hybrid atomic orbitals. Examples CH_4, NH_3 and H_2O.

31. Discuss structure of methane according to sp^3.

Ans: Electronic configuration of ${}_6C$, its electronic excitation and hybridization is given as follows:



The hybrid orbitals are oriented in space in such a manner that the angle between them is 109.5°. Methane molecule is formed by the overlap of sp^3 hybrid orbitals of carbon with 1s orbitals of four hydrogen atoms separately to form four sigma bonds. The molecule possesses a tetrahedral geometry. The four C-H bonds which result from sp^3 -s overlaps are directed towards the corners of a regular tetrahedron. There are six bond angles each 109.5°. The structure of CH_4 has four faces, four corners and six edges.

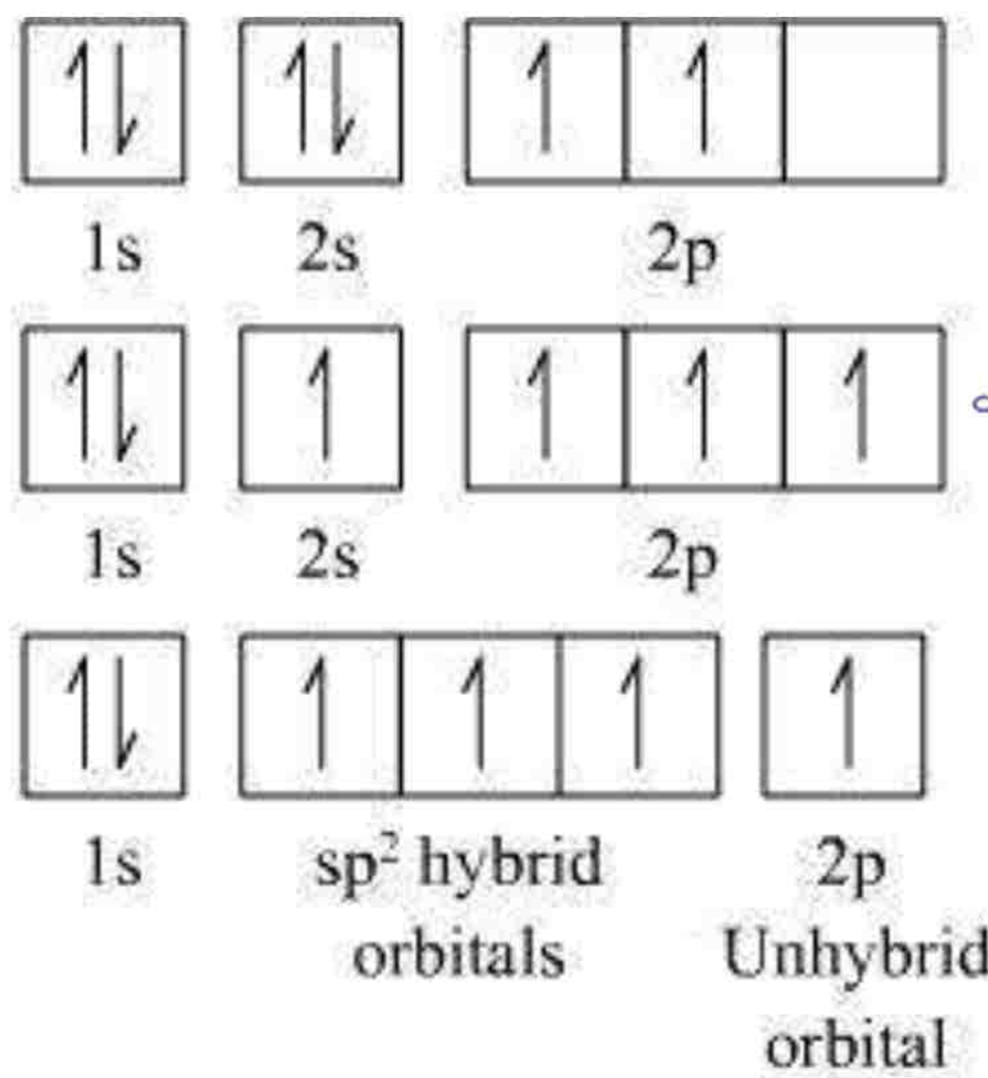


32. Define sp^2 hybridization.

Ans: In sp^2 hybridization, one ‘s’ and two ‘p’ atomic orbitals of an atom intermix three orbitals called sp^2 hybrid orbitals. Example BF_3 and Ethene.

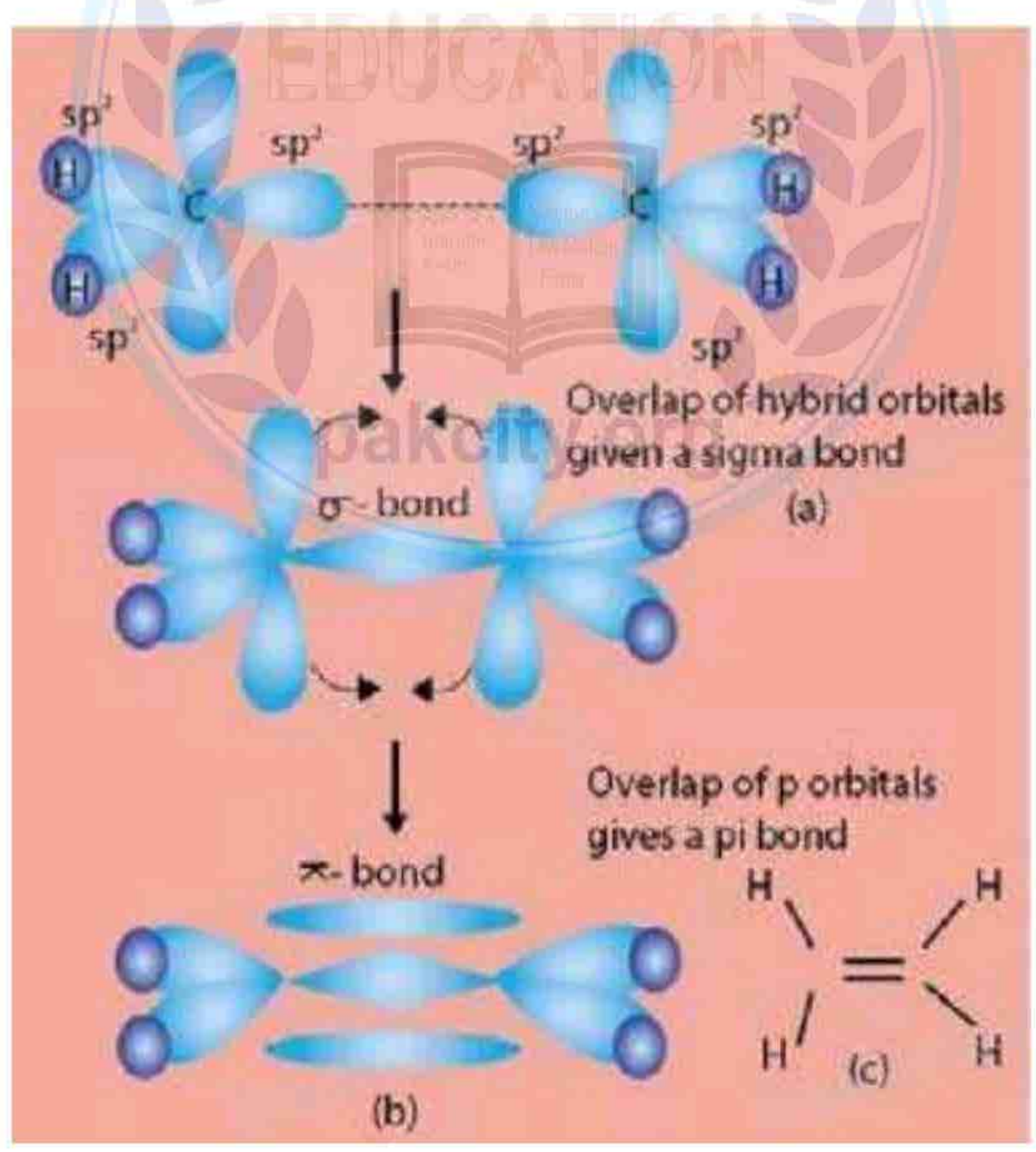
33. Explain structure of ethene (ethylene) according to hybridization.

Ans: Electronic configuration of $_6C$ is:



In the formation of ethene molecule, each carbon atom undergoes sp^2 hybridization to form three hybrid orbitals which are co-planar and are oriented at an angle of 120°. Each atom is left with one half-filled p-orbital perpendicular to the planar sp^2 hybrid orbitals.

Each carbon atom undergoes sp^2-s overlaps with two hydrogen atoms and sp^2-sp^2 overlap to form sigma bonds. The partially filled p-orbitals undergo sideways overlap to form a π−bond.



34. Define pi bond.

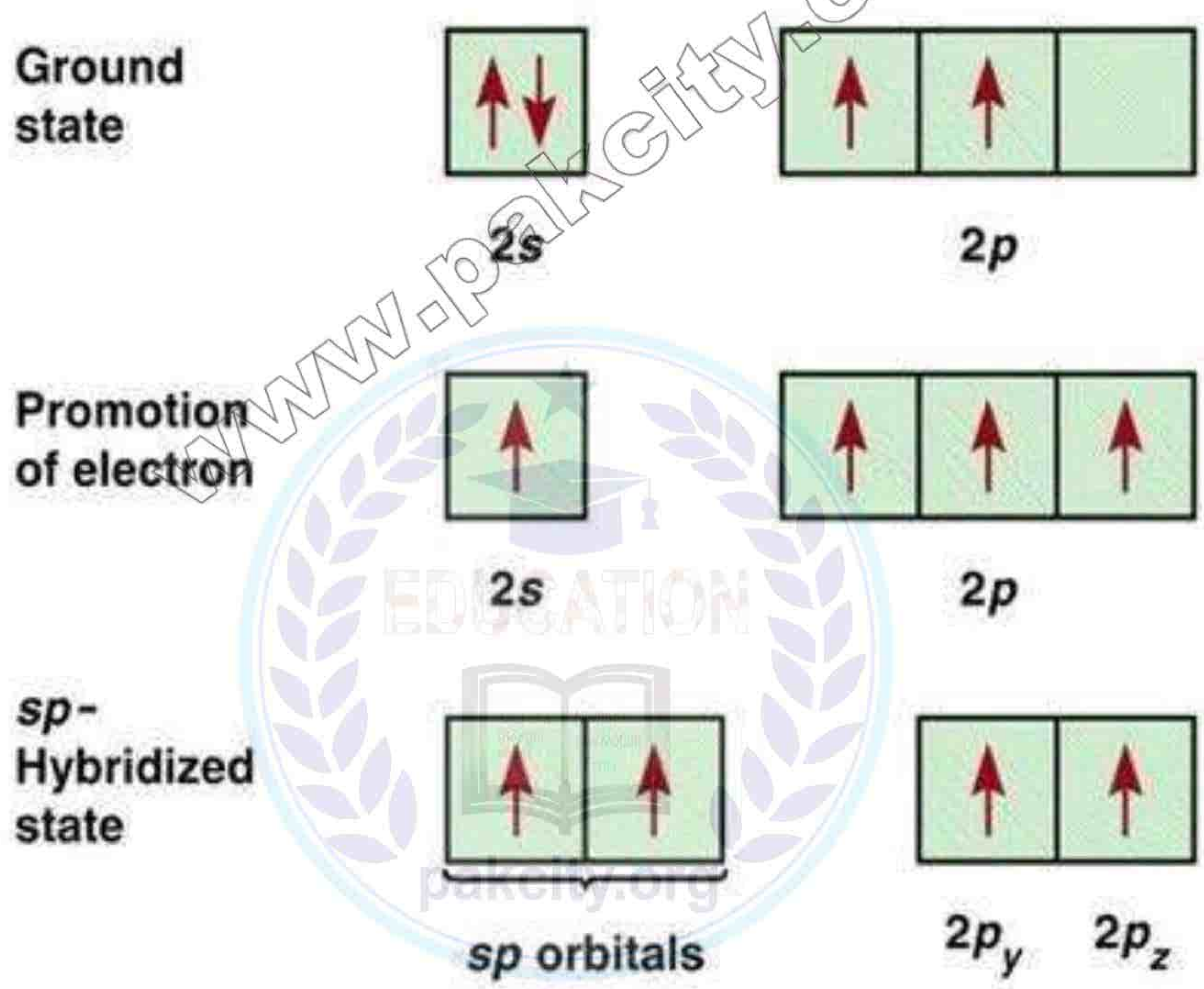
Ans: A pi-bond is formed by the sideways overlap of two half-filled co-planar p-orbitals in such a way that the probability of finding the electron is maximum perpendicular to the line joining the two nuclei.

35. Define sp hybridization.

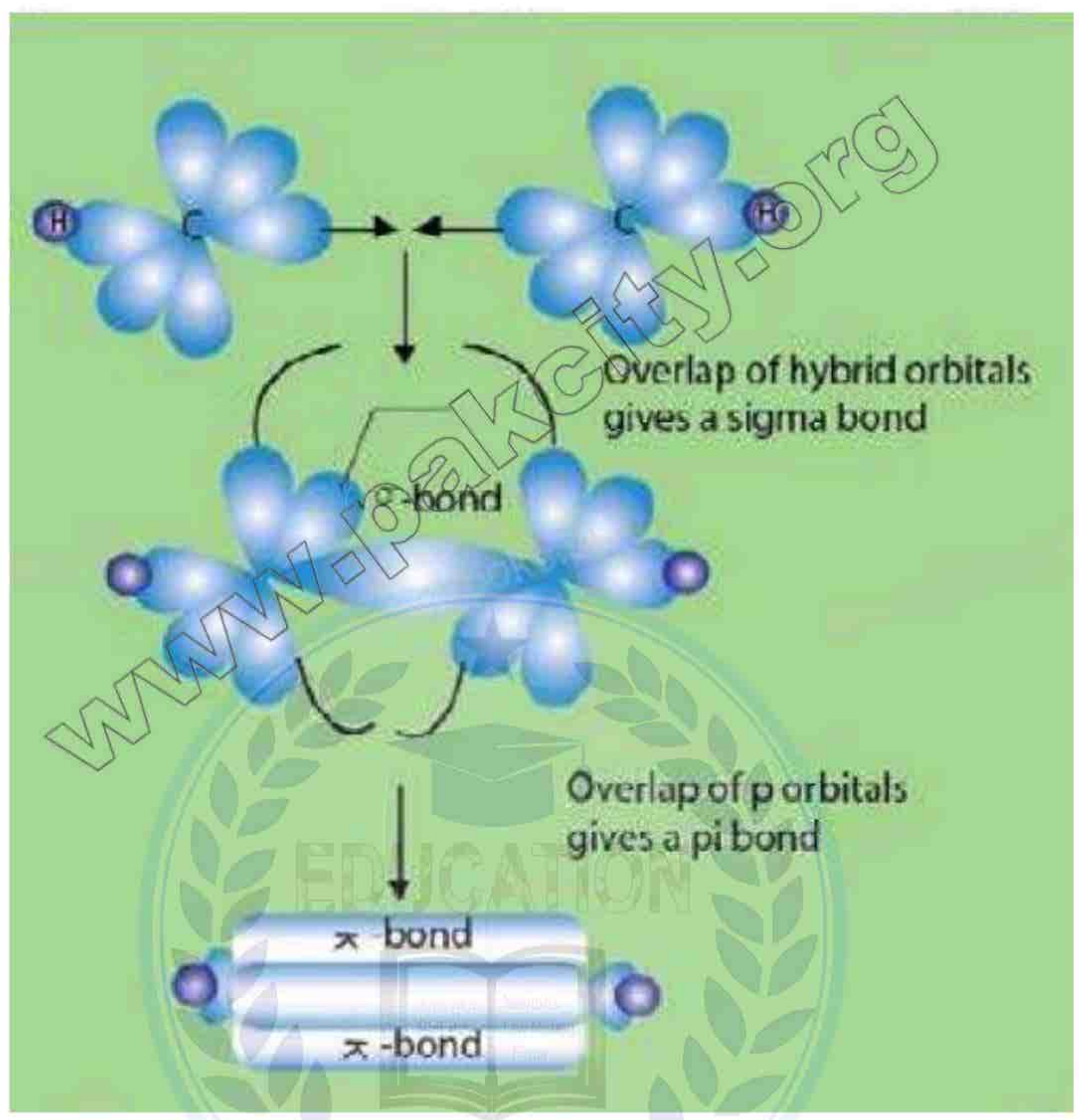
Ans: In sp hybridization, one 's' and one 'p' orbitals intermix to form two sp-hybrid orbital called sp hybrid orbitals. Examples $BeCl_2$ and ethyne.

36. Explain structure of ethyne according to hybridization.

Ans: Electronic configuration of $_6C$ is



Each carbon atom undergoes sp-s overlap with one hydrogen atom and sp-spoverlap with other carbon atom. Each carbon atom is left with two unhybridized p orbitals perpendicular to the plane of sp hybrid orbitals. The sideways overlap between the p-orbitals results in the formation of two pi-bonds. Ethyne molecule contains one sigma and two pi-bonds between the two carbon atoms and each carbon atom is bonded with, one H atom through s bond. Four electronic clouds of two pi-bonds intermix and they surround the sigma bond in the shape ofa drum.



37. Explain the types of bonds and the shapes of the following molecules using hybridization approach.

Ans: **CH_3-CH_3**

All sigma bonds, sp^3 hybridized, tetrahedral shape

CH_2= CH_2

Seven sigma bonds, one pi-bond, sp^2 hybridized, triangular shape

CH≡CH

Three sigma bonds, two pi-bonds, sp hybridized, linear shape

HCHO

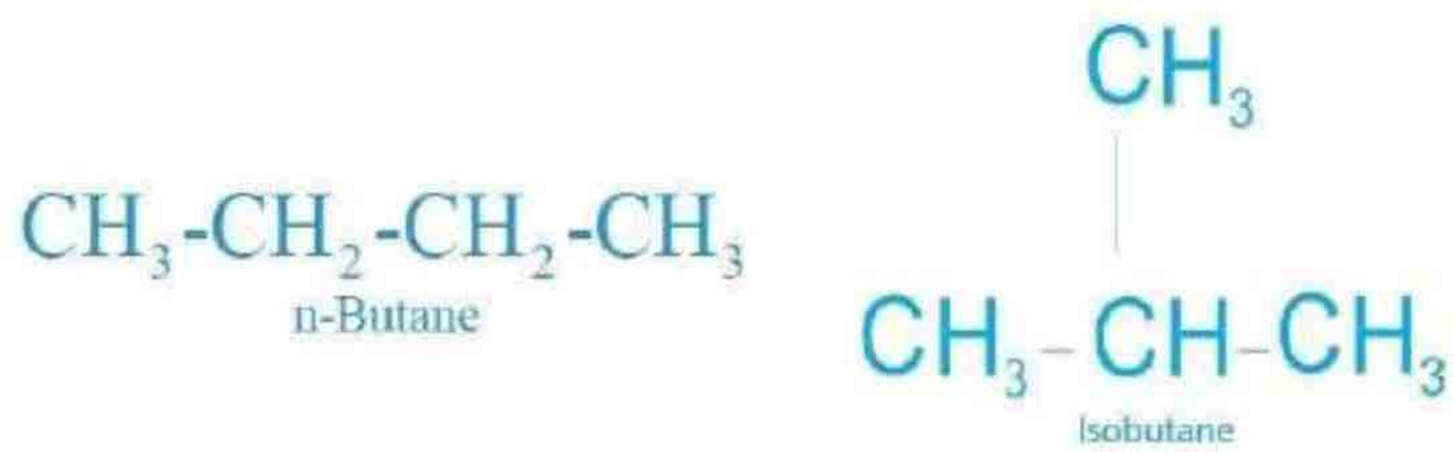
Three sigma bonds, one pi-bond, sp^2 hybridized, triangular shape

CH_3-Cl

All sigma bonds, sp^3 hybridized, tetrahedral shape

38. Define isomerism.

Ans: 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.

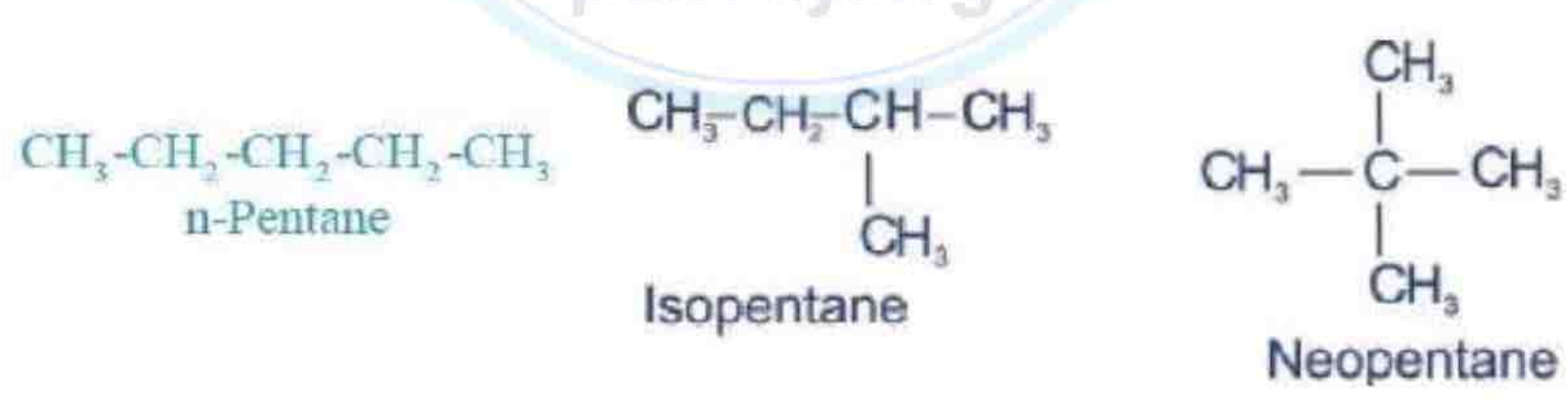


39. Define structural isomerism.

Ans: 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.

40. Define chain isomerism.

Ans: 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.



41. Define position isomerism.

Ans: 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.

$CH_3\text{-}CH_2\text{-}CH_2\text{-}Cl$
1-Chloropropane

$CH_3\text{-}\underset{\displaystyle Cl}{\underset{|}{CH}}\text{-}CH_3$
2-Chloropropane

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

$CH_3\text{-}CH_2\text{-}CH\text{=}CH_2$
1-Butene

$CH_3\text{-}CH\text{=}CH\text{-}CH_3$
2-Butene

42. Define functional group isomerism.

Ans: 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 C_2H_6O, but different arrangement of atoms.

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

$CH_3\text{-}CH_2\text{-}OH$
Ethyl alcohol

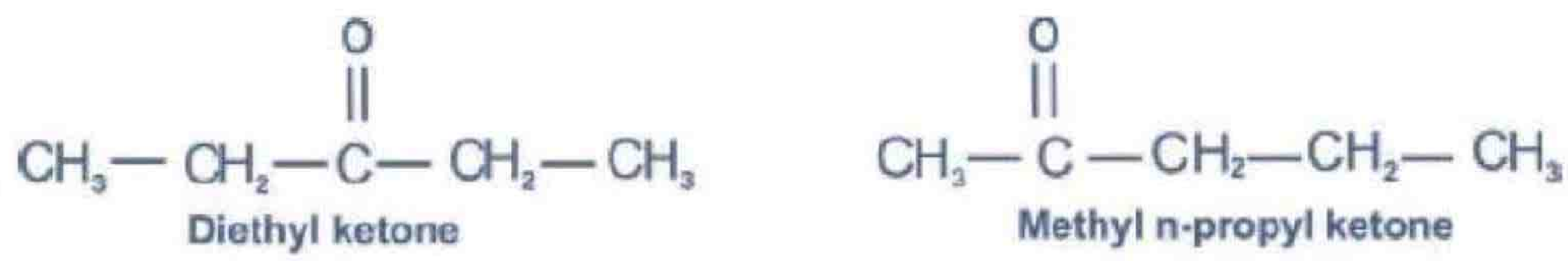
43. Define metamerism.

Ans: 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.

$CH_3 - CH_2 - O - CH_2 - CH_3$
Diethyl ether

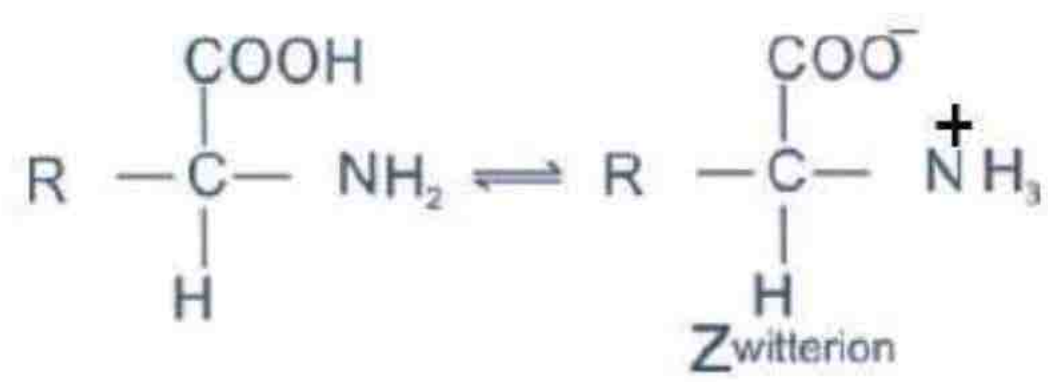
$CH_3 - O - CH_2 - CH_2 - CH_3$
Methyl n-propyl ether

For a ketonic compound having the molecular formula $C_5H_{10}O$, the following two metamers are possible.



44. Define tautomerism. Give an example.

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

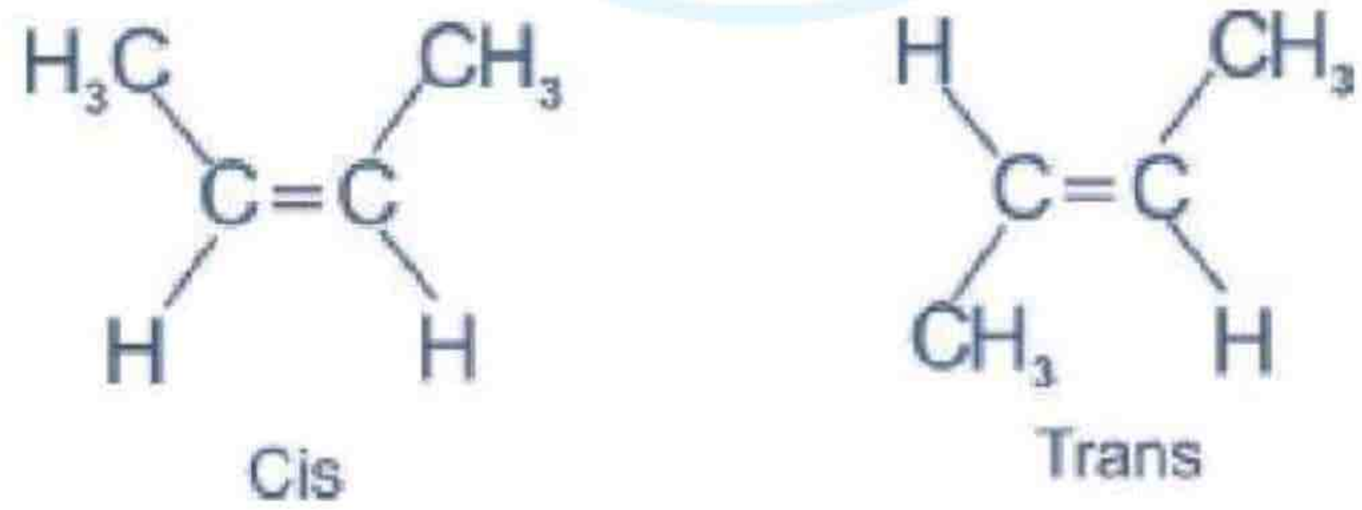


45. Write structural formulas of the two possible isomers of C_4H_{10}.

Ans:

46. What is cis-trans isomerism/geometric isomerism?

Ans: 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.



47. Why free rotation is not possible in case of a double bond?

Ans: A single bond is a sigma bond formed by the head to head overlap of half-filled orbitals. The electrons of this bond are on the line joining the nuclei and allow rotation of atoms on nuclear axis in alkanes. A double bond consists of a sigma and a pi bond. A pi bond is formed by the parallel overlap of the half-filled orbitals and its electron could lies above and below the nuclear axis. This parallel overlap of the orbitals in a pi bond restricts rotation of the double bonded carbon atoms in alkenes.

48. What are the important conditions of cis-trans isomerism?

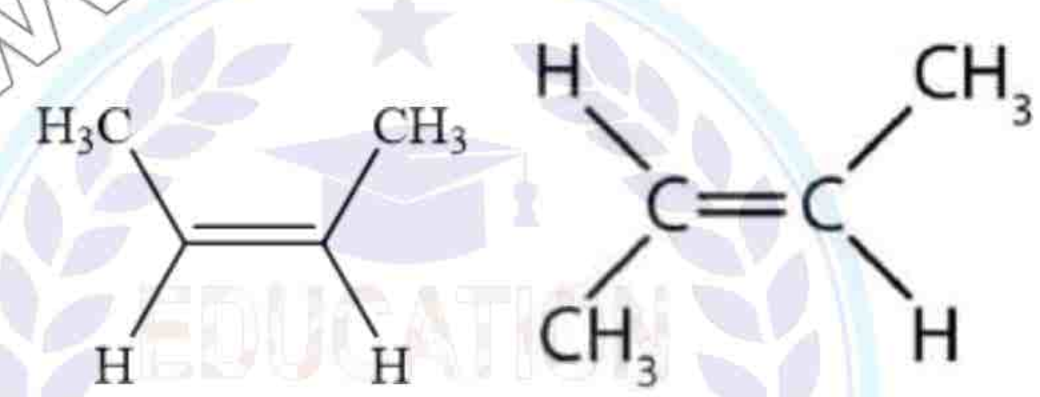
Ans: The conditions for cis-trans isomerism are:

1. Restricted rotation of carbon atoms due to a double bond.
2. Two different groups attached to each carbon atom making the double bond.

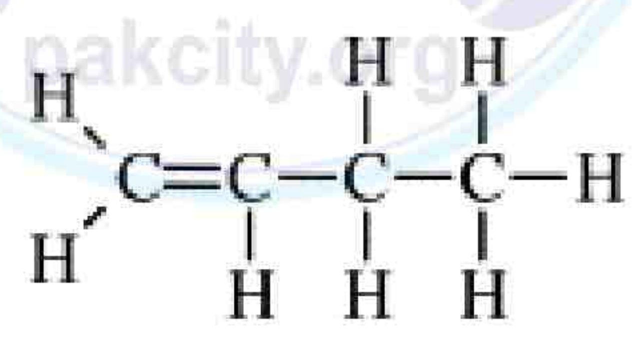
49. 2-Butene shows geometric isomerism but 1-Butene does not. Why?

Ans: The conditions for cis-trans isomerism are:

3. Restricted rotation of carbon atoms due to a double bond.
4. Two different groups attached to each carbon atom making the double bond.



Cis-2-Butene *trans*-2-Butene



1-Butene

2-Butene meets both these conditions therefore shows geometric or cis-trans isomerism. 1-Butene has two hydrogen atoms on first carbon atom therefore it does not fulfill the second condition necessary for geometric isomerism, hence, has no cis or trans isomers are seen in its case.

50. What is carbonization or destructive distillation of coal?

Ans: Carbonization or destructive distillation is 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.

51. What is importance of gasoline and gas oil?

Ans: Gasoline fraction of petroleum has hydrocarbons from C_4H_{10} to $C_{13}H_{28}$ with a boiling point range of 40 to 220 ºC. Gasoline is used as a motor fuel. Gas oil fraction ranges from $C_{12}H_{26}$ to $C_{18}H_{38}$ with boiling points above 275 ºC. This fraction is used as diesel and heating fuel.

52. What are the uses of Asphalt and Kerosene?

Ans: Asphalt of the petroleum coke is the solid fraction of crude oil and is obtained as residue after fractional distillation. It is used for paving, roofing and a fuel reducing agent. Kerosene fraction ranges from C_8H_{18} to $C_{14}H_{30}$. Its boiling point ranges from 175 – 325 ºC and it is used as a heating agent.

For uses of various fractions see the table below

Fraction	Boiling Point Rang (ºC)	Composition	Uses
Natural gas	< 20	CH_4 - C_4H_{10}	Fuel, petrochemicals
Petroleum Ether	20 - 60	C_5H_{12}, C_6H_{14}	Solvent
Ligroin, or naphtha	60 - 100	C_6H_{14}, C_7H_{16}	Solvent, raw material
Gasoline	40- 220	C_4H_{10} - $C_{13}H_{28}$ mostly C_6H_{14} - C_8H_{18}	Motor fuel
Kerosene	175 - 325	C_8H_8 - $C_{14}H_{30}$	Heating fuel
Gas oil	> 275	$C_{12}H_{26}$ - $C_{18}H_{38}$	Diesel and heating fuel
Lubricating oils and greases	Viscous liquids	> $C_{18}H_{38}$	Lubrication
Paraffin	M.p. 50 - 60	$C_{23}H_{48}$ - $C_{29}H_{60}$	Wax products
Asphalt, or petroleum coke	Solids	Residue	Roofing, paving, fuel reducing agent