

CHARACTERISTICS OF ORGANIC COMPOUNDS

Some important characteristics of organic compounds are given below.

PECULIAR NATURE OF CARBON. Carbon forms a large number of compounds. There are millions of organic compounds known today. This is due to some unique properties of carbon. For example:-

CATENATION:- It has ability to form long carbon chains and rings.

SINGLE DOUBLE AND TRIPLE BOND FORMING ABILITY. COMBINATION WITH OTHER ATOMS LIKE O, N, S, X etc

2 NON IONIC NATURE:- Organic compounds are generally covalent compounds. They do not give ionic reactions.

3 SIMILARITY IN BEHAVIOUR. The properties of organic compounds belonging to same homologous series closely resemble with each other. Thus study of millions of organic compounds is reduced to a few homologous series.

4 COMPLEXITY OF ORGANIC COMPOUNDS. Organic compounds have a complex structure containing large numbers of atoms. For example starch has formula $C_{600}H_{1000}O_{500}$ (or $(C_6H_{10}O_5)_n$ $n = 100$ to thousands). Protein molecule has very complex structure. Its MW is few thousand to a million.

5 ISOMERISM:- Compounds having same chemical formula but different structural formulae are called isomers and property is called isomerism.

RATES OF REACTIONS:- Organic compounds are mostly covalent compounds. Due to their molecular nature their rates of reactions are very slow with low yield.

SOLUBILITY:- They are mostly soluble in non polar solvents like benzene, ether, they are mostly insoluble in water.

IMPORTANCE OF ORGANIC CHEMISTRY. P-3

LIVING THINGS:- Almost all chemical reactions taking place in living things are organic in nature. These reactions involve proteins, carbohydrates, fats and oils etc. which are organic compounds.

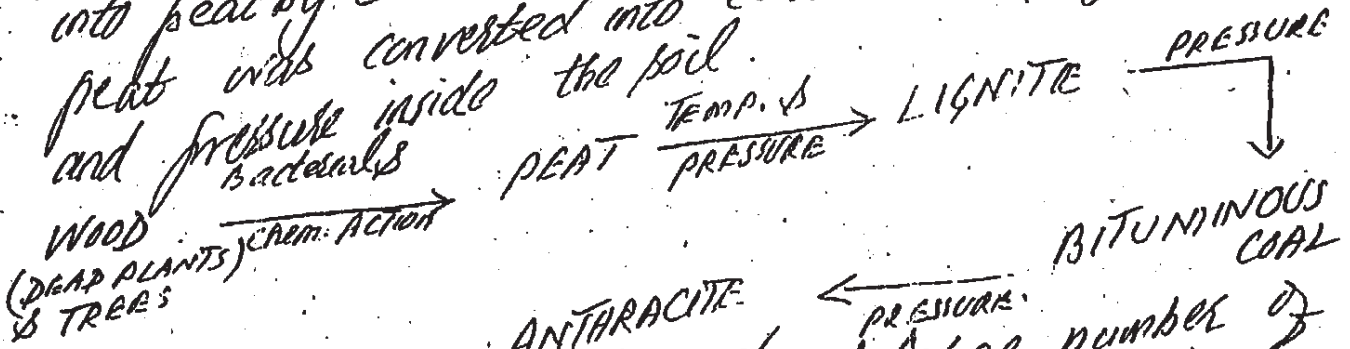
FOOD MEDICINES AND CLOTHING:- Organic compounds are involved in our food, medicines and clothing.

INDUSTRIES:- plastics, rubber, paints, fertilizers, textile products, detergents, cosmetics etc all include synthesis of organic compounds on industrial scale. Thus organic compounds play a very important role in our daily life.

SOURCES OF ORGANIC COMPOUNDS:-

The main source of organic compounds are fossil fuels. They are produced by chemical and biochemical decay of dead animals and plants. Fossil fuels include COAL, NATURAL GAS and PETROLEUM.

COAL:- Coal is formed by bacterial and chemical action on wood of trees which got buried in earth crust some 500 million years ago. Wood was first converted into peat by chemical and bacterial action. Then this peat was converted into coal due to high temp. and pressure inside the soil.



Coal is an important solid fuel. A large number of organic compounds are obtained from coal by a process called CARBONIZATION or DESTRUCTIVE DISTILLATION. When coal is heated to 500-1000°C in absence of oxygen it is converted into COKE, COAL GAS, COA. TAR. COAL TAR contains a large number of organic compounds which are separated by fractional distillation.

NATURAL GAS:- Natural gas is a mixture of hydrocarbons having low boiling points ($C_1 - C_4$). The major portion of natural gas is methane. It is formed by decomposition of organic matter. It is a cheap source of energy therefore used in power generation, cement industry, fertilizer industry and for domestic purposes.

PETROLEUM:- Mineral oil in its refined form is called petroleum. It is formed by biochemical and chemical decay of organic matter found between sedimentary rocks. In its crude form it is blackish coloured liquid called crude oil or rock oil. It is refined to get different petroleum fractions.

At present there are four oil refineries in operation in Pakistan.

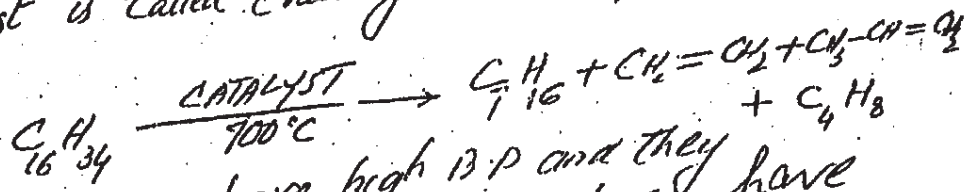
ATTOCK OIL REFINERY has 1.25 million oil refining capacity. Toba oil refineries (RWP) in Karachi has about 2.13 million tonnes oil refining capacity. PAR-ARAB OIL REFINERY is located at Mahmud Kot near Multan.

FRACTIONAL DISTILLATION OF PETROLEUM. Following fractions are obtained by fractional distillation of petroleum.

Boiling Point Range °C	No. of Carbons atoms in the fraction	Name of the fraction and Principal uses
Below 20	$C_1 - C_4$	Natural gas: As fuel for heating and cooking. Raw materials for other chemicals.
20-60	$C_5 - C_6$	Petroleum ether: As a non-polar solvent and cleansing fluid.
60-100	$C_6 - C_7$	Ligroin or light naphtha: As a non-polar solvent and cleansing fluid.
100-200	$C_8 - C_{10}$	Gasoline or Petrol: Fuel for vehicles.
175-325	$C_{12} - C_{16}$	Kerosene: Used for domestic purposes, jet fuel.
250-400	C_{12} and higher	Gas oil or diesel oil: Fuel for diesel engines.
Nonvolatile liquids	C_{20} and up	Lubrication oil: Used for lubrication.
Nonvolatile solids	C_{20} and up	Asphalt: used to surface roads and roofs.

WRITE A NOTE ON CRACKING OF PETROLEUM.

DEFINITION:- The process of breaking a long chain hydrocarbon into short chain hydrocarbon by heating in presence of suitable catalyst is called Cracking. For example consider cracking of $C_{16}H_{34}$



SIGNIFICANCE

The long chain hydrocarbons have high B.P and they are less volatile. The short chain hydrocarbons have low B.P, more volatile and better fuel. The cracking improves quality of fuel.

Thus less desirable petroleum fractions such as kerosene oil, gas oils are converted into better fuels such as gasoline. The C-C and C-H bonds are broken during cracking and both alkanes and short chain alkenes are produced.

"TYPES OF CRACKING":- Cracking is generally carried out in following ways

THERMAL CRACKING:- The cracking which is carried out at high temp. and pressure is called Thermal Cracking. It is particularly useful for production of unsaturated hydrocarbons like alkenes and ~~alkynes~~ propene.

CATALYTIC CRACKING:- The cracking in presence of a catalyst is called catalytic cracking. It requires lowest temperature and lower pressure. (500°C and 2 atm.) SiO_2 (silica) and Alumina (Al_2O_3) is used as catalyst. The catalytic cracking produces gasoline of higher octane number. This method improves quality of fuel.

STEAM CRACKING:- In this method a mixture of steam and vapours of long chain hydrocarbons are heated at 900°C for short duration. Then these are rapidly cooled. This process is suitable for obtaining lower unsaturated hydrocarbons.

IMPORTANCE OF CRACKING:-

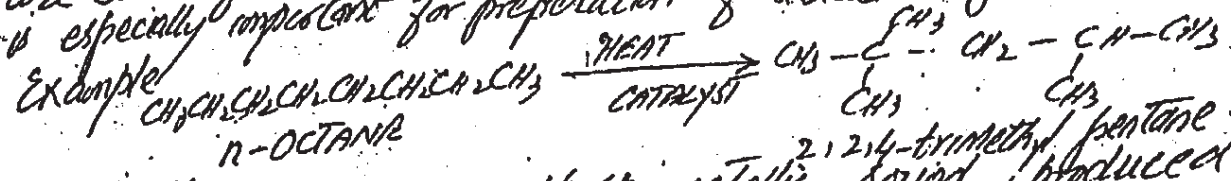
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1. YIELD OF GASOLINE & QUALITY OF FUEL:- Cracking improves yield of gasoline and quality of fuel. The less suitable, long chain hydrocarbons with high B.P. are converted into short chain hydrocarbons, which are better fuel, more volatile and have low B.P. Thus it improves octane number.

INDUSTRIOUSLY USEFUL PRODUCTS | By products such as ethene, Benzene, propene are obtained in cracking. These are used for manufacture of drugs, plastics, synthetic fibres, fertilizers, weed killers. These are also used to obtain Ethanol, Acetone, phenol etc.

DEFINE THE FOLLOWING TERMS. GIVE SUITABLE EXAMPLES

REFORMING The process in which a straight chain hydrocarbon is converted into branched chain alkane by heating in presence of suitable catalyst is called Reforming. It is used to increase quality of motor fuels. The branched alkanes are better fuels than straight chain hydrocarbons. Reforming is especially important for preparation of aviation fuel.

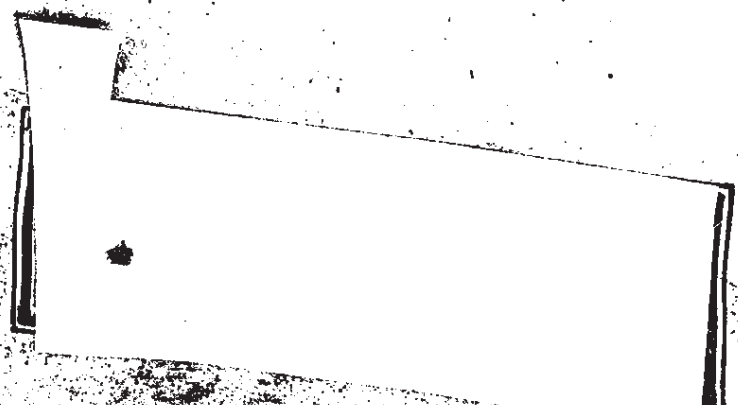


KNOCKING Knocking is a sharp metallic sound produced in internal combustion engine. If straight chain hydrocarbons are used as fuel, their ignition takes place prior to the high compression area. This energy released as a result of combustion is not utilized in moving piston. As a result, knocking is produced. Reforming process converts straight chain into branched chains and decreases knocking.

OCTANE NUMBER The value of fuel is expressed in terms of its octane number. The better the fuel the higher is its octane number. The straight chain hydrocarbons are less volatile and have low octane number. The branched hydrocarbons are more volatile and better fuels and they have high octane number.

HOW TO IMPROVE OCTANE NUMBER There are two methods by which octane number can be increased.

- 1) REFORMING converts straight chain into branched alkane which have high octane no.
- 2) KNOCK INHIBITORS such as tetraethyl lead $Pb(C_2H_5)_4$ also increases octane number of gasoline. At moderate in the explosions in cylinder of engine. However the fuels containing $Pb(C_2H_5)_4$ pollute the air with lead. Therefore the use of tetra ethyl lead is discouraged.



ORBITAL HYBRIDIZATION

WHAT IS ORBITAL HYBRIDIZATION? DISCUSS HYBRIDIZATION IN METHANE, ETHYLENE, & ACETYLENE?

ANSWER:

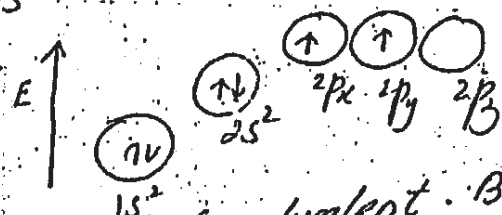
DEFINITION: - The process in which atomic orbitals of different energies and shapes are mixed together to form a new set of equivalent orbitals of same energy and shape is called HYBRIDIZATION. The new orbitals thus formed are called HYBRID ORBITALS.

There are many different types of orbital hybridization. The three types have been discussed over here.

sp³ HYBRIDIZATION - The mixing of one "s" and three p-orbitals to form four equivalent sp³ hybrid orbitals is called sp³ hybridization. Each hybrid orbital has 25% s-character and 75% p-character. The four hybrid orbitals are arranged at an angle of 109.5° from each other. This is called Tetrahedral arrangement. It is non planar.

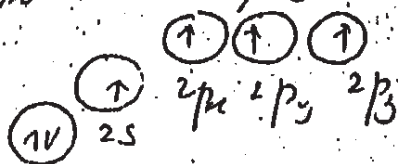
Let us consider formation of METHANE molecule. Carbon has atomic no = 6. Its electronic configuration in ground state is $C = 1s^2 2s^2 2p^2 2p^2 2p^2$.

It can be represented as
It has two unpaired electrons in ground state.

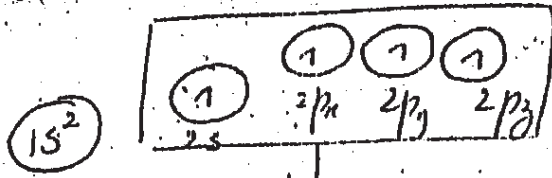


According to V.B.T. It should be divalent. But carbon is tetravalent in most of its compounds. In order explain tetravalency let us consider carbon in excited state. One electron from 2s is promoted to empty 2p_z.

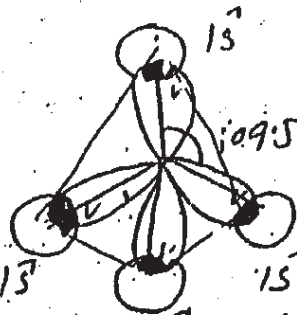
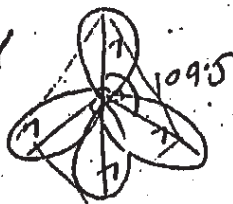
The mixing of 2s¹ and three p-orbitals produces four



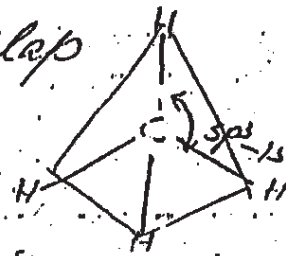
hybrid orbitals called sp³-hybrid which are tetrahedrally arranged is shown below



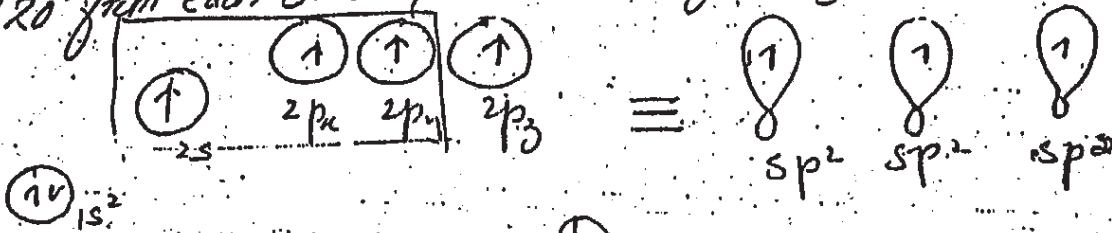
4 sp^3 Hybrid



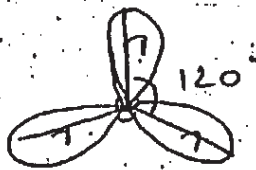
The four hybrid orbitals of carbon atom overlap $1s$ with $1s$ orbitals of four hydrogen atoms thus four sigma bonds are produced each due to sp^3-1s overlap. The bond angle is 109.5° . Thus a nonplanar tetrahedral structure of methane is produced.



sp^2 HYBRIDIZATION The mixing of one "s" and two "p" orbitals to produce three equivalent orbitals is called sp^2 -hybridization. Each hybrid orbital is called sp^2 -hybrid. "s" and "p" orbitals have mixed in 1:2 ratio. The three hybrid orbitals are situated at an angle of 120° from each other. These are trigonal planar.

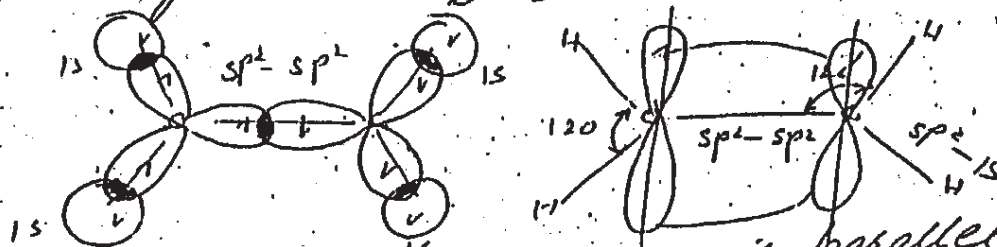


3 sp^2 Hybrid



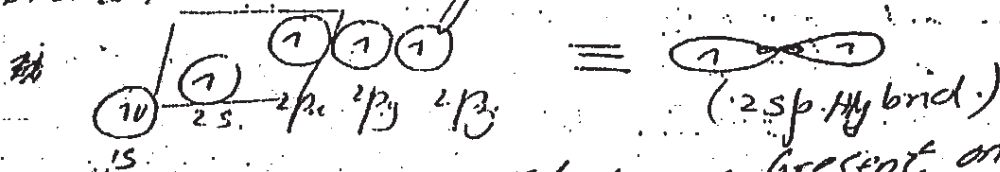
One unhybridized p-orbital remains present on these three hybrid orbitals. It is utilized in π -bond formation. An example of sp^2 -hybridization is ethylene molecule. Each carbon in ethylene is sp^2 hybridized. Thus producing three sp^2 on each carbon. One sp^2 of each carbon overlaps linearly with sp^2 of other carbon.

that C-C σ -bond is formed. The remaining two sp^2 of each carbon overlap with $1s$ orbitals of two hydrogens to form C-H σ bonds as shown below

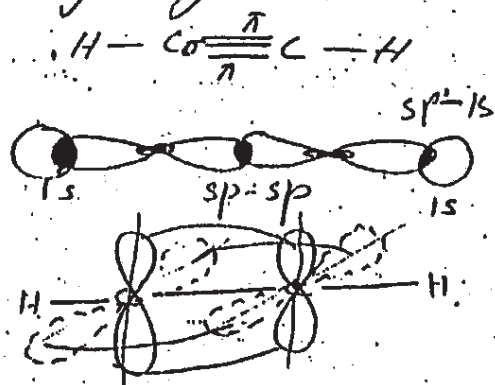


The unhybridized p -orbitals have their axis parallel to each other. They form a π -bond. This in a double bond there is a sigma and a π -bond.

SP-HYBRIDIZATION In this type of hybridization one "s" and one p -orbital mix to form two equivalent "sp" hybrid orbitals. These two hybrid orbitals are located at an angle of 180° from each other. This a linear structure is produced. They are co-axial.



Two unhybridized p -orbitals remain present on each carbon atom. These are utilized in π -bond formation. In ACETYLENE each carbon is sp -hybridized. The C-C σ -bond is formed due to $sp-sp$ linear overlap. C-H σ -bonds are formed due to $sp-1s$ overlap. The unhybridized p -orbitals are perpendicular to each other and also perpendicular to C-C long axis.



The $p_y p_y$ and $p_z p_z$ overlap to form two π -bonds between two carbon atoms. Thus there is a triple bond present between two carbons. In a triple bond there is one sigma and two π -bonds.

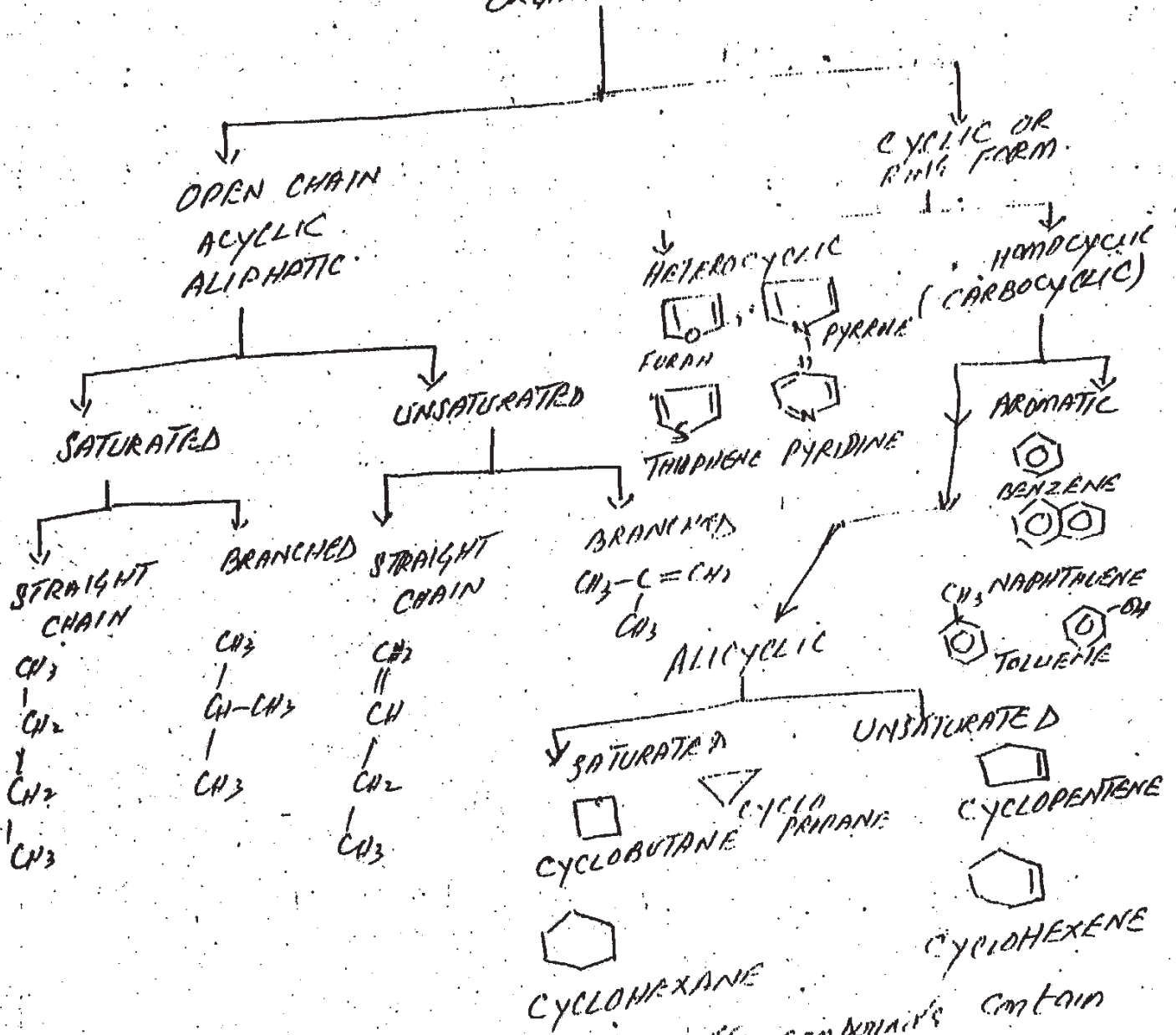
Thus Acetylene has linear structure.

(CONSULT PAGE 1017 OF EXERCISE)

WRITE CLASSIFICATION OF ORGANIC COMPOUNDS II

Organic compounds may be divided into two classes:

- (i) OPEN CHAIN OR ACYCLIC
- (ii) CLOSED CHAIN OR CYCLIC OR RING COMPOUNDS.

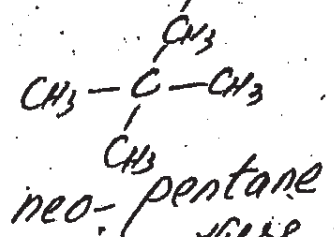
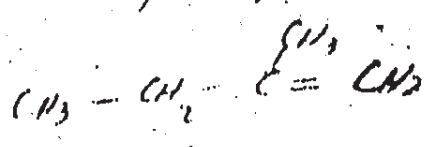
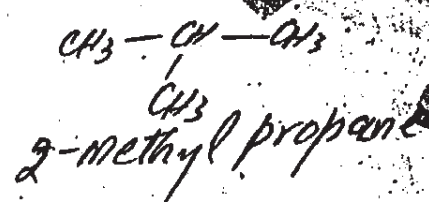
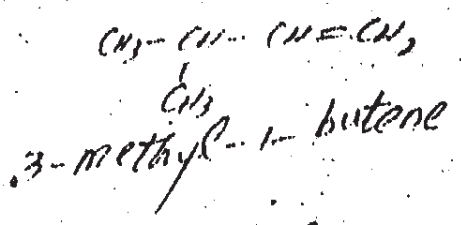


OPEN CHAIN OR ACYCLIC: - These compounds contain an open chain of carbon atoms with chain may be saturated (single bonds), unsaturated (double & triple) and they may be straight chain or branched.

STRAIGHT CHAIN COMPOUNDS: - $CH_3 - CH_2 - CH_2 - CH_3$
(SATURATED) BUTANE.

STRAIGHT CHAIN UNSATURATED COMPOUND $CH_3 - CH_2 - CH = CH_2$
(UNSATURATED) - 1-BUTENE.

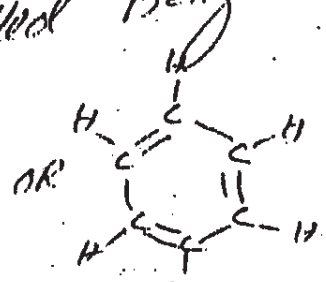
BRANCHED UNSATURATED AND UNSATURATED COMPOUNDS



CLOSED CHAIN OR CYCLIC COMP.

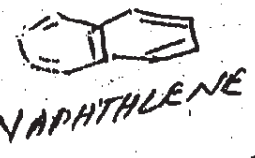
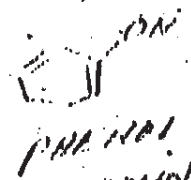
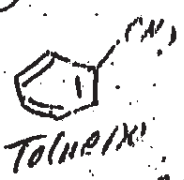
These compounds contain one or more rings, these may be (i) HOMOCYCLIC OR CARBOCYCLIC (ii) HETEROCYCLIC. These are cyclic compounds which contain only carbon atoms in the ring. These may be divided into two classes.

AROMATIC COMPOUNDS These are compounds which contain one or more benzene rings. A six membered ring containing three alternate double bonds is called Benzene ring. It may be represented as



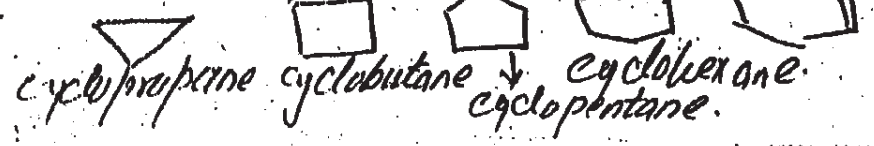
Aromatic compounds may also have a functional group attached to it.

Some more examples are given below



ALICYCLIC COMPOUNDS

These are cyclic compounds containing three or more carbon atoms. They resemble alkane in their structure and have general formula C_nH_{2n} . Some examples are given below



Cyclic compounds may also contain a double bond. For example cyclopentene & cyclohexene



HETEROCYCLIC COMPOUNDS:-

The cyclic compounds which contain atoms of more than one kind are called heterocyclic compounds. Heterocyclic compounds contain N, S, O atoms besides carbon. These are called heteroatoms.

Some examples are given below



PYRIDINE



PYRROLE



THIOPHENE

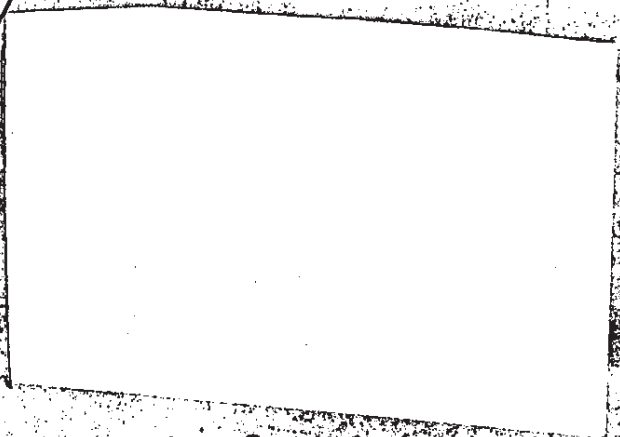


FURAN

v. imp.

FUNCTIONAL GROUP:-

An atom or group of atoms which determines characteristic properties of organic compound is called functional group. The simplest organic compounds are hydrocarbons. The other organic compounds are obtained by replacement of hydrogen of alkane by some other atom or group of atoms. A double bond or triple bond can also act as a functional group. Some important functional groups are given in tabular form over here



See

Table 7.2 Functiond Groups

Functional group		Class of compounds	Example
Formula	Name		
$\begin{array}{c} \diagup \\ \text{C} \\ \diagdown \end{array} - \begin{array}{c} \diagup \\ \text{C} \\ \diagdown \end{array}$	None	Alkane	$\text{CH}_3 - \text{CH}_3$ <i>ETHANE</i>
$\begin{array}{c} \diagup \\ \text{C} = \text{C} \\ \diagdown \end{array}$	Double bond	Alkene	$\text{H}_2\text{C} = \text{CH}_2$ <i>ETHENE</i>
$-\text{C} \equiv \text{C}-$	Triple bond	Alkyne	$\text{HC} \equiv \text{CH}$ <i>ETHYNE</i>
$-\text{X} (\text{X} = \text{F}, \text{Cl}, \text{Br}, \text{I})$	Halo (Fluoro, Chloro, Bromo, Iodo)	Alkyl halide	<i>ETHYL CHLORIDE</i> $\text{CH}_3 - \text{CH}_2 - \text{Cl}$
$-\text{OH}$	Hydroxyl group	Alcohol or alkanol	$\text{CH}_3 - \text{CH}_2 - \text{OH}$
$-\text{NH}_2$	Amino group	Amine	<i>ETHYL AMINE</i> $\text{CH}_3 - \text{CH}_2 - \text{NH}_2$
$\begin{array}{c} \diagup \\ \text{C} = \text{NH} \\ \diagdown \end{array}$	Imino group	Imine	<i>ETHYL IMINE</i> $\text{CH}_3 - \text{CH} = \text{NH}$
$\begin{array}{c} \\ \text{C} - \text{O} - \text{C} \\ \end{array}$	Ether linkage	Ether	$\text{CH}_3 - \text{CH}_2 - \text{O} - \text{CH}_2 - \text{CH}_3$ <i>DIBETHYL ETHER</i>
$\begin{array}{c} \text{O} \\ \\ \text{---C} \\ \\ \text{H} \end{array}$	Formyl group	Aldehyde or alkanal	$\text{CH}_3 - \text{C} \begin{array}{l} \diagup \text{O} \\ \diagdown \text{H} \end{array}$ <i>ACETALDEHYDE</i>
$\begin{array}{c} \text{R} \diagdown \\ \text{C} = \text{O} \\ \text{R} \diagup \end{array}$	Carbonyl	Ketone or alkanone	$\text{CH}_3 - \text{C} = \text{O}$ <i>ACETONE</i>
$\begin{array}{c} \text{O} \\ \\ \text{---C} \\ \\ \text{OH} \end{array}$	Carboxylic group	Carboxylic acid (or alcanoic acid)	$\text{CH}_3 - \text{C} \begin{array}{l} \diagup \text{O} \\ \diagdown \text{OH} \end{array}$ <i>ACETIC ACID</i>
$\begin{array}{c} \text{O} \\ \\ \text{---C} - \text{X} \end{array}$	Acid halide	Acid halide	$\text{CH}_3 - \text{C} \begin{array}{l} \diagup \text{O} \\ \diagdown \text{Cl} \end{array}$
$\begin{array}{c} \text{O} \\ \\ \text{---C} - \text{NH}_2 \end{array}$	Acid amide	Acid amide	$\text{CH}_3 - \text{C} \begin{array}{l} \diagup \text{O} \\ \diagdown \text{NH}_2 \end{array}$

$\begin{array}{c} \text{O} \\ \\ \text{---C} \\ \\ \text{OR} \end{array}$	Carbalkoxy (ester) group	Ester	$\text{CH}_3 - \text{C} \begin{array}{l} \diagup \text{O} \\ \diagdown \text{OCH}_3 \end{array}$
$-\text{SH}$	Mercapto	Thioalcohol or Thiol	$\text{CH}_3 - \text{CH}_2 - \text{SH}$
$-\text{C} \equiv \text{N}$	Cyano	Alkyl cyanide or Alkane nitrile	$\text{CH}_3 - \text{C} \equiv \text{N}$ <i>METHYL CYANIDE</i>
$\begin{array}{c} \text{O} \\ \\ \text{---N} \\ \\ \text{O} \end{array}$	Nitro	Nitro compounds	$\text{C}_6\text{H}_5\text{NO}_2$ <i>NITRO BENZENE</i>

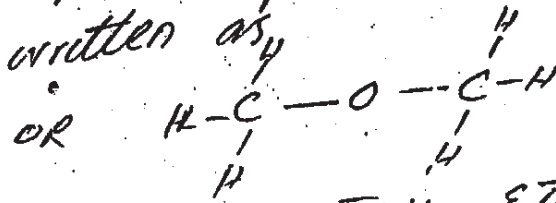
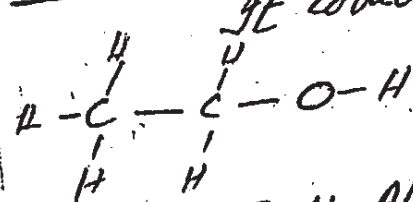
WRITE A NOTE ON ISOMERISM:

DEFINITION:- The compounds having same chemical formula but different structural formulae are called isomers and phenomenon is called isomerism.

CHEMICAL FORMULA:- The formula which indicates number of atoms of different elements present in molecule of compound is called molecular formula or chemical formula.

STRUCTURAL FORMULA:- The formula which indicates arrangement of atoms in molecule is called structural formula.

EXAMPLE OF ISOMERS:- For example consider C_2H_6O it could be written as

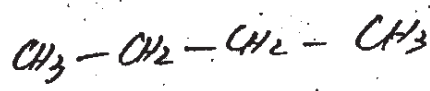


ETHYL ALCOHOL

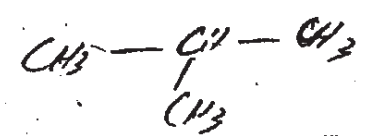
DIMETHYL ETHER

These two have same chemical formula but different structural formulae. They have different physical and chemical properties. These are called isomers.

BUTANE C_4H_{10} could be written as



n-BUTANE



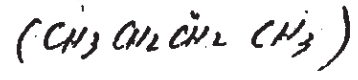
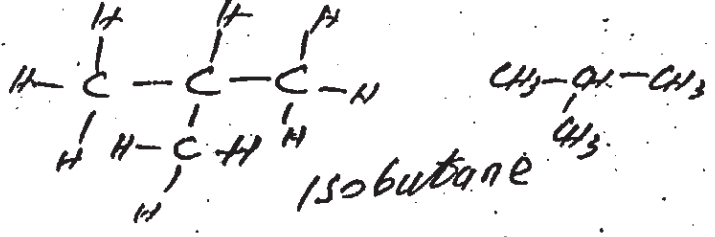
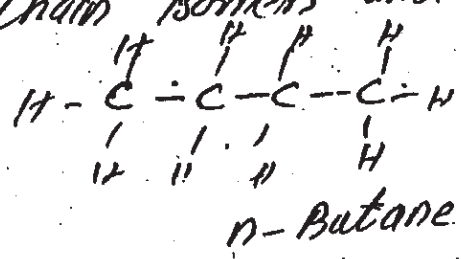
ISOBUTANE

As number of carbon atoms increase in M. Formula the number of isomers also increase. Butane has two isomers, pentane has three, and a compound having 30 carbon atoms can have over four billion isomers.

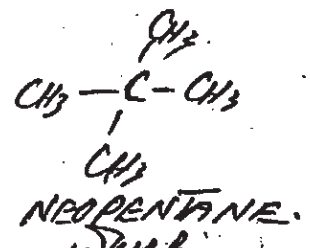
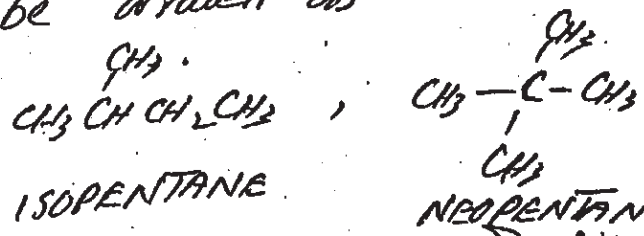
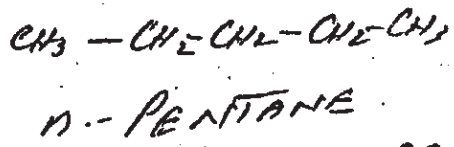
TYPES OF ISOMERS:- The isomers are basically divided into following two types
(i) STRUCTURAL ISOMERS (ii) GEOMETRICAL ISOMERS
CIS/TRANS ISOMERS

STRUCTURAL ISOMERS: These have same chemical formula but different arrangement of atoms within the molecule. It is not only present in hydrocarbons but also present in all classes of compounds and their derivatives. The structural isomers can also be divided into following types

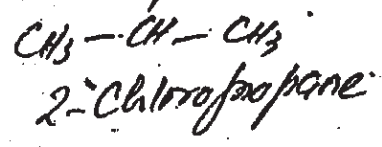
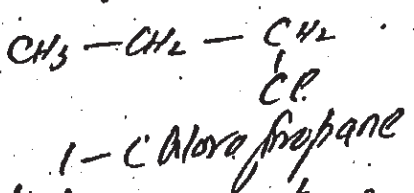
1) **CHAIN ISOMERS:** These isomers have same chemical formula, same functional group, same position of functional group but different longest carbon chains. For example Butane (C₄H₁₀) has two chain isomers and pentane has three chain isomers.



Pentane C₅H₁₂ could be written as



POSITION ISOMERS: These are isomers which have same chemical formula, same longest C-chain, same functional group but different position of functional group. Simplest example is "C₃H₇Cl".

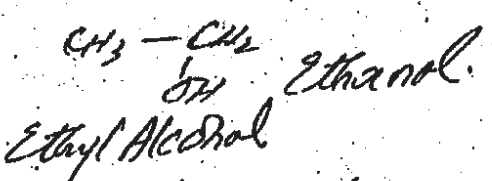
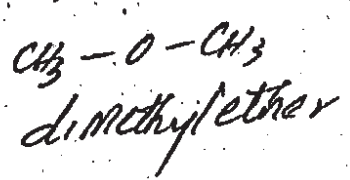


Similarly 1-Butene and 2-Butene are position isomers.



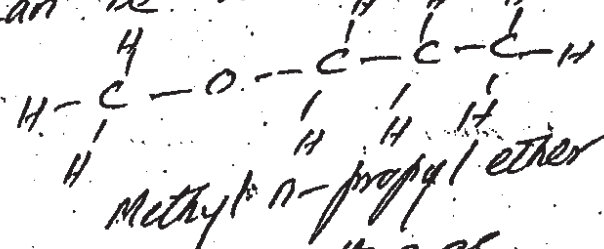
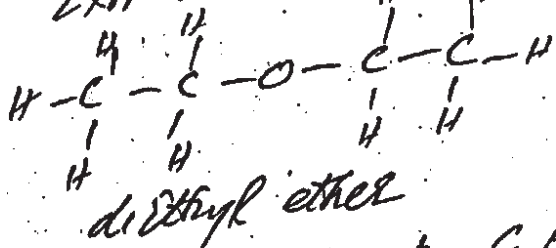
FUNCTIONAL GROUP ISOMERS: These are isomers which have same molecular formula but different functional

groups. For example consider C_2H_6O

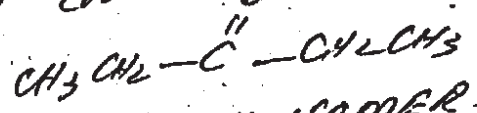
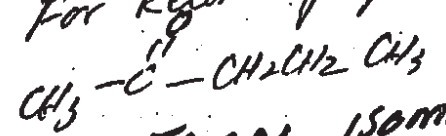


METAMERISM: The compounds having same molecular formula but different alkyl groups attached to the same multivalent atom. These isomers belong to same homologous series.

EXAMPLE 1 - $C_4H_{10}O$ can be written as



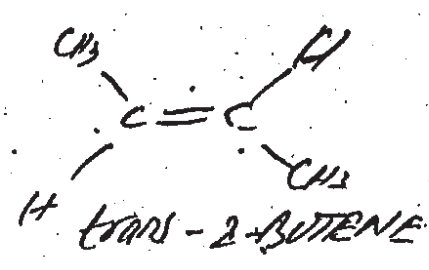
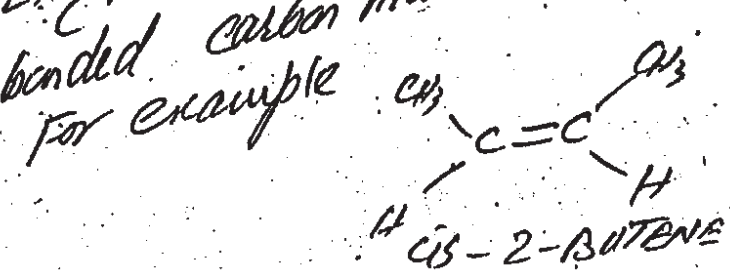
For ketone group $C_5H_{10}O$ could be written as



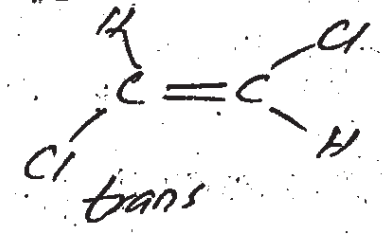
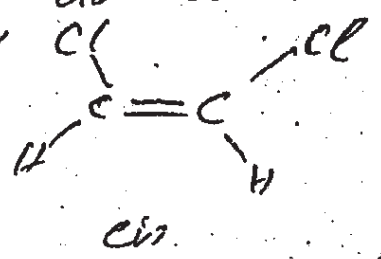
GEOMETRICAL ISOMERS: (CIS-TRANS ISOMERS) (STEREISOMERS)

These are isomers which have same chemical formula same structural formula, but different arrangement of identical side groups, but different arrangement of cis/trans isomers. This phenomenon is called Geometrical isomerism or cis/trans isomerism. CONDITIONS: (1) The geometrical isomerism is possible in double bonded compounds which have restricted rotation between two carbons.

(2) The substituents attached to each double bonded carbon must be different.



Similarly, cis-dichloroethene and trans dichloroethene



REASON FOR GEOMETRICAL ISOMERISM

When there is a single bond present between two atoms there is free rotation around C-C bond axis. However when there is a double bond present between two atoms, there is a sigma bond and a pi bond. The pi bond is formed by parallel overlap of "p" orbitals. This pi bond restricts free rotation and relative position of substituents attached to both double bonded carbons becomes fixed. This gives rise to geometrical isomerism.

The rotation of two carbons joined by a double bond could take place only by breaking pi-bond. This can require a lot of energy. Such is not possible available at room temp. This restricted rotation causes geometrical isomerism in organic compounds.

