

. stereochemistry .

# Stereochemistry of Organic Compounds.

## # Introduction.

The phenomenon in which two or more chemical compounds which having same molecular formula but having different structure is termed as isomerism. Isomerism causes different properties due to different arrangement of atoms within the molecule.

Isomerism is classified into two types,

- 1) Structural isomerism.
- 2) Stereoisomerism.

## # Structural Isomerism :-

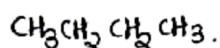
It is the isomerism shown by the compounds which having the same molecular formula but different structural formulae.

further structural isomerism classified into five types.

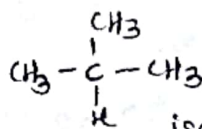
### - a) Chain or Nuclear isomerism :-

This type of structural isomerism shown by compounds which differ in the nature of carbon atom chain.

#### 1) Butane $C_4H_{10}$ .

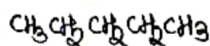


n. Butane.

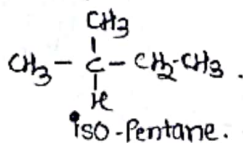


iso. Butane.

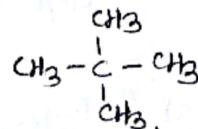
#### 2) Pentane $C_5H_{12}$ .



n. Pentane.



iso. Pentane.

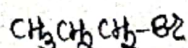


neo. Pentane.

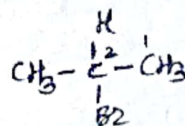
### - b) Position Isomerism :-

This type of isomerism shown by the difference in position of same substituent in the same carbon chain.

e.g. Bromopropane.



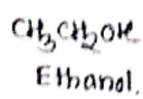
1-Bromo Propane.



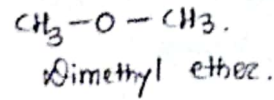
2-Bromo Propane.

### 3) Functional Isomerism :-

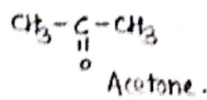
In this type of isomerism, there is differ in their functional groups.  
 e.g. 1) Comp. having mol. formula  $C_2H_6O$  shows two functional isomerism.



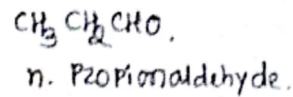
and.



2) mol. for.  $C_3H_6O$



and

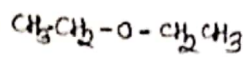


### 4) Metamerism :-

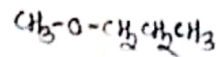
This type of Isomerism is shown by members of the same homologous series. These members differ in the nature of the alkyl groups attached to the Polyvalent atom.

1) e.g ether of mol. for.  $C_4H_{10}O$  shows following three metamer.

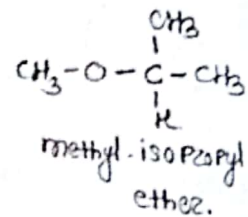
metamer.



Diethyl ether



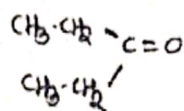
methyl-n. Propyl ether



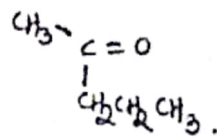
methyl-isopropyl ether.

2) Ketone having mol. for.  $C_5H_{10}O$ . shows following metamerism.

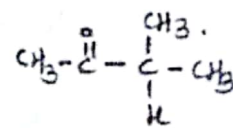
metamerism.



Diethyl ketone.



methyl-n. Propyl ketone.



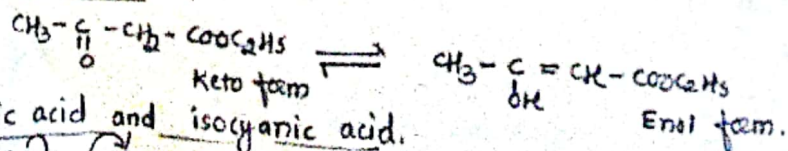
methyl isopropyl ketone.

### 5) Tautomerism :-

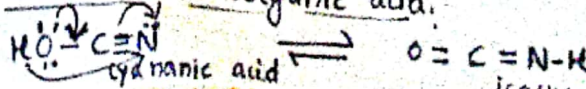
It is a dynamic isomerism wherein one isomer is constantly changes into other & vice-versa.

This is caused by the wandering of a labile hydrogen atom between two Polyvalent atoms.

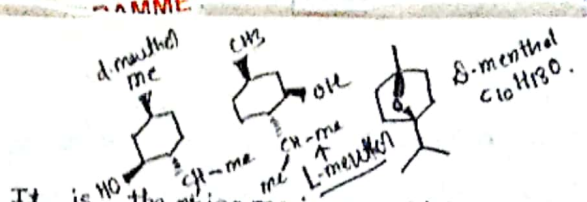
1) Acetoacetic ester.



2) Cyanic acid and isocyanic acid.



# # Stereoisomerism :-



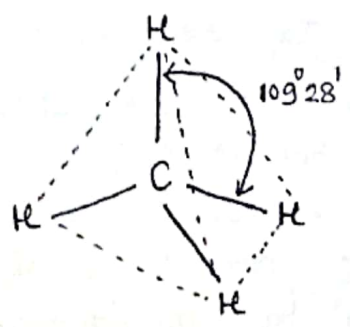
It is the isomerism which shown by two or more compounds with the same molecular and structural formulae but different configuration. i.e (spatial arrangement of atoms or groups in a molecule) is termed as "Stereoisomerism."

Isomers which have same constitution but differ in the spatial arrangement of their atoms or groups of atoms are called "stereoisomers."

Stereochemistry refers to chemistry of molecules in three dimensions. The foundations of organic stereochemistry were laid by Vant Hoff and LeBel.

They have suggested that the four bonds of the Carbon atom in methane are arranged in a way so as to point towards the corners of a regular tetrahedron.

Vant Hoff was the recipient of Nobel Prize winner in 1901. for this work.



Tetrahedral structure of methane.

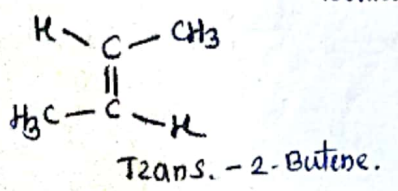
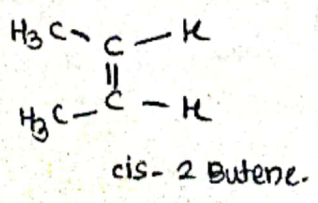
Stereoisomerism is of two types,

- 1) Geometrical isomerism.
- 2) Optical isomerism.

## - 1) Geometrical isomerism :-

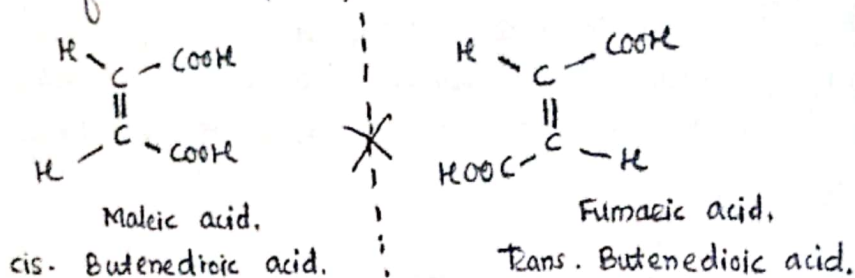
It is the isomerism shown by the compounds having the same molecular formula and structural formula but differ in spatial arrangement of atoms or groups around the doubly bonded carbon atoms.

e.g. 2-Butene shows following two Geometrical isomerism.



- 1) Compounds having similar or identical groups on the same side are called as cis Compounds whereas,
- 2) Compounds having similar or identical groups on the opposite side, are called as trans Compounds.
- 3) These geometrical isomers differ in their Physical Properties and Chemical Reactions.
- 4) The presence of a double bond restricts the rotation and also a change from one form to another.
- 5) Geometrical isomers are not mirror images of each other thus they are not enantiomers but may be considered as diastereoisomers.

e.g. Maleic and fumaric acid. shows cis & Trans forms respectively.



It is easy to name the geometrical isomers if two groups are similar but if all four groups are different then Nomenclature becomes difficult.

A new system of nomenclature i.e. E and Z nomenclature system has been introduced.

### # E-Z Nomenclature :-

E - German word entgegen - opposite  
Z - Zusammen - follow together.

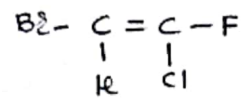
There are following rules for E-Z Nomenclature.

#### 1) Rule-I.

When two different atoms or groups are attached to the two double bonded Carbon atoms, then the sequence of priority of atoms or groups at each Carbon is decided on basis of atomic numbers.

e.g. are as,

e.g. 1-bromo-2-chloro-2-fluoro ethene.

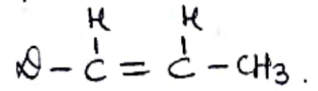


Sequence of Priority of atoms at Carbon 1 is, Br > H and

at Carbon '2' is Cl > F.

Rule (Ia). If two atoms attached to double bonded carbon atom are isotopes of same element, at that time atom of higher mass number gets higher priority.

e.g. 1-deutero propene.



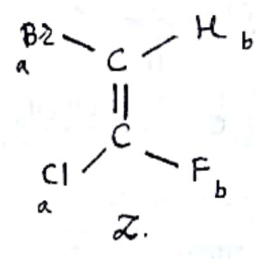
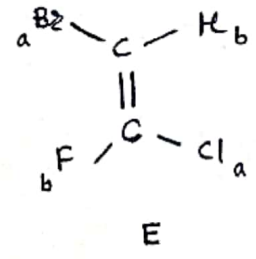
Priority at Carbon 1 is D > H & at Carbon '2' is CH<sub>3</sub> > H.

2) Rule II :-

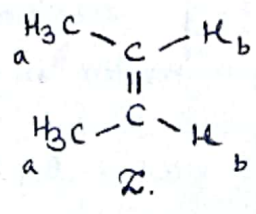
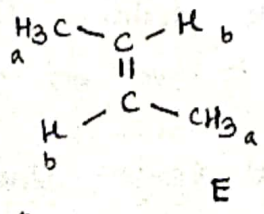
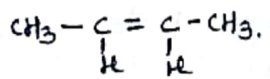
atoms or groups with higher atomic number at each double bonded carbon atom suppose as "a" & with lower atomic number suppose as "b".

If two "a" atoms or groups are on same side is designated as 'Z' and another in which two "a" atoms or groups are on opposite side, is designated as 'E'.

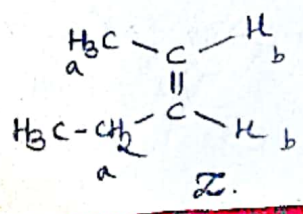
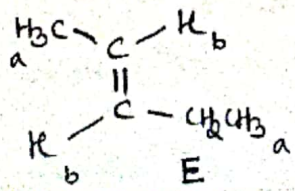
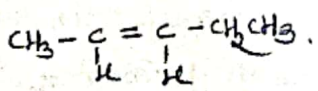
1) for e.g. E and Z forms of 1-bromo-2-chloro-2-fluoro-ethene.



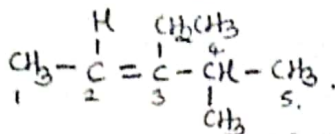
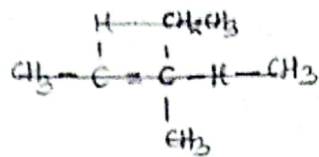
2) 2-Butene.



3) 2-Pentene

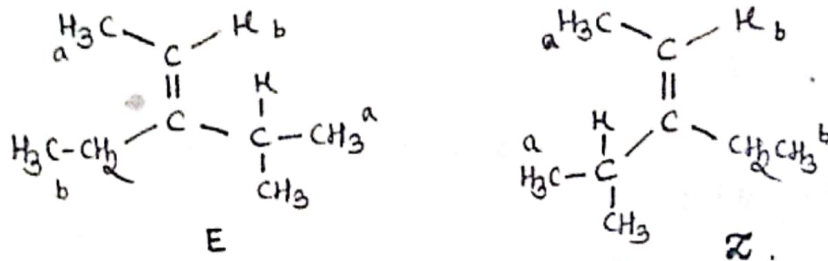


4) 3-ethyl-4-methyl-2-pentene

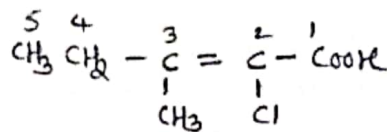


Sequence of priority at Carbon '2' is  $\text{CH}_3 > \text{H}$  and at Carbon '3' is  $\text{H} > \text{CH}_3 > \text{CH}_2\text{CH}_3$ .

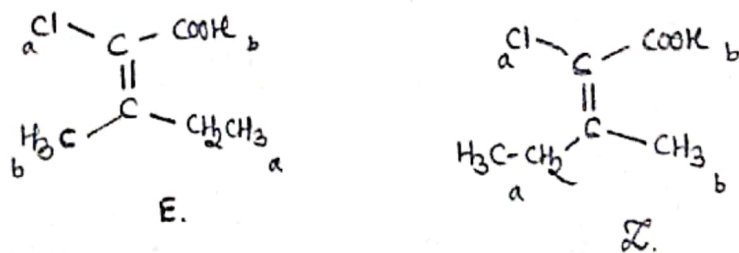
Hence,



5) 2-chloro-3-methyl-2-pentanoic acid :-



Priority at Carbon '2' is  $\text{Cl} > \text{COOH}$  and at Carbon '3' is  $\text{CH}_2\text{CH}_3 > \text{CH}_3$ .



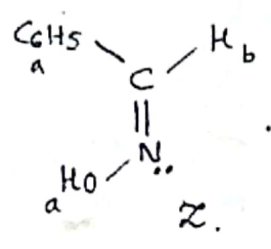
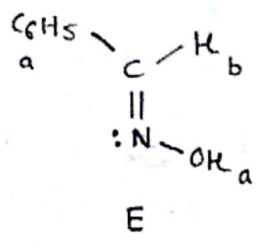
5) Rule III :-

If one of the double bonded atom is not having any substituent then while deciding priority, that vacant position is considered to have an atomic number zero.

e.g. Benzaldoxime, at nitrogen atom, there is only  $-\text{OH}$  gr. and another position is vacant hence  $-\text{OH}$  as "a" & vacant position as "b".

At double bonded Carbon atom  $\text{C}_6\text{H}_5$  is "a" &  $\text{H}$  is "b".

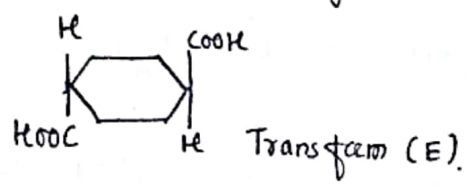
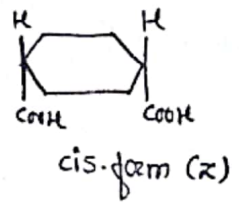
Therefore, E and Z forms of benzaldoxime is as,



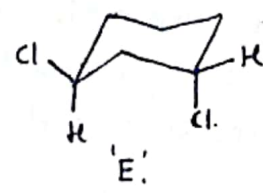
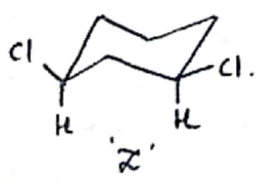
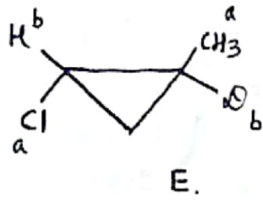
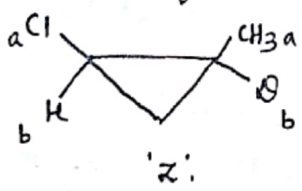
# Geometrical isomerism in alicyclic compounds :-

In case of substituted alicyclic compounds, due to restricted rotation about a ring, geometrical isomerism may also develop.

e.g. cis and Trans 1,4-cyclohexane dicarboxylic acid.



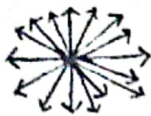
When two different atoms or groups are attached to the two carbon atoms of alicyclic ring, then the sequence of priority of atoms or groups is decided on the basis of atomic numbers.



# Optical Isomerism :-

Light is the transverse wave motion. ordinary light consists of electromagnetic waves vibrating in all planes i.e. to the path of propagation. (ie direction in which light travels). Such a ray of light when passed through Nicol Prism, emerges out vibrating only in one plane, so ray of light whose vibrations takes place only in one plane is called as plane polarised light (PPL)





ordinary light.



Nicol Prism



P.P.L.

The Property of a substance of rotating the Plane of P.P.L. either towards left or right is called as optical activity. Compounds which are mirror images of each other and non-superimposable are called enantiomers or enantiomorphs or optical stereoisomers.

The enantiomer which rotates the Plane of P.P.L. towards right hand side (clockwise) is called as dextro rotatory and is designated as d or (+).

The enantiomer which rotates the Plane of P.P.L. towards left hand side (anticlockwise) is called as laevo rotatory is designated as l or (-).

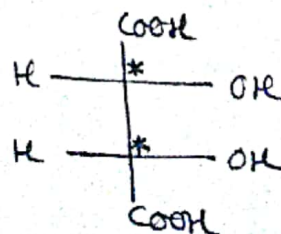
Optical activity is entirely due to the asymmetry of the molecular structure.

Optical isomerism is the isomerism exhibited by the compounds having the same molecular and structural formulae but different configuration and because of molecular asymmetry. These compounds rotate the Plane of P.P.L.

A Carbon atom of which four valencies are satisfied by linking with four different atoms or groups is called as asymmetric carbon atom. and a molecule having asymmetric carbon atom is called as asymmetric molecule. Asymmetric carbon atom is also called as stereogenic center and is indicated by asterisk. \*

It should be remembered that the essential requirement for optical activity is the asymmetry of the molecule. A molecule even containing two or more asymmetric carbon atoms shows optical inactivity.

e.g. meso tartaric acid.



Although tartaric acid contains two asymmetric carbon atoms, is optically inactive because it possesses plane of symmetry.

Whether the molecule is symmetric or not it is determined by knowing the molecule possesses a plane of symmetry or centre of symmetry or alternating axis of symmetry.

A molecule having none of the above elements of symmetry is termed as asymmetric molecule which is optically active. If the molecule contains at least one of these elements of symmetry the molecule is symmetric or achiral.

In order to study the symmetry of molecule, certain operations such as rotation and reflection are performed. If by performing these operations, an arrangement is obtained which is indistinguishable from the original structure of molecule, the operation is called as symmetry operation and the molecule is said to possess an element of symmetry.

Symmetry of a molecule is described in terms of four symmetry operations and four corresponding elements of symmetry.

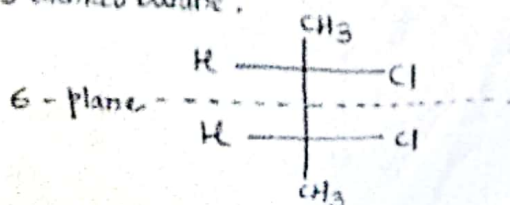
- 1) Plane of symmetry
- 2) Centre of symmetry
- 3) Simple or proper axis of symmetry
- 4) Alternating axis of symmetry

### # Plane of symmetry :-

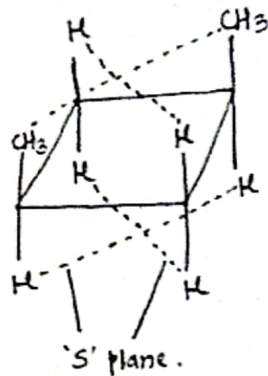
It is a plane which divides the molecule (or an object) into two halves which are mirror images of each other.

In other words, reflection of the two half parts of the molecule across the reflection plane gives a structure indistinguishable from the original molecule. The plane is called as 'S' plane & operation is termed as  $\sigma$  operation.

e.g. Meso 2,3 dichlorobutane.



e.g. cis, 1,3 dimethyl cyclobutane has two vertical 's' planes, one passing through methyl bearing carbon atoms and the other passing through two methylene carbon atoms.

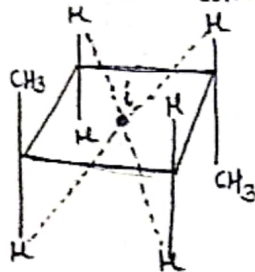


# Centre of symmetry :-

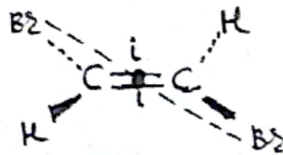
It is a point within a molecule such that if an atom or point is joined to it and the line drawn to an equal distance beyond, it meets an equivalent atom. In other words, inversion of all atoms in the molecule through the point gives an arrangement indistinguishable from the original molecule.

It is designated by 'i' & operation is 'i' operation.

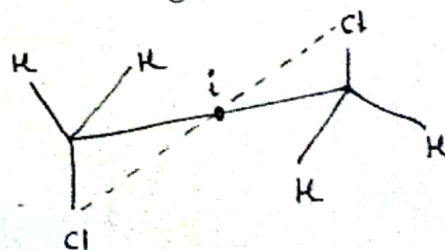
e.g. 1) trans-1,3 dimethyl cyclobutane has one centre of symmetry at the centre of the ring.



2) trans-dibromo ethene has one centre of symmetry at the midpoint of C=C bond.



3) Staggered ethylene dichloride,

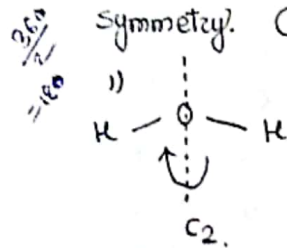


# Simple & Proper axis of symmetry (Proper rotation axis) :-

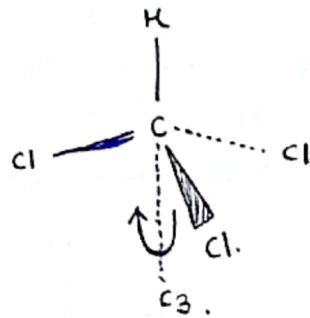
It is an axis such that when a structure having this axis, is rotated by an angle of  $2\pi/n$  ( $360/n$ ) around the axis another identical structure results. Rotation is usually taken as clockwise. Designated as 'C<sub>n</sub>'. & operation is called as C<sub>n</sub> operation.

The operation, if repeated 'n' times leads to an orientation identical with the original.

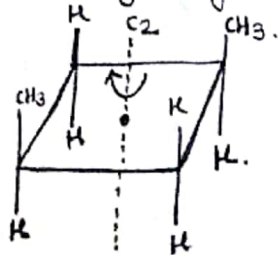
eg. water molecule has one two fold simple axis of symmetry. (C<sub>2</sub>) bisecting the H-O-H angle.



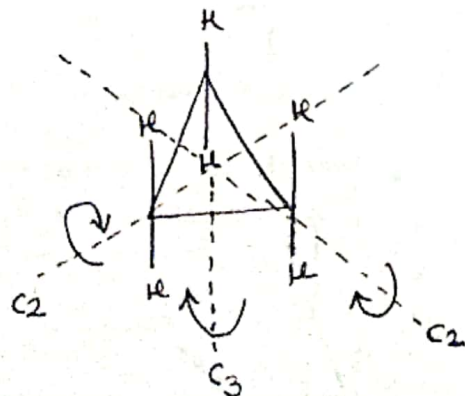
2) chloroform has one C<sub>3</sub> axis along C-Cl bond.



3) cis-1,3 dimethyl cyclobutane has one C<sub>2</sub> axis (vertical).



4) cyclopropane has one vertical C<sub>3</sub> axis and three horizontal C<sub>2</sub> axes.



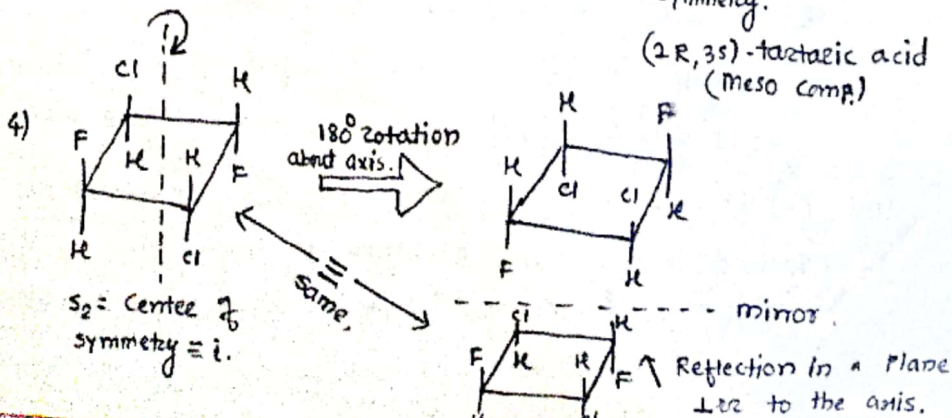
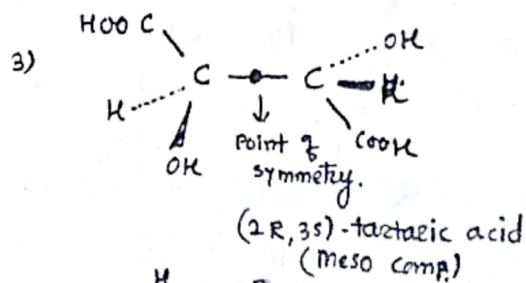
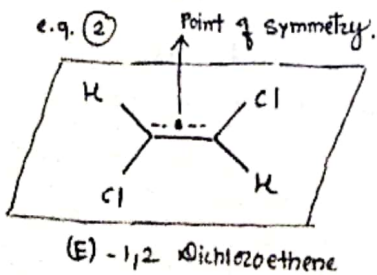
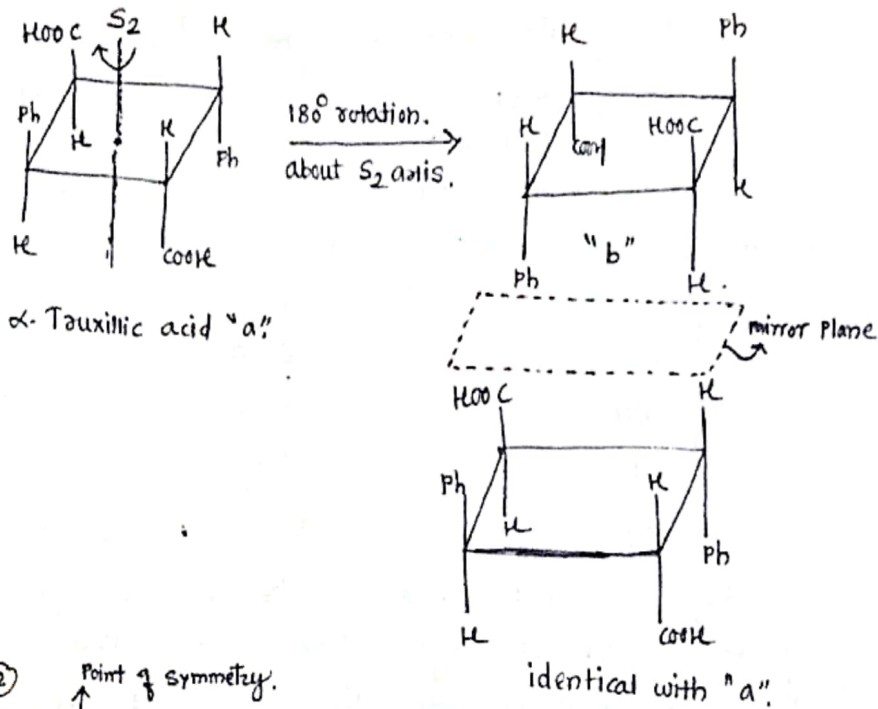
# Alternating axis of symmetry :- (Rotation-Reflection axis).

$n$ -fold alternating axis of symmetry is an axis such that, when the structure possessing this axis is rotated around the axis by an angle of  $2\pi/n$  ( $360/n$ ) and then reflected across a plane at right angles to the axis, another identical structure results.

It is designated as  $S_n$  & the operation is designated as  $S_n$  operation.

e.g.  $\alpha$ -Tauxilic acid has  $S_2$  axis which passes through the centre &  $\perp$  to cyclobutane ring.

By rotating through  $180^\circ$  through a plane  $\perp$  to the axis produces other structure (say 'b'). Reflection of structure 'b' across a plane at right angles to the axis, produces an equivalent structure as that of 'a'.



## # Specification of Configuration :-

The arrangement of atoms or groups that characterises a particular stereo-isomer is called as its configuration. There are two systems used to designate configuration of molecule.

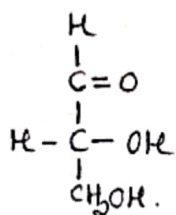
- 1) Relative Configuration (D-L Notational system).
- 2) Absolute Configuration (R-S Notational system).

### 1) Relative Configuration (D-L Notational system) :-

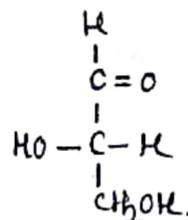
It is a configuration which is related to arbitrarily assigned configuration. The reference substance chosen by Rosanoff in 1906 were (+) and (-) forms of glyceraldehyde.  $\text{CHO}-\text{CHOH}-\text{CH}_2\text{OH}$ .

The enantiomer having -OH group on the right when the aldehyde group is placed at the top, is assigned 'D' configuration.

If the -OH group is at the left, it is assigned 'L' configuration.



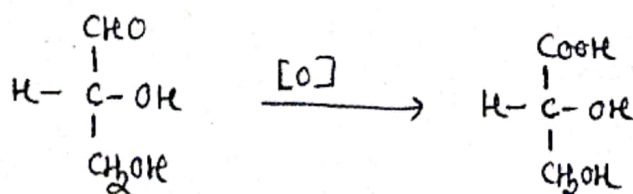
(D) (+) Glyceraldehyde



L (-) Glyceraldehyde.

Any compound that can be prepared from or converted to (D) (+) Glyceraldehyde will belong to D-series, and similarly any compound that can be prepared from or converted into (L) (-) Glyceraldehyde will belong to L-series.

e.g.

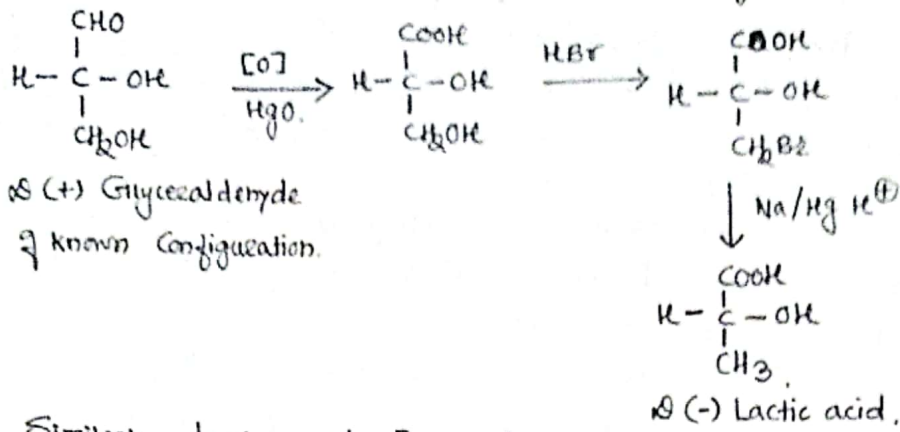


(D) (+) Glyceraldehyde.

(D) (-) Glycolic acid.

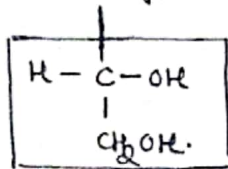
(+) and (-) i.e. d and l refers to the rotation of the plane of polarised light. It is a physical property.

Lactic acid prepared by following series of reactions from (D) (+) Glyceraldehyde.

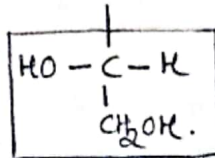


Similarly lactic acid prepared from (L) (-) Glyceraldehyde will have L (+) Configuration.

If more than one asymmetric carbon atoms are present at that time asymmetric carbon is always drawn at the bottom of rest of the molecule is then built up.

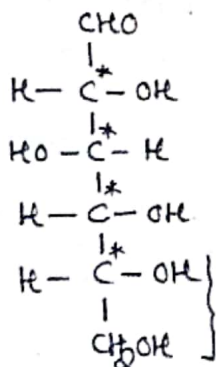


D series.

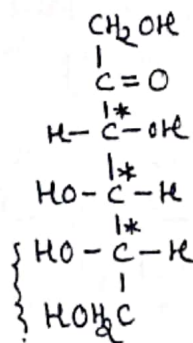


L-series.

Glucose and fructose having following structural formulae.



D (+) Glucose.



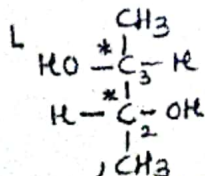
L (+) Fructose.

# Drawbacks of D-L notational system :-

-1) Different authors have adopted the system of assigning the Config. with respect of either bottom or top asymm. Carbon atom. thus creates ambiguity.

-2) Sometimes two similar asymmetric carbon atoms having the same Configuration are assigned opposite Configuration. e.g. in (-) 2,3 butane diol.

According to R-S system both asymmetric carbon atoms show same Configurations.



D (-) Butane-2,3-diol.

## # Absolute Configuration :-

The absolute configuration in Particular specifies the order of Priority of atoms or groups attached to asymmetric Carbon atom.

R.S. Cahn (Chemical Society London), Sir Christopher Ingold (London) and V. Prelog (Zurich) Proposed this Configuration.

R - means Rectus (Greek word) - Right.

S - means sinister (Greek word) - Left.

Overall system is known as Cahn-Ingold-Prelog (CIP) system of nomenclature after the names of authors.

R-S notational system there are following Sequence Rules.

### 1) Sequence Rule I :-

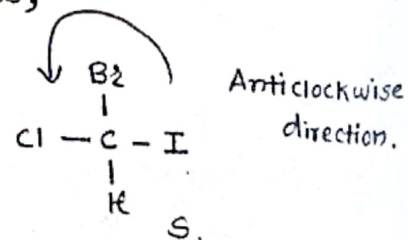
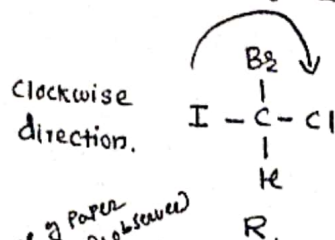
A sequence of Priority is assigned to the four different atoms or groups. Priority is based on atomic numbers.

An atom with higher atomic number gets higher Priority.

e.g. In case of bromo chloro iodo methane Sequence of Priority is,  $I > Br > Cl > H$ .

If the arrangement is  $I \rightarrow Br \rightarrow Cl$  gives a right handed turn (clockwise), the Configuration is 'R'. If  $I \rightarrow Br \rightarrow Cl$  traces a left handed turn (anticlockwise) the Configuration is 'S'.

R and S config. in the form of Fischer Projection Structures can be represented as,



↑ above the plane of paper (towards observer)  
 ↓ vertical (behind the plane of paper) away from the observer.

In Fischer Projection, horizontal lines represents bonds rising above the plane of paper (towards observer) and vertical lines represent bonds projecting behind the plane of the paper (away from the observer).

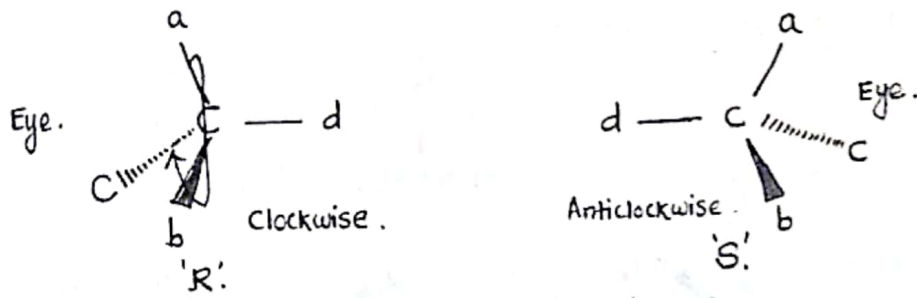


'R' and 'S' Config. in three dimensional structures can be represented by observing the following rules.

Visualize the tetrahedral structure oriented so that the atom or group of atoms of lowest priority (d) is directed away from us and observe the arrangement of the remaining atoms or groups of atoms.

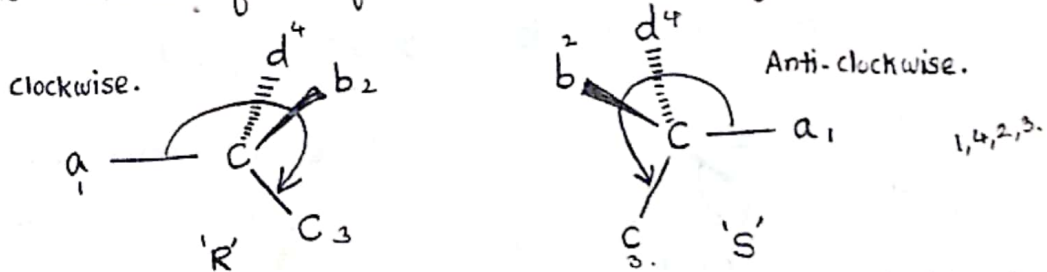
Suppose Priority order is  $a > b > c > d$ .

If our eye travels in a clockwise direction the config. is specified as 'R' & if anticlockwise the config. is 'S' config.



- ..... broken line represents behind the plane of paper.
- ▀ dark wedge line represents in front of the plane of paper.
- solid line represents in the plane of paper.

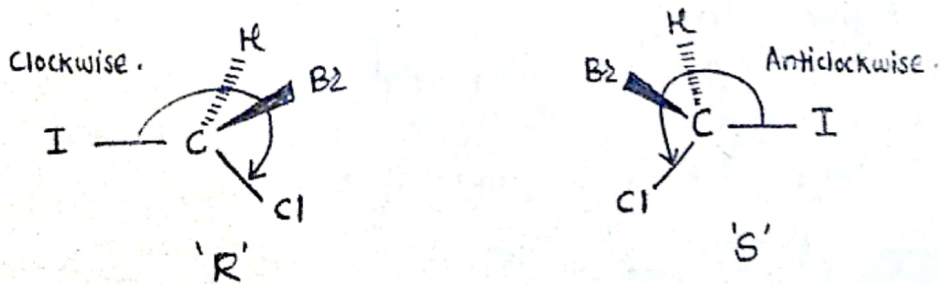
If projecting the atom or group of lowest priority (d) behind the plane of paper & visualizing the structure from front side R & S config. is shown as,



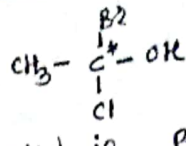
The position of atom or group of atoms of lowest priority (d) is to be ignored while deciding the sequence of priority for a, b & c.

On the basis, R & S Config. of some compounds are,

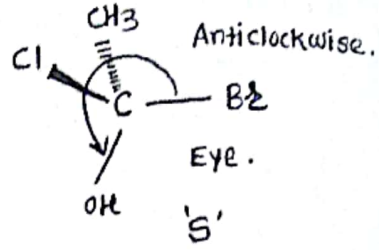
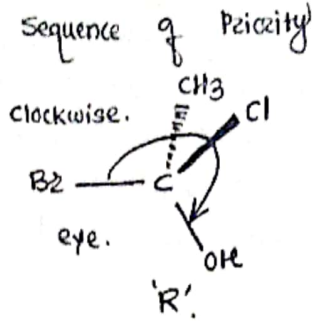
— 1) Bromo chloro iodo methane.



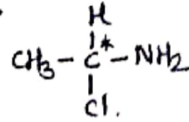
2) 1-Bromo-1-chloro ethanol.



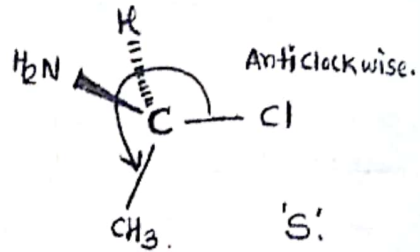
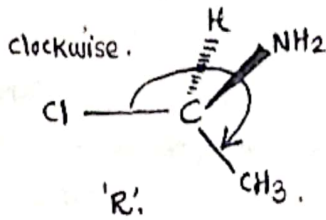
Sequence of Priority is  $\text{Br} > \text{Cl} > \text{OH} > \text{CH}_3$ .



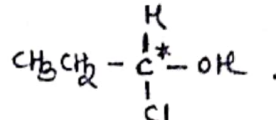
3) 1-chloro ethylamine.



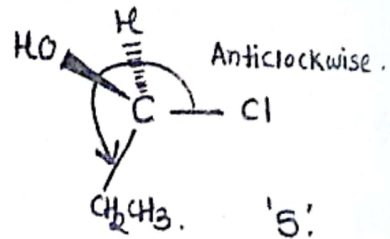
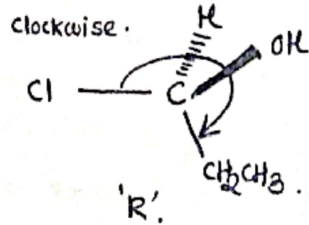
Sequence of Priority is  $\text{Cl} > \text{NH}_2 > \text{CH}_3 > \text{H}$ .



4) 1-chloro-1-Propanol.



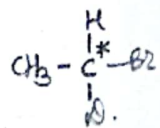
Sequence of Priority is  $\text{Cl} > \text{OH} > \text{CH}_2\text{CH}_3 > \text{H}$ .



2) Sequence Rule. II. :-

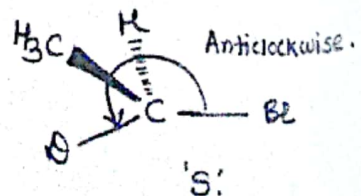
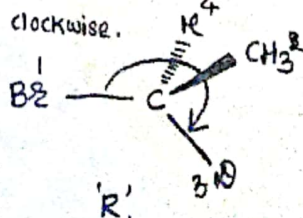
If two atoms are isotopes of the same element, the atom of higher mass number gets the higher Priority.

e.g.  $\alpha$ -deutero ethyl bromide.



Sequence of Priority is  $\text{Br} > \text{CH}_3 > \text{D} > \text{H}$ .

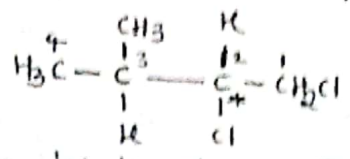
Hence R & S config. of them are,



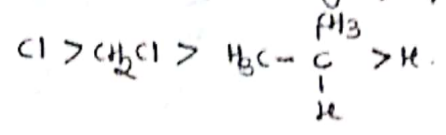
# Sequence Rule III :-

If two or more atoms attached to chiral carbon atom are the same, sequence rule I cannot decide the Priority. In such cases, compare the second atoms attached to each of these first atoms.

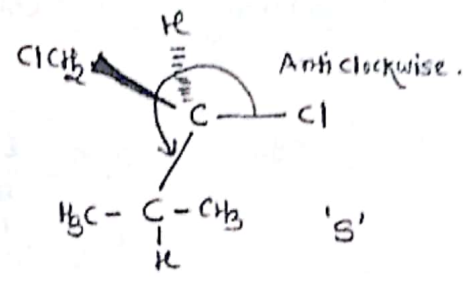
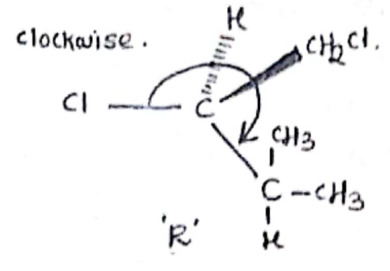
e.g. 1,2 Dichloro-3-methylbutane.



Carbon '2' is chiral. Two atoms (Carbon 1 & 3) attached to chiral centre are same, In -CH<sub>2</sub>Cl second atoms are H, H & Cl while in (CH<sub>3</sub>)<sub>2</sub>C-H second atoms are C, C and H. Among these atoms, Cl has higher atomic number. Hence -CH<sub>2</sub>Cl group gets Priority over (CH<sub>3</sub>)<sub>2</sub>C-H group (ie isotopyl group). Hence sequence is,

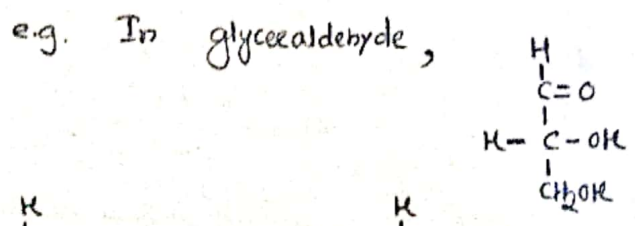
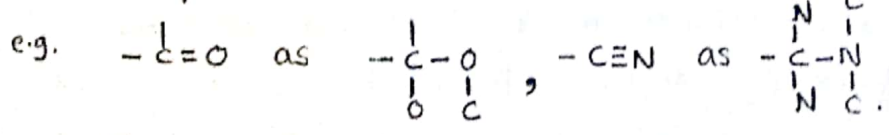


on this basis 'R' and 'S' Config. Can be represented as,



# Sequence Rule IV :-

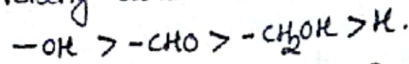
If a molecule contains group with multiple bond (double or triple bond), then for the determining priority, both atoms of that group are considered to be duplicated or triplicated.



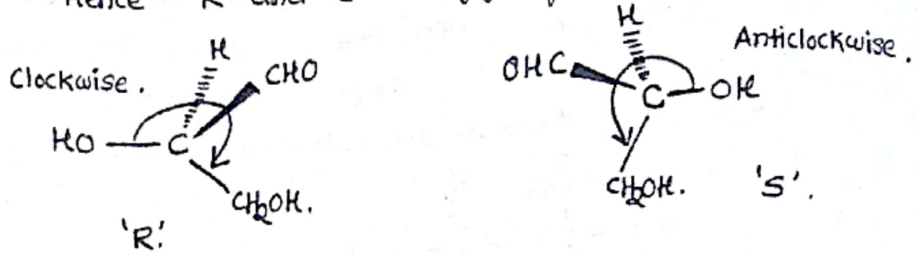
$-\overset{\text{H}}{\text{C}}=\text{O}$  is equivalent to  $-\overset{\text{H}}{\text{C}}-\overset{\text{O}}{\text{O}}-\overset{\text{O}}{\text{C}}$  ie in -CHO group.

Second atoms attached to Carbon atoms are H, O & O. In -CH<sub>2</sub>OH second atoms are H, O & H. Hence -CHO gets Priority over -CH<sub>2</sub>OH.

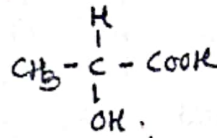
Thus Priority order is as,



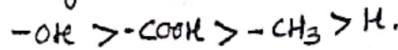
Hence 'R' and 'S' Config. of Glyceraldehyde are,



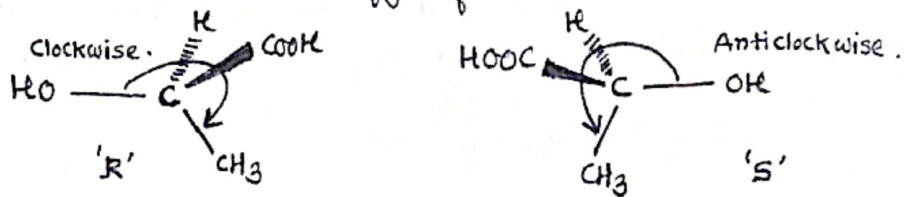
2) In lactic acid,



Sequence of Priority in lactic acid,



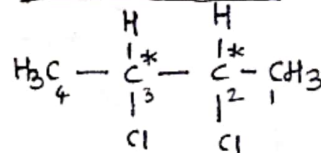
'R' and 'S' Config. of lactic acids are,



### # Optical Isomerism exhibited by Compounds Containing two Chiral Centres :-

e.g.

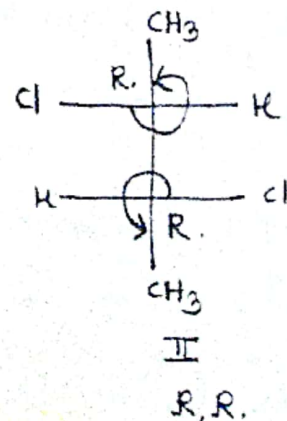
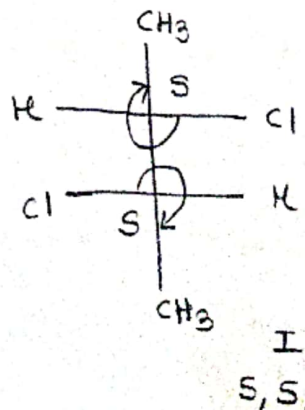
2,3 Dichlorobutane.



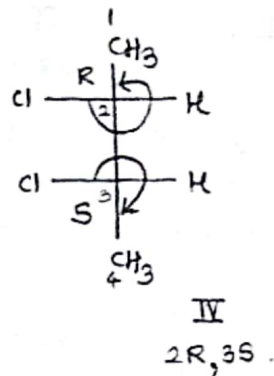
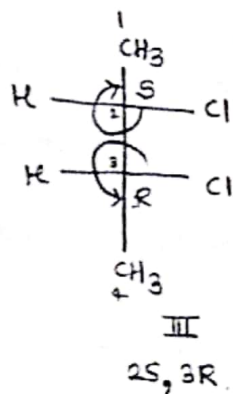
This compound contains two chiral centres i.e. C<sub>2</sub> & C<sub>3</sub>.

These two chiral centres occupy equivalent positions along the carbon chain.

The optical isomers shown by 2,3 Dichlorobutane in two dimension i.e. Fischer Projection formulae can be represented as,



Optical stereoisomers I have S,S & II have R,R Config.  
 both stereoisomers are mirror images of each other and nonsuperimposable. Hence I and II forms are optically active enantiomers.



In III and IV stereoisomers both chiral centers possess opposite configuration. (ie 2S, 3R and 2R, 3S) III form is superimposable with its IV form i.e. mirror image of III.

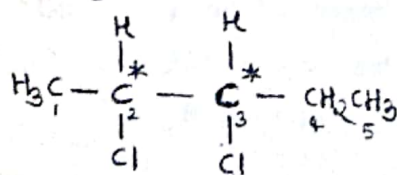
but both III and IV forms having a plane of symmetry hence these forms become achiral molecules and they do not show optical activity. i.e. they are optically inactive. that has chiral centers but itself is achiral is called as Mesoform.

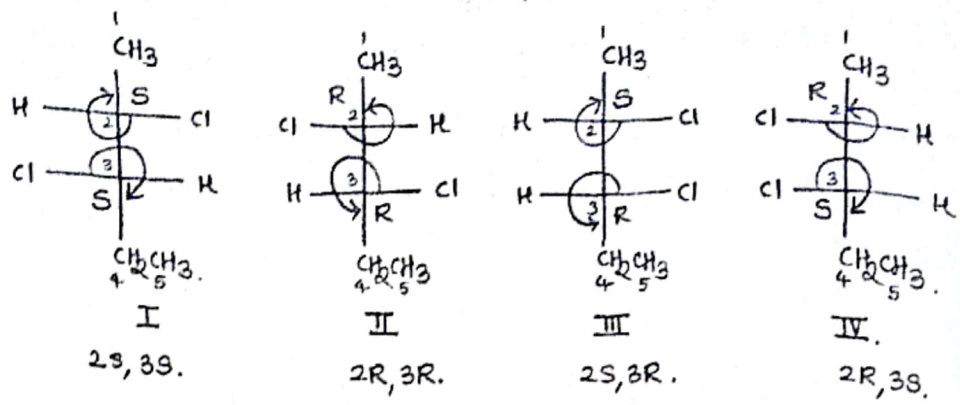
Note:-

In Fischer projection formula when atom or group of lower priority (e.g. H) is on the horizontal line, the config. opposite to the config. exhibited by chiral center is considered. e.g. In fig. of I form, arrows indicate R,R config. for both chiral centers but they are considered as S,S.

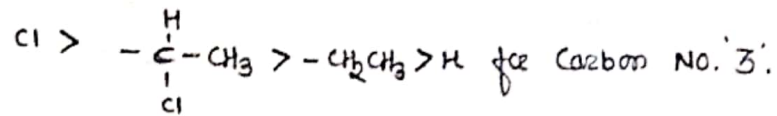
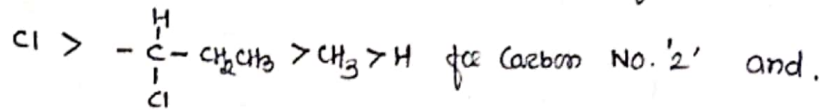
When atom or group of lowest priority (e.g. H) in Fischer structure is on the vertical line, no change in configuration is made.

Similarly other example is, 2,3-dichloropentane.





According to sequence rule order of 'priority' is,



I and II are mirror image of each other and nonsuperimposable, Hence they are enantiomers. not Posses Plane of symmetry & optically active.

Similarly III and IV are enantiomers.

I and II forms are nonsuperimposable on III form but they are not mirror images of each other. Hence they are not enantiomers. Such stereoisomers which are not mirror images of each other but non-superimposable, are called as, 'Diastereoisomers'.

Thus Comp. III is a diastereoisomer of I and II.

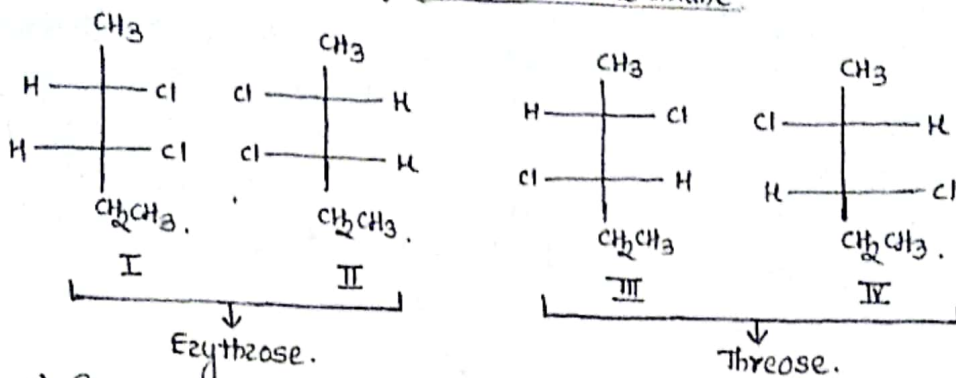
II. Similarly Comp. IV is a diastereoisomer of I and II.

Diastereoisomers differ in their Physical Properties, like Boiling Points, Melting Points, densities, Refractive indexes, and Solubilities in the given solvent. They have similar Chemical Properties but Chemical Reactions are not identical.

There is informal nomenclature based on Fisher Projections to distinguish between diastereoisomers.

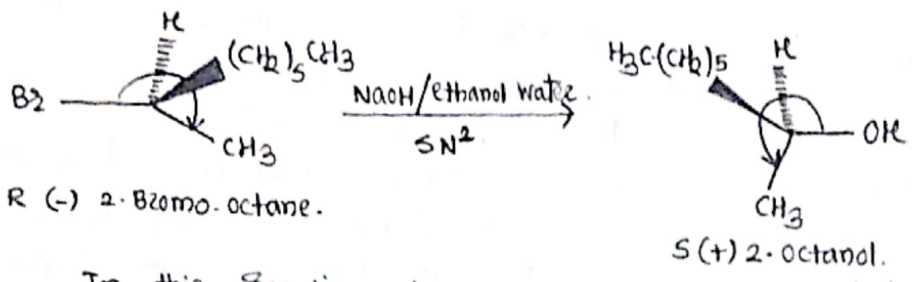
When the Carbon chain is vertical and similar Substituents are on the same side of the Fisher Projection. The molecule is described as the 'erythrose' diastereoisomer. When similar substituents are on opposite side of the Fisher Projection, the molecule is described as the 'threose' diastereoisomer.

e.g. stereoisomers of 2,3-dichloropentane



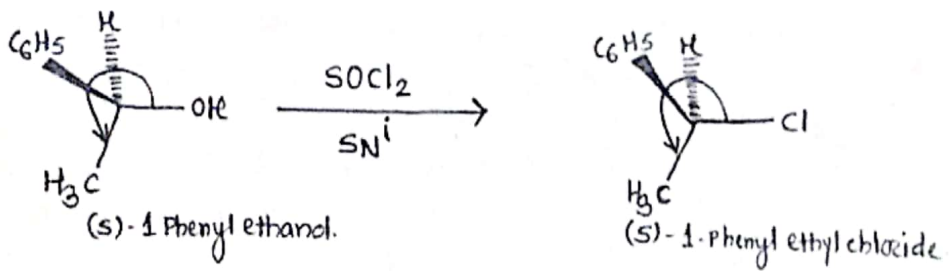
Some other examples of R & S config. via. chemical reactions are,

- 1) R(-) 2-bromo-octane on hydrolysis with NaOH solution gives S(+)-2-octanol.



In this reaction nucleophile attacks to the substrate from the side opposite to the bond of the leaving group. This is called as "backside displacement" or substitution with inversion of configuration. or Walden inversion.

- 2) (S)-1-phenyl ethanol on treatment with thionyl chloride (SOCl<sub>2</sub>) gives (S)-1-phenyl ethyl chloride.



In this reaction nucleophile attacks to the substrate at the same face from which the leaving group departs. This is called as 'front side displacement' or substitution with retention of configuration. Reaction is S<sub>N</sub>i (Internal Nucleo. subs.)

- 3) (S)-1-phenyl ethyl chloride on solvolysis with aq. Acetone gives a mixture of (S)-1-phenyl ethanol and (R)-1-phenyl ethanol.

Solvolysis is a Nucleophilic Substitution in which the Nucleophile is a molecule of the solvent.

