

Unit IV

Chapter - I

Stereochemistry :- The branch of chemistry concerned with the 3-dimensional arrangement of atoms and molecules and the effect of this on chemical reactions.

[OR]

Stereochemistry, a subdiscipline of chemistry, involves the study of the relative spatial arrangement of atoms that form the structure of molecules and their manipulation.

The study of stereochemistry focuses on Stereoisomers, which by definition have the same molecular formula & sequence of bonded atoms; but differ in the 3D orientations of their atoms in space. For this reason, it is also known as 3D chemistry - the prefix "stereo" - means "3 Dimensionality".

→ Representation of Three dimensional structure : Projection formulae

"Projection formula is a perspective formula projected so as to represent the molecule in two dimensions by comparing it with its three dimensional structural formula."

The projection formula of the molecule is drawn ~~on~~ on the plane of paper by observing the shadow of the 3 dimensional model on the plane of the projection.

Different projections of the same molecule may be obtained by orienting the three dimensional model in different ways with respect to the plane of projection or viewer.

Generally four different types of projection formulas are employed

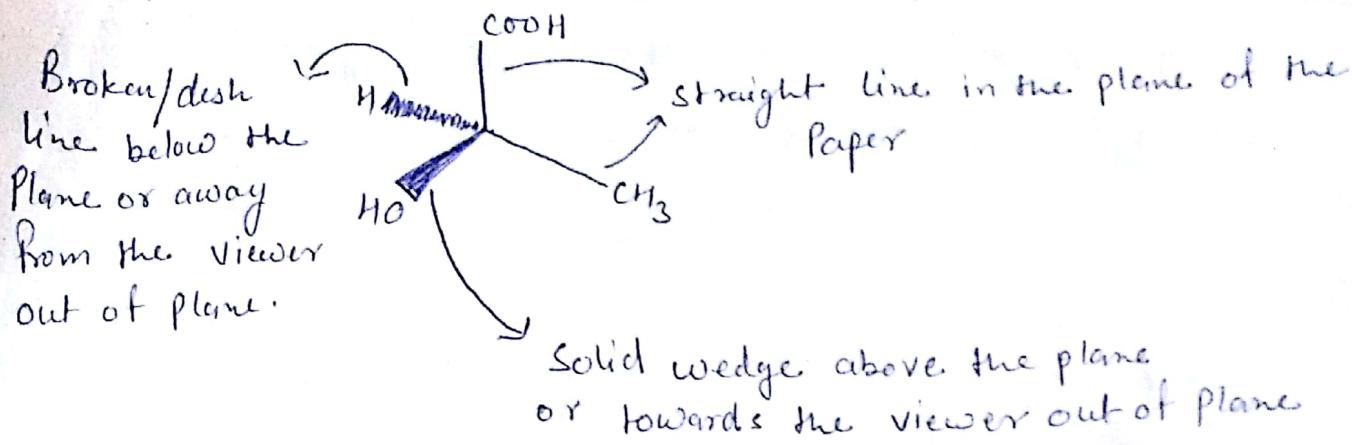
- 1) Flying wedge projection
- 2) Fischer projection
- 3) Sawhorse projection
- 4) Newmann projection

1) Flying wedge / wedge dash / (3 dimensional projection)

It is most common method of representation of chiral & A chiral molecules. Three types of line are used in representing a 3 dimensional structure by wedge dash projection.

- a) Solid line - (—) : denote bonds in the plane of the paper.
- b) dashed line (---) : represents bonds that extend away from the viewer (below the plane of paper but goes back behind)
- c) Wedge-shaped line (—) : represent bonds oriented towards the viewer. (above the plane of the paper)

e.g. Lactic Acid (2-hydroxypropanoic acid) with a chiral carbon in flying wedge projection can be represented in the following way:



2) Fischer projection formula (Planner representation)

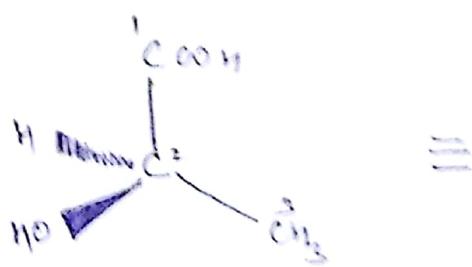
Emil Fischer (1891) introduced planner formula to represent 3-D formula of any molecule. These planner representations are called Fischer projection formulae.

→ Points to write Fischer projection formula

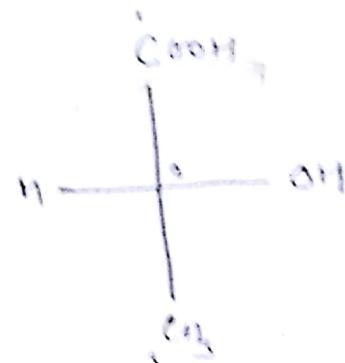
- The molecule or chiral carbon is viewed in such a way that two groups of chiral centre point towards observer and two groups away from the observer and chiral carbon at the centre.
- ~~Draw~~ Draw a cross with one vertical line and one horizontal line.
- Chiral carbon is assumed at the intersection point of both line. (It is never written).
- The vertical part of the projection formula represents the longest chain of carbon atoms in the molecule and carbon atoms numbered as one (1) according to IUPAC system place at the top of the vertical line and rest part of main chain

e) Represented at the bottom.
Group pointed towards observer are placed on horizontal line, one at each end.

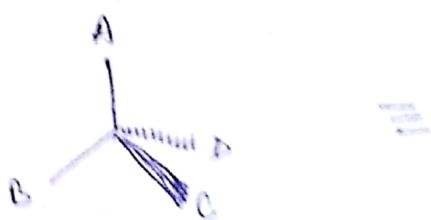
e.g.



=



Fischer projection



Fischer projection

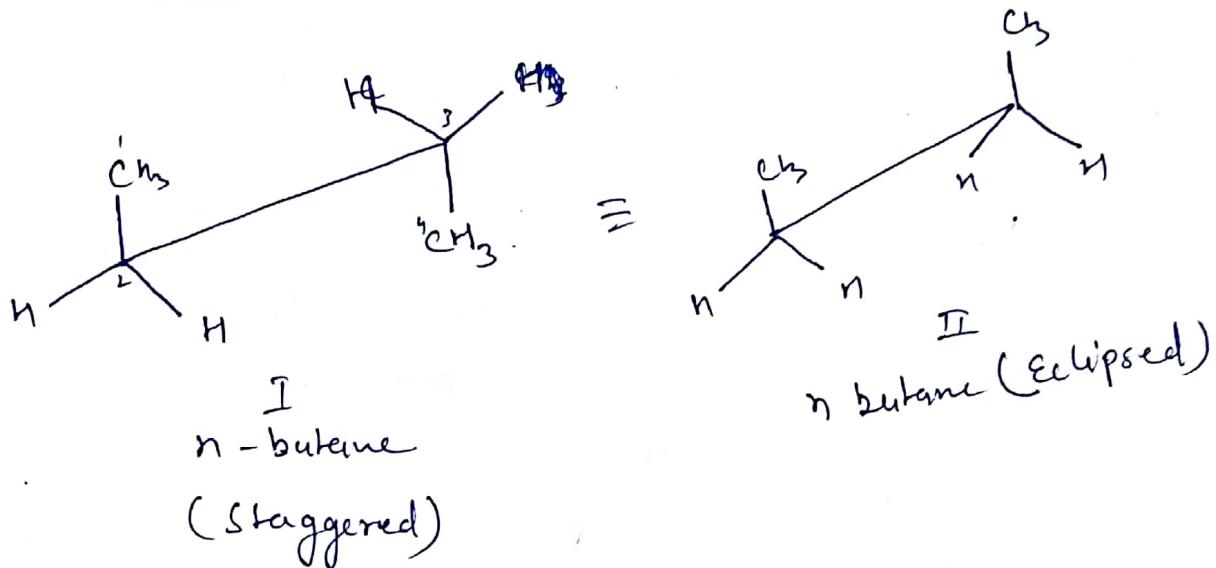
3. Sawhorse projection

The use of sawhorse projection in visualizing the chiral behaviour of a molecule is significant b/c it displays the actual molecular shape of 3 dimensions.

In this projection, the two carbon atoms (chiral or achiral) are joined, for better visualization, by a longer diagonal line which is taken to be the plane of the paper and the remaining bonds, projected above & below the plane, are shown by small lines.

There is normally free rotation about C-C bond and the three groups attached to one carbon may be rotated clockwise or anticlockwise with respect to the three groups attached to the other carbon atom.

e.g! n-butane

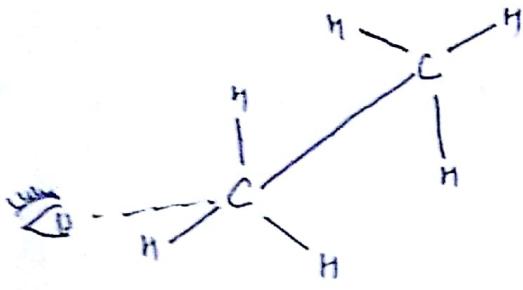


conformation I is called staggered form where the bulky methyl and other group on C-2 & C₃ are oriented as far apart from each other as possible.

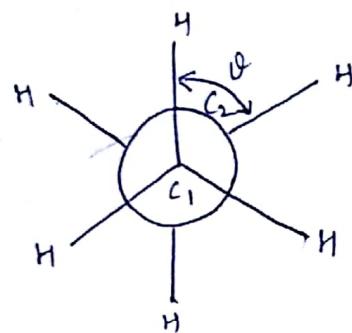
conformation II is known as eclipsed form where the groups on C-2 & C₃ are nearest (exactly, behind each other). sawhorse projection is also called perspective formulae.

Newman projection

more useful & simple representation related to projection formula is the Newman projection in which the molecule is viewed along the bond joining the carbon atoms. These carbon atoms C₁ & C₂ in ethene, are represented as superimposed circles; only one circle is drawn.



Sawhorse



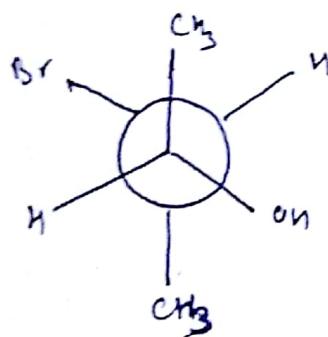
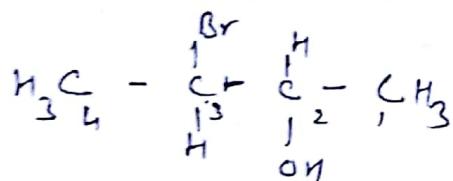
Newman projection

C₁ = represent front carbon

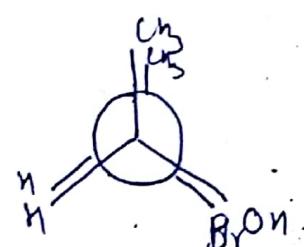
C₂ = Circumference represent back carbon

The remaining bonds on each carbon atoms are shown by small straight lines at angle of 120° joined to the centre and to the circumference.

Ex: 3-bromobutan-2-ole



Staggered form



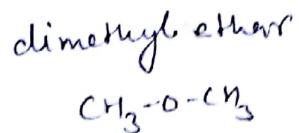
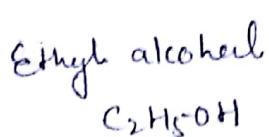
Eclipsed form

Isomerism

There are certain compounds which have same molecular formula but different chemical & physical properties are called isomers and phenomenon to show different properties by the compounds having same molecular formula is called isomerism.

Isomerism → Iso = same
merism = parts

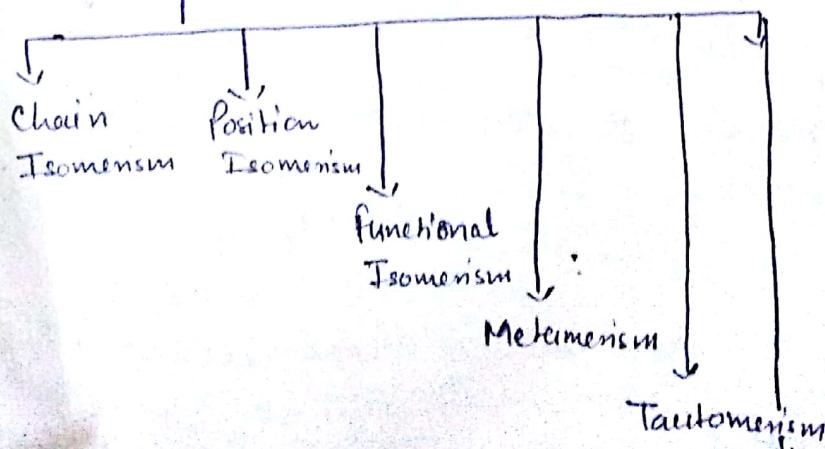
e.g.: Ethyl alcohol & dimethyl ether have same molecular formula i.e. C_2H_5O . and yet are distinctly different compounds.



Isomerism

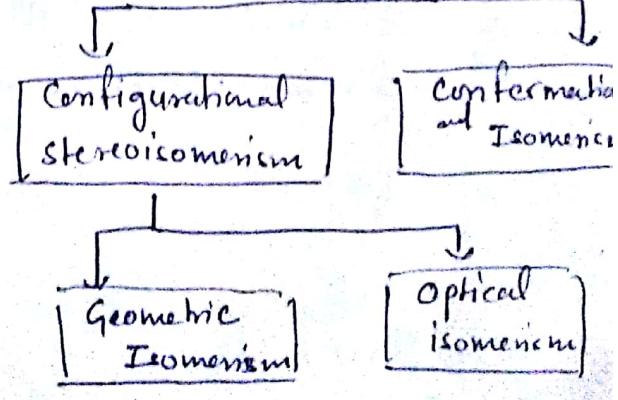
Structural Isomerism

(same molecular formula (connecting atoms)
but different structural (or charges) formula)



Stereoisomerism

(same molecular formula and same structural formula but different orientation of group in space)



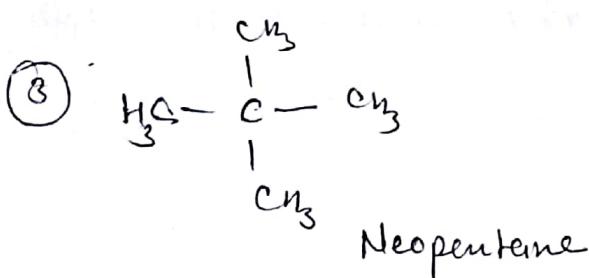
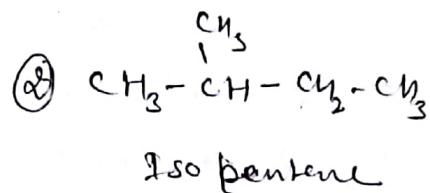
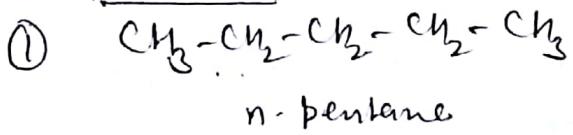
① Structural Isomerism

Isomers which differ in the arrangement of atoms within the molecule are called structural isomers and this phenomenon is called structural isomerism

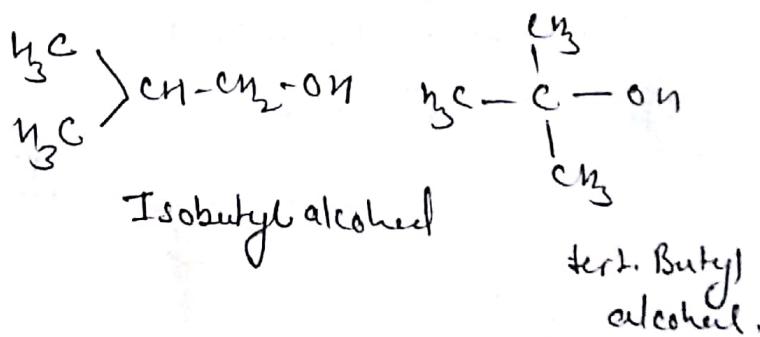
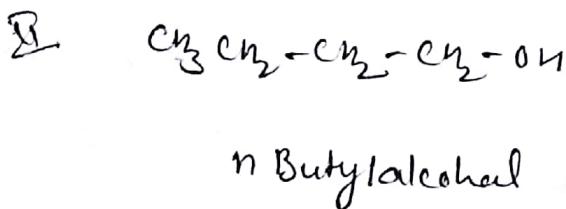
Wednesday
Thurs

① Chain Isomerism or skeletal Isomers

Isomers which differ in the arrangement of carbon atoms within the molecule are called chain isomers and this phenomenon is called chain isomerism

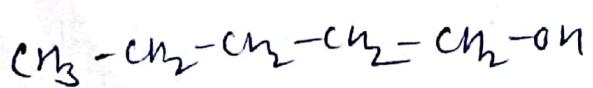
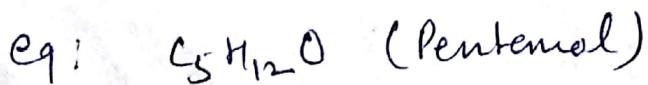


3 isomer structures

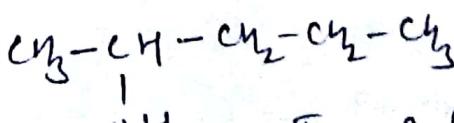


② Position Isomerism

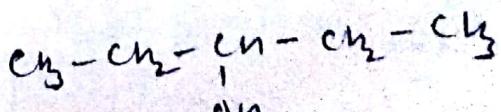
Isomers which differ in position of functional gp or multiple bond.



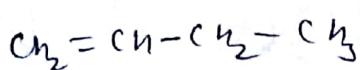
Pentenol 2



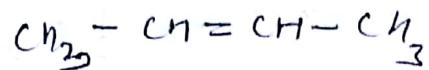
2-Pentenol



3-Pentenol



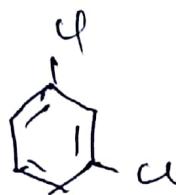
I
But-1-ene



But-2-ene



O dichloro
benzene
I



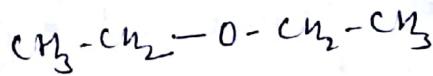
II



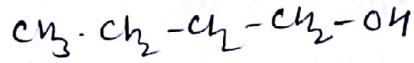
III

iii) functional Isomerism \rightarrow which differ in the ~~shape~~^{nature} of the functional groups associated with them are called functional isomers and this phenomenon is called functional isomerism. Eg:

I $\text{C}_4\text{H}_{10}\text{O}$

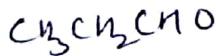


diethyl ether

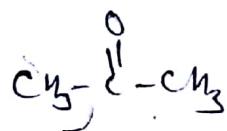


Butyl alcohol

II $\text{C}_3\text{H}_6\text{O}$

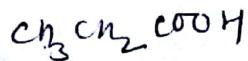


Propanal

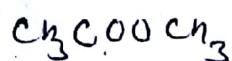


Acetone

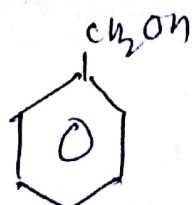
III $\text{C}_3\text{H}_6\text{O}_2$



propanoic acid



methyl acetate



Benzyl alcohol



O-Cresol



P-Cresol



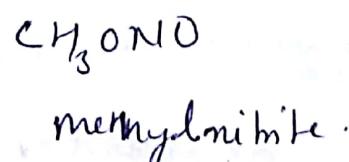
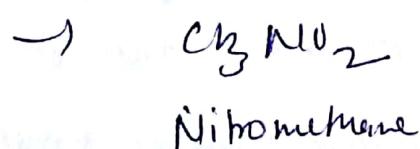
M-Cresol

Position isomers



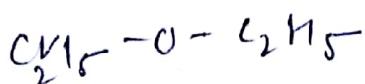
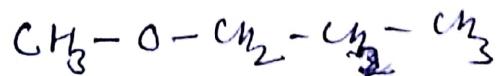
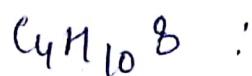
\rightarrow $\text{CH}_3\text{C}\equiv\text{N}$
methyl cyanide.

$\text{CH}_3\text{N}\equiv\text{C}$
Methyl Isocyaniide



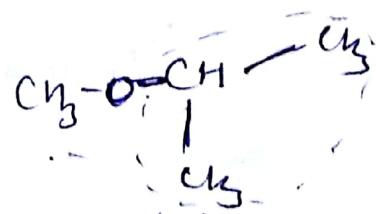
Isomers which

i) Metamers → differ in the alkyl gp's attached on either side of the ~~exposed~~ functional gp in the molecule are called metamers and this phenomenon is called metamersim.



Diethyl ethers

II methyl propyle
methyl-n-propyl ether



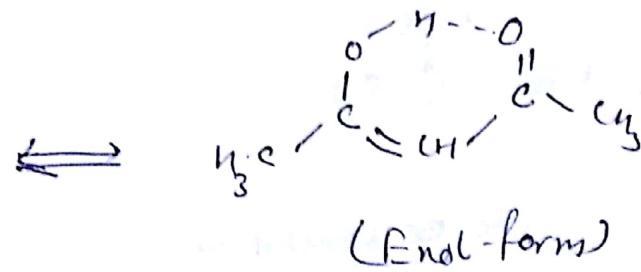
Iso propyl methyl ~~isopropyl~~ ether

Tautomerism

Special type of functional isomers which exist in dynamic equilibrium with each other are *tautomers*. A good example of keto-enol tautomerism is β -diketone and β -ketoesters.



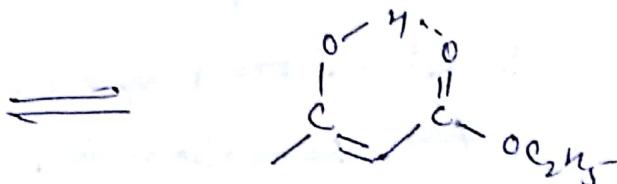
Acetylacetone
(Keto-form)



(Enol-form)



Ethyl Acetoacetate
(Keto-form)

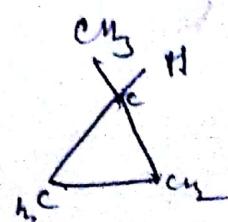
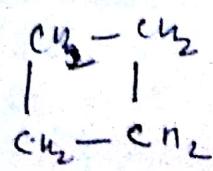
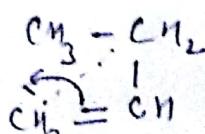
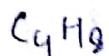


(Enol form)

Keto-enol tautomerism involves 1,3 migration of a proton from one polyvalent atom to another within a molecule.

→ Aldehyde or ketone having no α -H cannot show keto-enol tautomerism.

v) Ring-Chain isomerism: Isomers having open chain and cyclic structures are called ring-chain isomers and this phenomenon is called ring-chain isomerism.

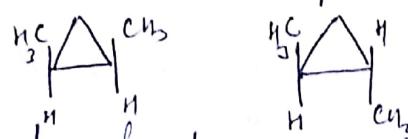


Stereoisomerism

Greek:

(Stereo = space, meros = part)

Isomers having the same structural formulae but differ only in the arrangement of the constituent atoms or groups in space are called stereoisomers and the phenomenon is called as stereoisomerism



The spatial rearrangement of atoms or groups is also referred to as configuration of molecule.

Stereoisomerism is broadly divided into two classes:

a) Configurational stereoisomerism:

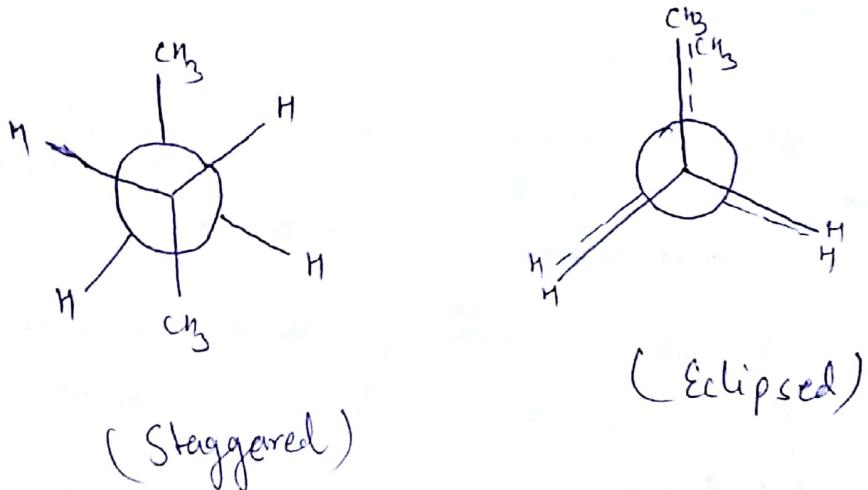
The stereoisomers which interconvert with difficulty and can be isolated under normal conditions are called configurational isomers and the phenomenon is known as configurational stereoisomerism. Interconversion of such stereoisomers usually involves the breaking and remaking of the bonds. *

(b) Conformational stereoisomerism:

Conformations of a molecule are 3 dimensional arrangement that differ only by rotation around a single bond. This is due to cylindrically symmetrical nature of σ -MO's along the internuclear axis. As a result free rotation around σ - σ single bond is possible and it requires very little energy for rotation. In particular, the atoms remain connected in the same order during conformational change,

With bonds being neither formed nor broken.

ii) The infinite number of momentary arrangements of atoms or groups in space due to free rotation around C-C single bond are called conformers or rotomers and this phenomenon is called Conformational isomerism.



Newman projection formulae

* Configurational isomerism are divided in to two parts

(i) Geometrical Isomerism:-

The configurational isomerism that arises due to the rigidity in a molecule i.e. Geometrical Isomerism.

(ii) The configurational isomerism that arises due to the right or left-handed arrangement of atoms or groups around the carbon atom, i.e., Optical Isomerism.

→ Optical Isomerism:-

Stereoisomers having identical physical properties like M.P. B.P., density, solubility etc. and resemble each other in most of their chemical properties but differ in their action towards plane polarized light are called optical isomers and the phenomenon is called

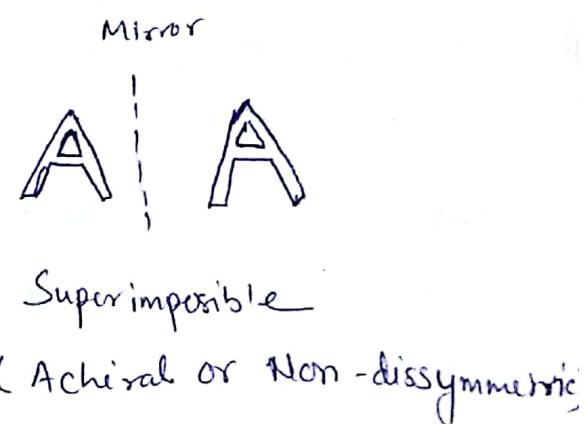
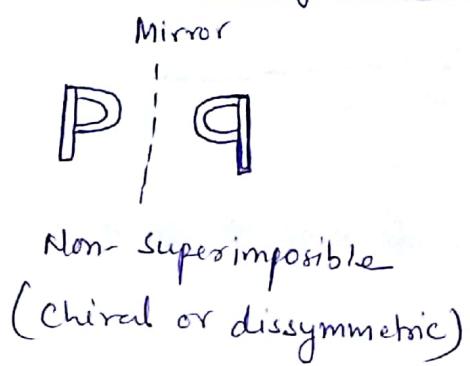
Optical Isomerism or Optical activity.

EP \rightarrow Some General Concepts about Optical Isomerism

point (i) Chirality (Chiral & Achiral Molecules) :-

A molecule or an object is said to be chiral or dissymmetric, if it is not superimposable on its mirror image and this property is called chirality.

On the other hand, A molecule or an object which is superimposable on its mirror image is called achiral or non-dissymmetric or symmetric. eq:



Molecular Chirality & Asymmetric Carbon:

Chirality in organic molecules arises due to tetrahedral nature of sp^3 - hybrid carbon.

Eq: Consider a molecule attached to the carbon ^{*C} in which four atoms or groups are different.

Such carbon atom which is attached to four different atoms is called asymmetric carbon atom or a chiral carbon atom (^{*}C).

..... it has also been used for diastereomers having chiral centres. Thus, before further discussing enantiomerism we will have an account of optical activity in the following pages.

3.3 OPTICAL ACTIVITY

Ordinary light is composed of rays of different wavelengths vibrating in all directions perpendicular to the path of its propagation. The same is the case with a light of a single wavelength, i.e., a monochromatic light. These vibrations can be made to occur in a single plane (polarisation) by

passing ordinary light through the polarising Nicol prism (made of calcite, a special crystalline form of CaCO_3). Such light whose vibrations occur in only one plane is called **plane polarized light**. The polarisation of ordinary light transmitted through a Nicol prism is easily detected by viewing through a second Nicol prism called analyser (Fig. 3.1).

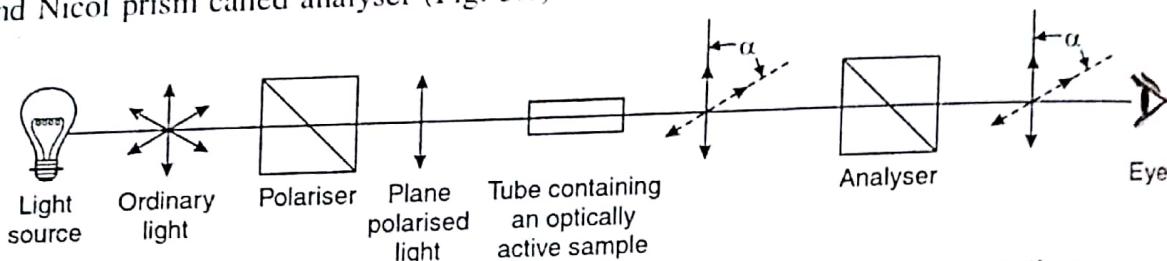


Fig. 3.1. Schematic diagram of a polarimeter. Solid lines : before rotation.
Broken lines : after rotation. α is angle of rotation.

Compounds which rotate the plane of polarised light are called **optically active** compounds and this property is known as **optical activity**. If the compound rotates the plane of polarisation to the right (clockwise), it is said to be **dextrorotatory** (Latin : *dexter* = right) and is denoted by (+), or *d*. If the rotation is to the left (anticlockwise), the compound is said to be **laevorotatory** (Latin : *laevis* = left) and is denoted by (-), or *l*. Now the notations *d* and *l* are not used.

The change in the angle of plane of polarisation is known as **optical rotation**. The optical rotation is detected and measured by an instrument called polarimeter (Fig. 3.1). The degree of rotation depends on the nature of the compound, the temperature, the solvent, the concentration of the solution, the length of the polarimeter tube, and on the wavelength of the light used. It is therefore, necessary to introduce some standard by which rotating powers of different compounds may be compared. Thus, the measurement of optical activity is reported in terms of **specific rotation** $[\alpha]$, or molecular rotation [M].

$$[\alpha]_t^{\lambda} = \frac{\alpha}{lc}$$

Where $[\alpha]$ = specific rotation

t = temperature of the measurement

λ = wavelength of the light used (usually sodium D line, 5893 Å)

α = observed angle of rotation

l = length of sample tube in decimeter

c = concentration of the sample in g/mL of solution

For example, the specific rotation of cane sugar (sucrose) in water is $[\alpha]_D^{20} = +66.4^\circ$.

In most cases, the concentration of the sample g/mL of solution and the solvent used are reported in parentheses after the value of the specific rotation. For example, the specific rotation of camphor is $[\alpha]_D^{20} = -44.2^\circ$ ($c = 0.165$, ethanol).

$$\text{Molecular rotation } [M]_{\lambda}^t = \frac{[\alpha]_{\lambda}^t \times \text{mol. wt.}}{100}$$

mol. wt. = the molecular weight of the optically active compound.

The specific and molecular rotations of a compound are its characteristic property similar to m.p., b.p., density, and refractive index.

3.4 CHIRALITY

The term chiral (Greek : *cheir* = hand) was first introduced by Kelvin (1884) for those objects which have "handedness", i.e., object and mirror-image relationship of a left and right hand.

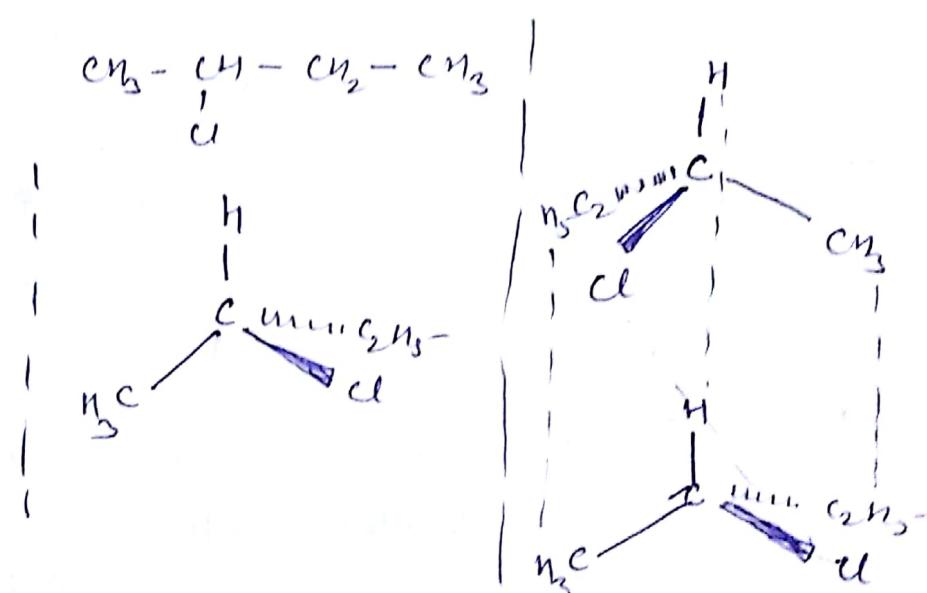
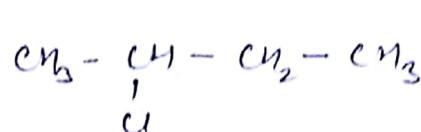
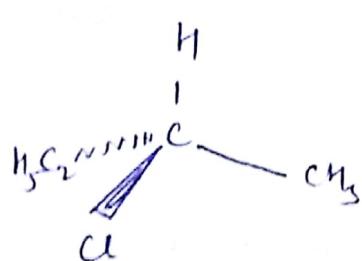
(3rd) 4) Enantiomers:

The molecules whose structures are non-superimposable on their mirror images are called enantiomers. They rotate the plane polarized light equally but in opposite directions. This phenomenon is called enantiomerism.

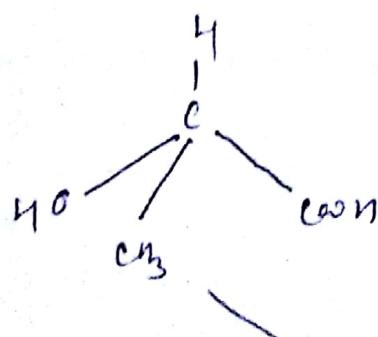
These enantiomers are represented as (+) or (d) and (-) or (l). It may be noted that the enantiomers are due to non-superimposability of mirror images and gives them the property of optical activity. Therefore, enantiomers are also called as optical isomers.

for eg:

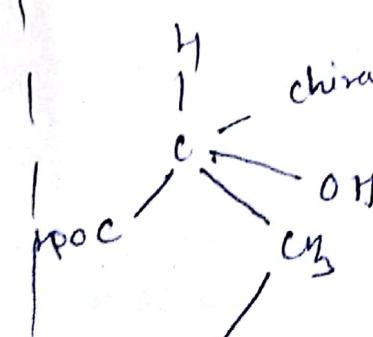
i) 2-chlorobutane



ii) Lactic Acid



mirror



chiral carbon
or
Asymmetric carbon

enantiomers
non-superimposable mirror image (Optically active)

to axis AB

Dissymmetry - Condition for Enantiomerism :-

Ti: The essential criterion for chirality of a molecule i.e. To form enantiomers (non-superimposable mirror image) is the dissymmetry (absence of plane of symmetry). In other words, the fundamental condition for enantiomerism is dissymmetry.

Characteristics of Enantiomer

- 1) Optically active — The two enantiomers rotate the plane polarized light exactly to the same extent but in the opposite directions.
- ii) No plane of symmetry : — Do not have plane of symmetry.
- iii) Identical physical properties such as M.P., B.P., density, solubility etc.
- iv) Identical chemical properties: → They form same products. However, they differ in the reactivity towards other optically active substances.

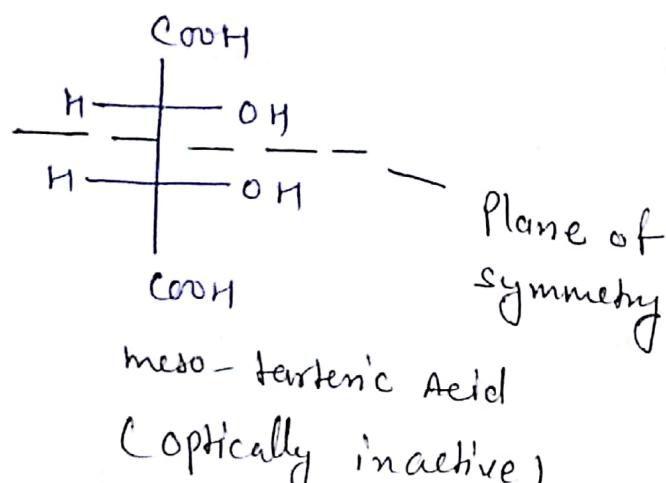
Element of Symmetry -

- optically active structure mainly related to lack of symmetry in molecular structure.
- To determine whether a molecule is symmetrical or not involves three criteria of symmetry ~~lakhs~~ Element of symmetry.
- A chiral molecule, though not always contains at least one chiral molecule, or asymmetric carbon atom. Asymmetric carbon means lack of symmetry.
- These help us to determine whether a molecule is chiral or achiral.
- A molecule as a whole is asymmetric if it does not possess any element of symmetry such as:
 - 1) Plane of symmetry
 - 2) Centre of "
 - 3) axis of "
 - 4) Alternating axis of symmetry.
- * Element of symmetry offers a simple device to decide whether a molecule (or object) is chiral or not. i.e whether it is superimposable on its mirror image or not. When a molecule has element of symmetry, it is superimposable on its mirror image and is achiral optically inactive.

1. Plane of symmetry - (σ)

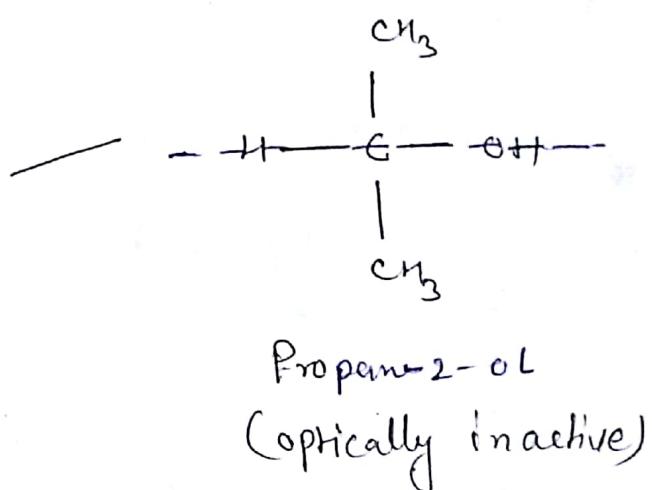
A molecule has plane of symmetry if an imaginary plane when passed through the molecule bisects the molecule so that half the molecule is the mirror image of the other half. It is also called a "σ" (sigma) plane.

e.g.: meso-tartaric acid



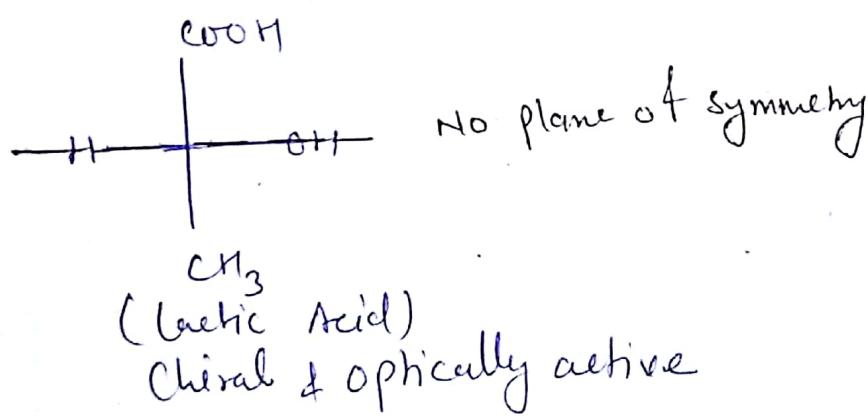
meso-tartaric Acid

(Optically inactive)



Propane-2-ol

(Optically inactive)

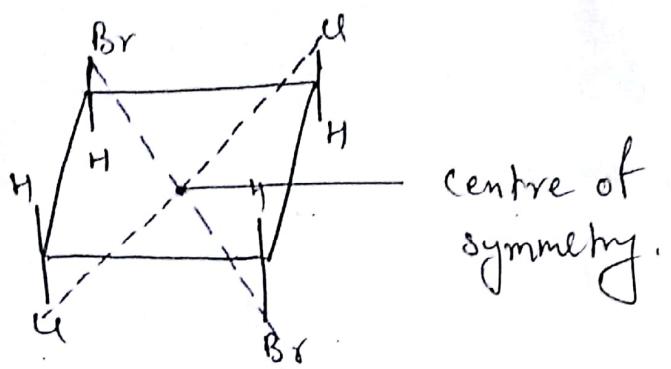


CH₃
(Lactic Acid)

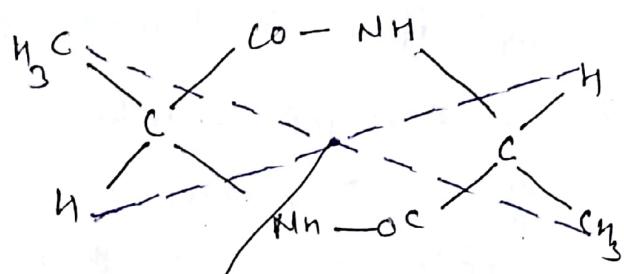
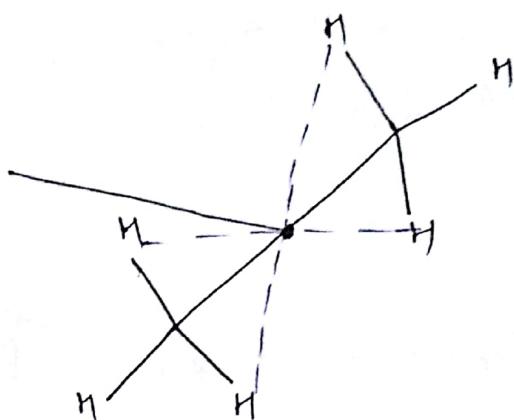
Chiral & optically active

2. Centre of symmetry - (i)

A molecule is said to have centre of symmetry, if any line drawn from the centre of the molecule meets identical atoms at equal distance from the centre.



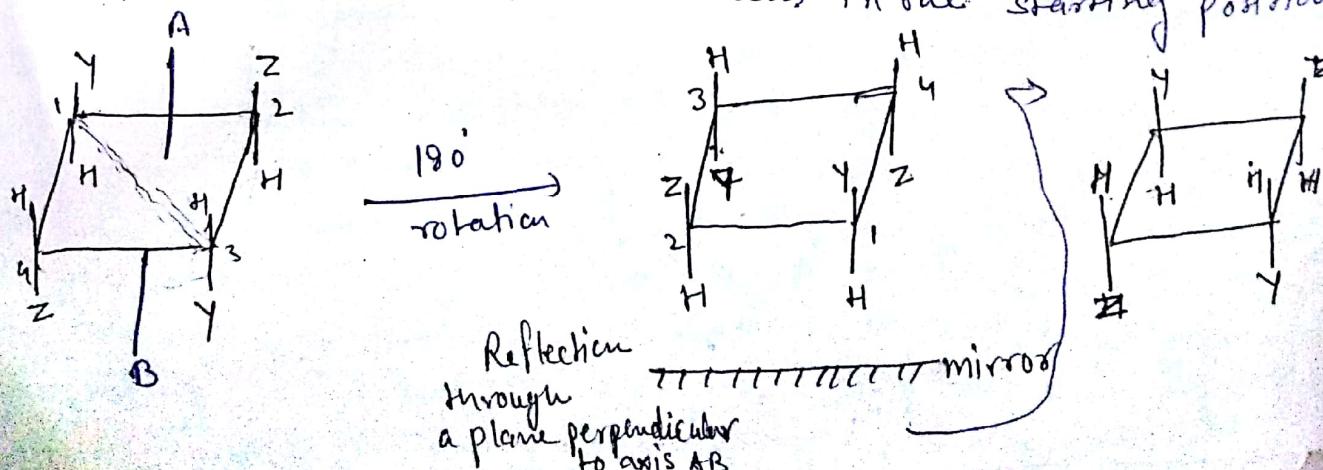
Optically Inactive



Centre of symmetry
Optically inactive

3 Alternating Axis of symmetry

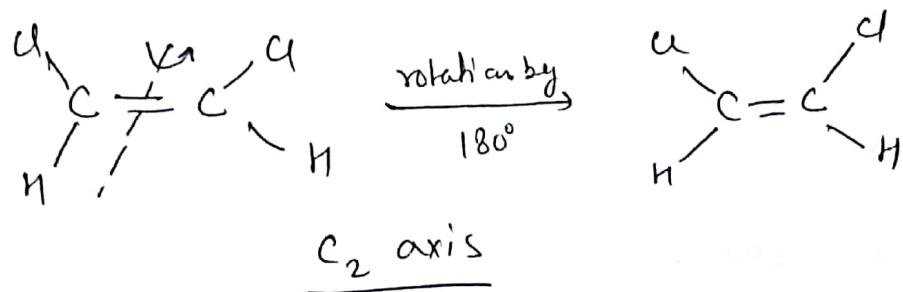
A molecule possesses an n -fold alternating axis of symmetry if it is rotated through an angle of $360^\circ/n$ about this axis and then reflected in a plane perpendicular to the axis the molecule is the same as it was in the starting position.



Thus, the molecule has a two-fold ($360/180 = 2$) alternating axis of symmetry. Hence it is achiral.

4. Simple or Proper or Rotational Axis of Symmetry (C_n)

A molecule is said to have a simple symmetry axis (C_n) of multiplicity (means circulate also called of order n or n fold axis of symmetry) if a rotation of $360^\circ/n$ around this axis leads to an arrangement which is indistinguishable from the original. The axis is designated as C_n where $C_n = 360^\circ/\theta$ where θ is the no. of degrees of rotation required for superimposition on the original. $C_2 = 180^\circ$ rotation.



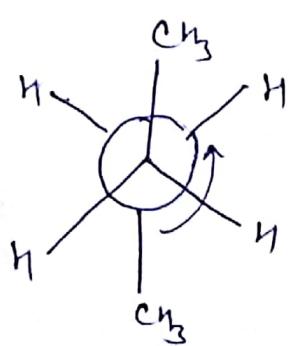
Conformations:

Conformations of a molecule are three-dimensional arrangement that differ only by rotation around a single bond. This is due to cylindrically symmetrical nature of σ MO's along the internuclear axis. As a result free rotation around C-C single bond is possible and it requires very little energy for rotation.

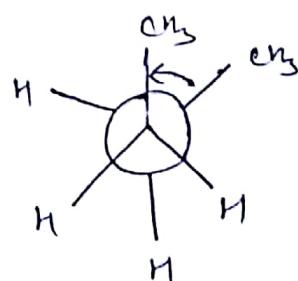
Each increment of rotation, however small, produces a change of conformation. In particular, the atoms remain connected in the same order during conformational changes with bonds being neither formed nor broken.

The infinite no. of momentary arrangement of atoms or groups in space due to free rotation around C-C single bond are called conformers or rotamers and this phenomenon is called conformational isomerism.

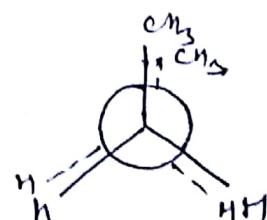
However, certain conformations are more stable than others and are preferred.



Staggered
or
(Anti $^{\circ}$)



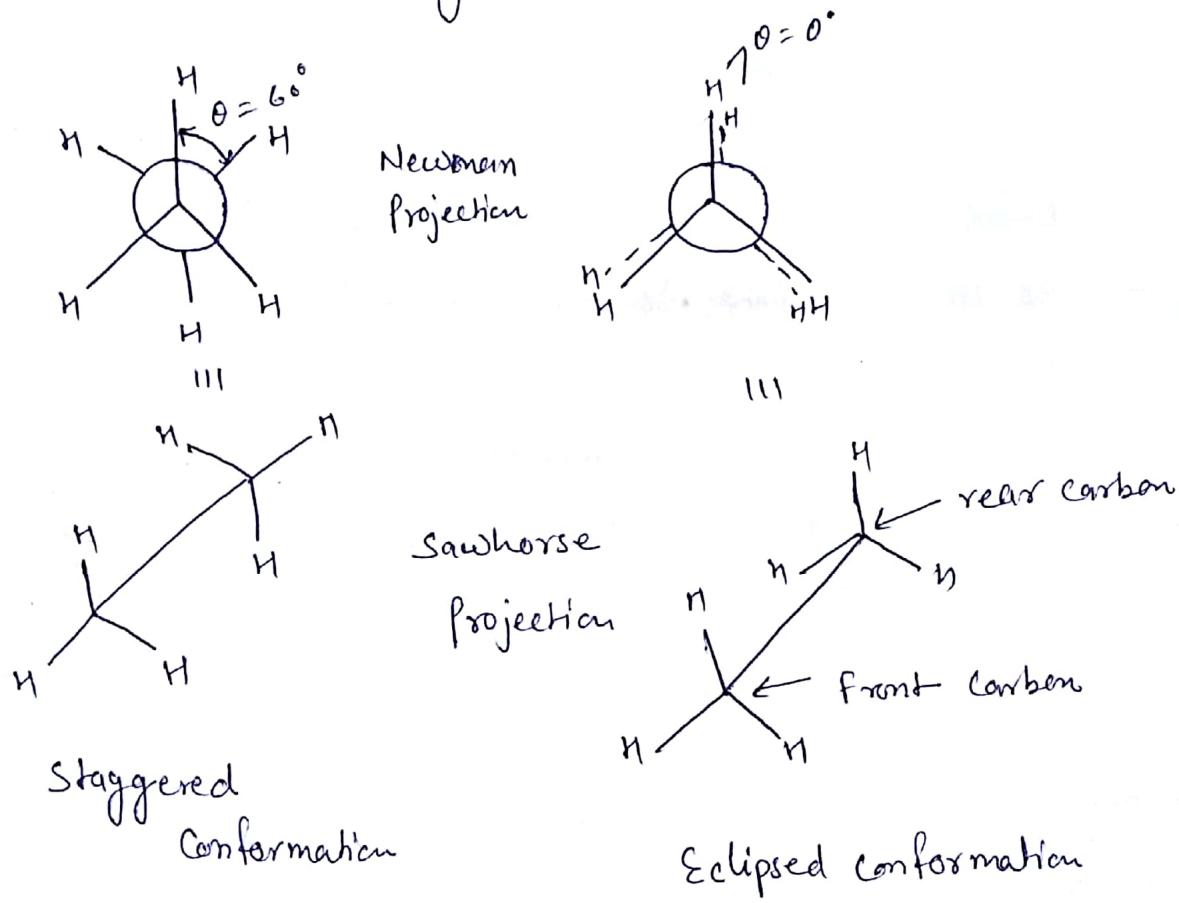
Gauche



Eclipsed

Conformational Analysis of Ethene

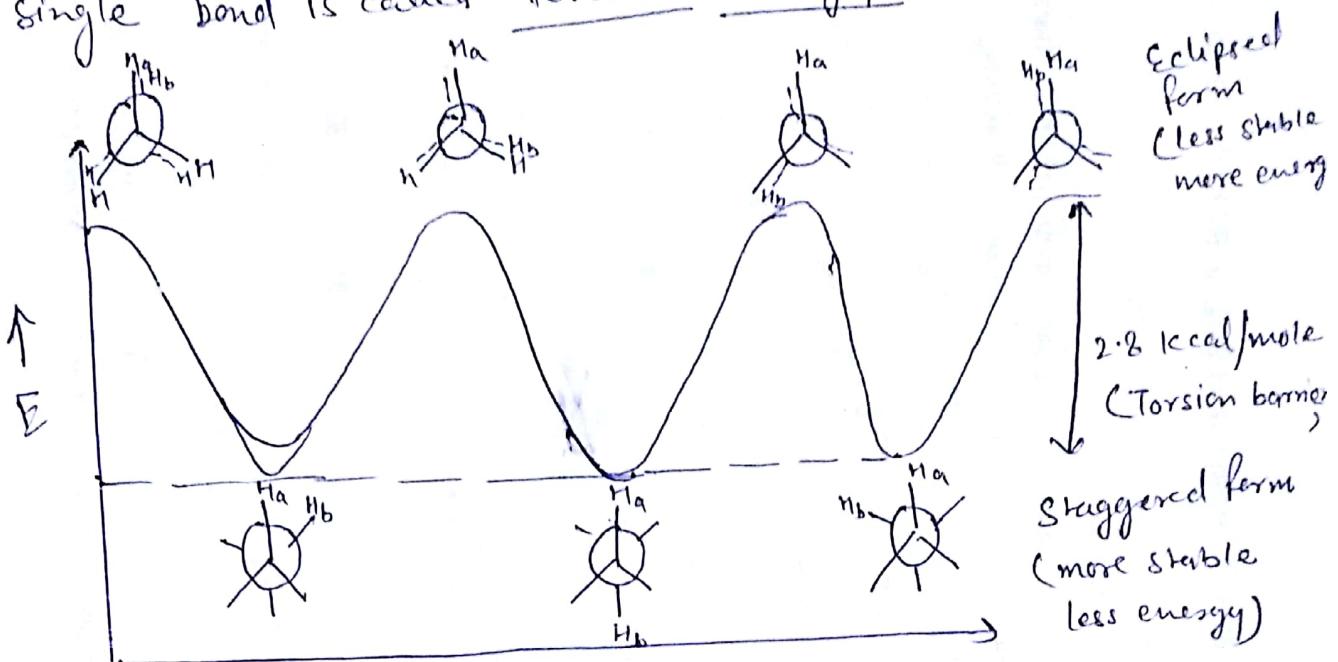
Ethene can have a continuous series of conformations as rotation proceeds around the C-C single bond. Any of these conformations can be specified by its dihedral angle (θ), i.e. the angle between the C-H bonds on the front carbon and C-H bonds on the rear carbon atom in the Newman projection. Thus, there are two limiting possibilities for the dihedral angle in ethene.



The conformation in which the Hydrogen atoms are as far as possible ($\theta = 60^\circ$) is called staggered conformation, whereas the conformation, when $\theta = 0^\circ$, is called eclipsed conformation because the Hydrogen atoms on the rear carbon in the Newman projection are eclipsed (as close as possible) by the Hydrogen atoms on the front carbon. Any other intermediate is called a skew conformation.

The eclipsed conformation of ethene is about 2.8 kcal/mole higher in energy than the staggered conformation.

The energy required to rotate the molecule about C-C single bond is called torsional energy.



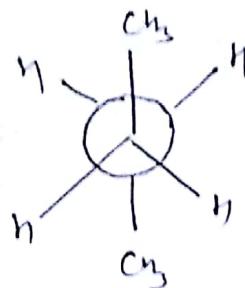
Degree of rotation C-C bond
in ethene

Torsional strain energy vs bond rotation energy

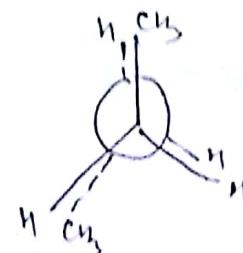
Figure clearly reveals that the eclipsed conformations are of highest energy & the staggered conformations are of lowest energy (more stable), the energy b/w the highest & lowest energy conformation is about 2.8 kcal/mole. and is referred to as the torsional torsion barrier.

⇒ Conformational Analysis of n-Butane

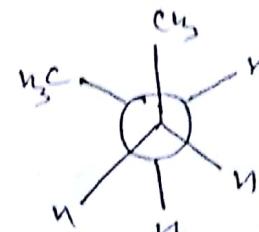
Rotation of C-C bond by 60°



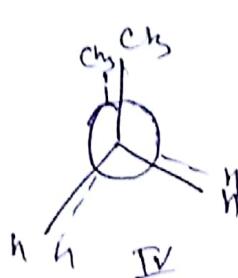
Anti or
staggered



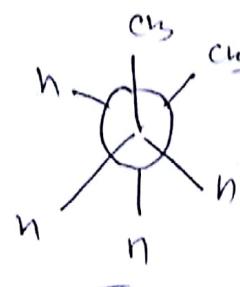
Eclipsed ^{II}



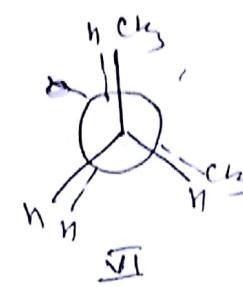
Gauche ^{III}



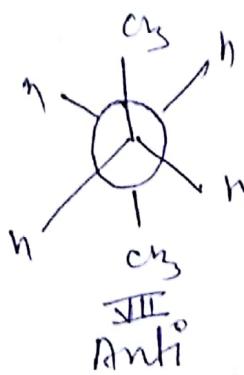
fully eclipsed



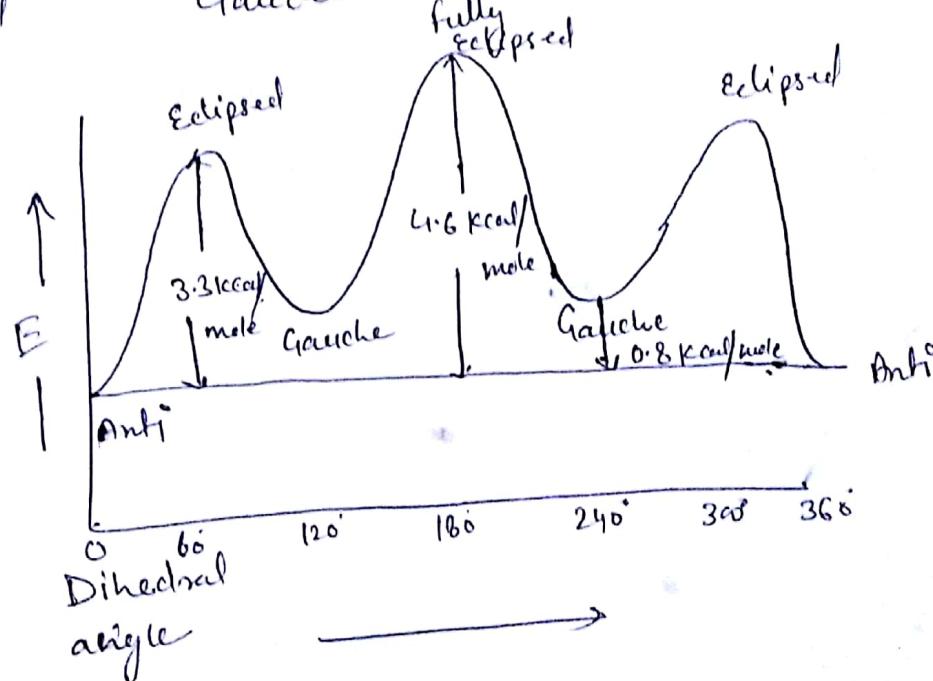
Gauche ^{IV}



Eclipsed ^V



Anti ^{VI}



Conformations of cyclohexane:-

A cyclohexane ring can assume many shapes and any single cyclohexane molecule is in a continuous state of flexing or flipping into different shapes. It exists in four conformation i.e chair, half chair, twist boat & boat form.

~~(D)~~

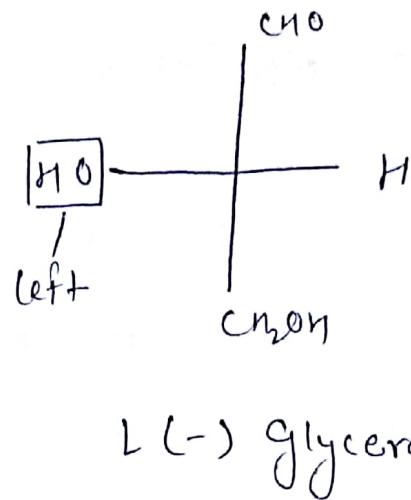
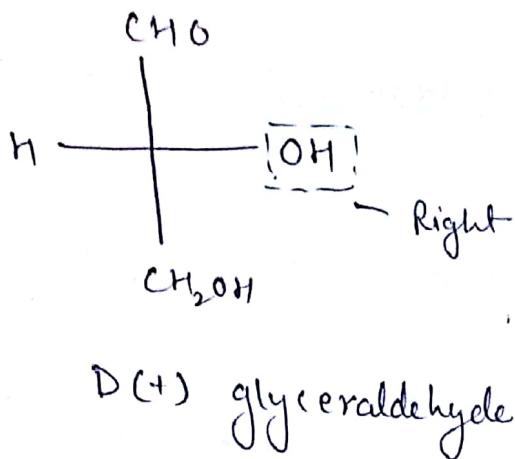
Configurational Notation for optical isomers

To define the structure of a compound completely it is necessary to specify configuration at each chiral centre. Following are the different ways to assign configuration to stereoisomers.

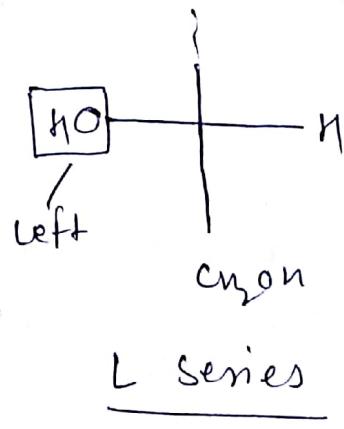
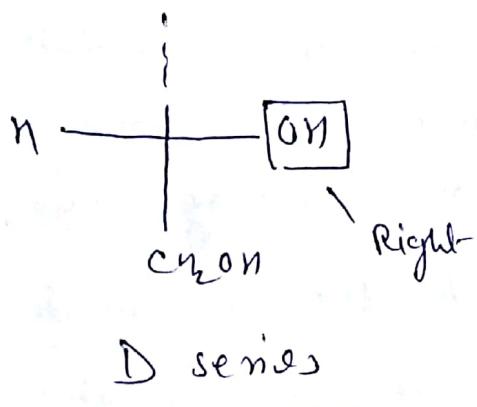
- a) Relative configuration (D, L Notation)
- b) Absolute Configuration (R, S Notation)
- c) ~~E~~
- a) Relative Configuration (D, L Notation)

Before 1951, there was no method for determining the absolute configuration, hence the configuration of molecules were described with respect to glyceraldehyde, which was arbitrarily chosen as a standard by Rosanoff (1906). All the configurations described with respect to glyceraldehyde are called relative configuration.

(+) Glyceraldehyde having the -OH group on the right and H on the left, the -CHO and -CH₂OH group being on the top and bottom, respectively was arbitrarily given the configurational symbol 'D'.
(-) glyceraldehyde having the -OH group ~~on~~ on the left side and given the configurational symbol 'L'.



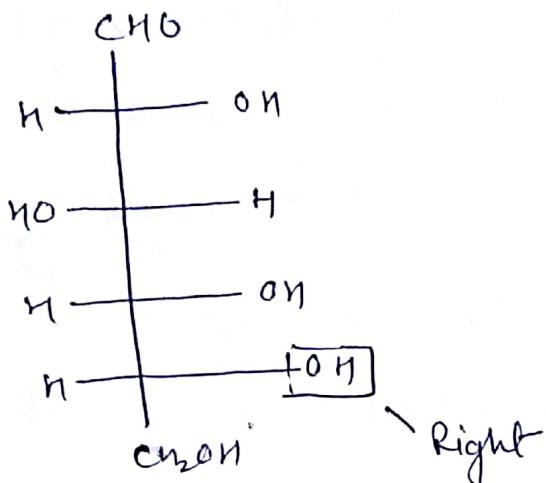
Any compound that can be prepared from, or converted into $\text{D}(+)$ glyceraldehyde will belong to D series, and similarly any compound that can be prepared from or converted into $\text{L}(-)$ glyceraldehyde will belong to L series.



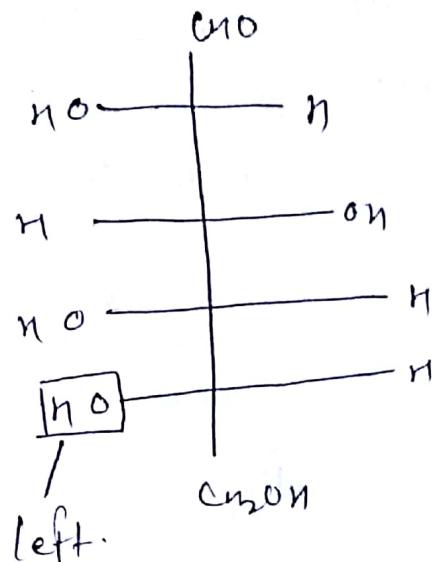
The (+) enantiomer in which -OH group attached to chiral carbon is towards right, was given the symbol D, the

(-) enantiomer in which -OH group attached to chiral carbon is towards left was given the symbol L.

→ In compound containing several chiral carbon atoms, the bottom most chiral centre is related to glyceraldehyde.

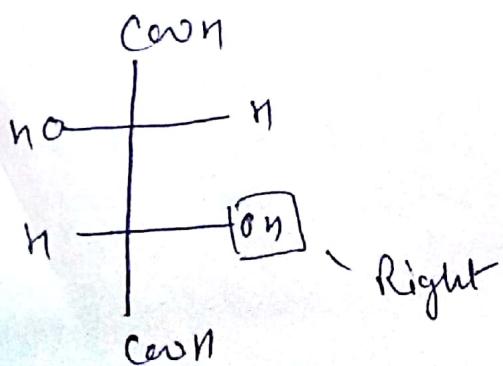


D(+) glucose

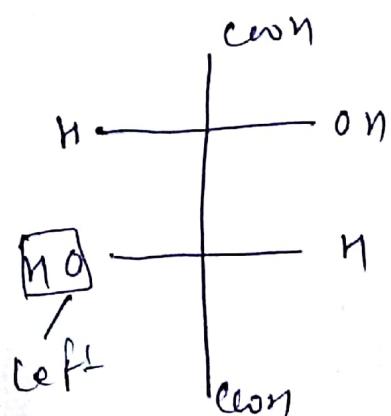


L(-) glucose

→ The (+) & (-) sign in parenthesis refers only to direction of rotation while capital letters D & L denote the configurational relationship i.e. there is no relationship b/w configuration & direction of ^{PPL}~~rotation~~



D(-)-Tartaric acid



L(+) Tartaric acid

2) Absolute configuration (R, S Notation)

F₂
mm

There are several drawbacks of D, L nomenclature.
Thus, an unambiguous and universally applicable system
for specifying the absolute configuration of each chiral
centre in a molecule was devised by Cahn - Ingold - Prelog.

Absolute configuration :-

or groups in space around a chiral carbon atom is called
Absolute configuration.

R/S Nomenclature (Absolute configuration)

- (i) Assign priorities to the four substituents linked to the chiral centre according to the Cahn-Ingold-Prelog convention.
- (ii) If the lowest priority group is on the vertical line (either top or bottom) then assign configuration by tracing a path of other three groups.
- (iii) If the lowest priority group is not on the vertical line then perform even no. of interchanges to place the lowest priority group on one of the vertical positions (top or bottom).

Alternatively, if the lowest priority group does not lie on positions of the vertical line (i.e. top or bottom) then move the eye from the top priority group to the third priority group via the second priority one. In doing so, if the configuration comes out as "S", actually it is reported as "R" and vice versa. (GOLDEN RULE)

CIP Sequence Rule :-

1)

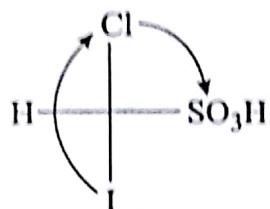


3.6.3 Sequence Rules

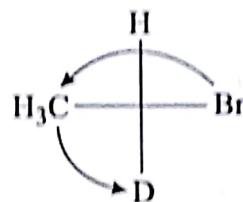
The priorities of the four ligands (atoms or groups) attached to a chiral centre are decided by applying the following sequence rules in turn, as long as necessary to reach a decision. The sequence rules are arbitrary but consistent.

- 1 If all the four atoms directly attached to the chiral centre are different, sequence of priorities is determined by their atomic numbers, the atom of higher atomic number is given higher priority. If two atoms are isotopes of the same element, the isotope of higher mass number has the higher priority.

For example, in chloroiodomethanesulphonic acid the sequence is I > Cl > S > H, where > denotes "has higher priority;" in α -deuteroethyl bromide it is Br > C > D > H.



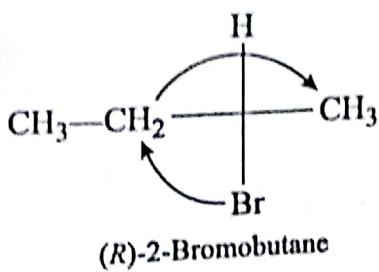
Chloroiodomethanesulphonic acid
S configuration; (I → Cl → S sequence
is clockwise but the group of lowest
priority (H) is on the horizontal line,
hence the configuration will be S)



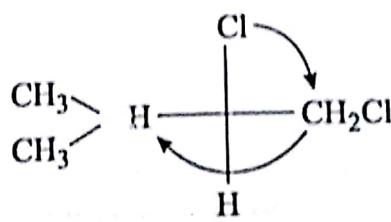
α -deuteroethyl bromide (Br → CH₃ → D
sequence is anticlockwise and the group of
lowest priority (H) is on the vertical line,
hence the configuration will be S)

2. If two or more atoms attached to the chiral centre are the same, the priority is decided by applying the sequence rule 1 to the next to the next atoms in the groups and so on, if necessary, working outward from the chiral centre. When a group has branches the branch of highest priority is followed.

For example, in 2-bromobutane two of the atoms directly attached to the chiral centre are carbon. In CH₃ the second atoms are H, H, H; in C₂H₅ they are C, H, H. Since carbon has a higher atomic number than hydrogen, C₂H₅ has the higher priority than CH₃. Therefore, a complete sequence of priority for 2-bromobutane is Br > C₂H₅ > CH₃ > H.



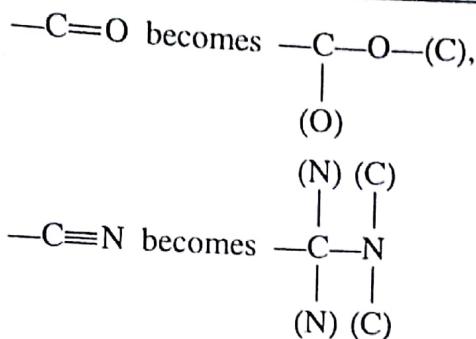
(R)-2-Bromobutane



(R)-1,2-Dichloro-3-methylbutane

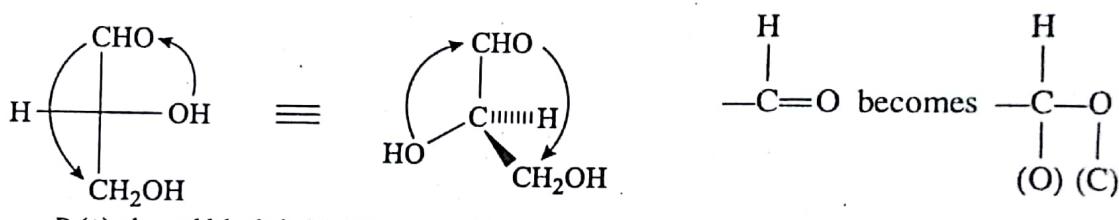
In 1, 2-dichloro-3-methylbutane the Cl, H, H of CH₂Cl has a higher priority than the C, C, H of isopropyl. Chlorine has a higher atomic number than carbon, and the fact that there are two C's and only one Cl does not matter. One higher number is worth than two or three of a lower number.

3. If there is a double or triple bond, both double or triple bonded atoms are considered to be duplicated or triplicated. The priority sequence is then, determined by considering the structure containing the duplicated or triplicated atoms. Thus,



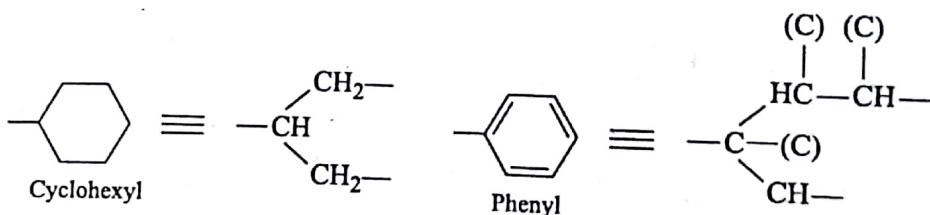
The *phantom (duplicate) atoms* are enclosed in parentheses and bear no further substituents. For example :

In glyceraldehyde the ---OH group has highest priority and the O, O, H of ---CHO takes priority over O, H, H of $\text{---CH}_2\text{OH}$. Thus, the complete sequence of priority is $\text{---OH} > \text{---CHO} > \text{---CH}_2\text{OH} > \text{H}$.



D-(+)-glyceraldehyde is (*R*)-(+)-glyceraldehyde

Ring systems are treated as branched chains, and if unsaturated, then duplication is used for a double bond or triplication for a triple bond. Thus, the C, C, C of a phenyl group takes priority over C, C, H of a cyclohexyl group.

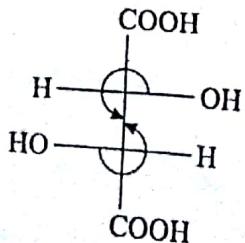


By using the above sequence rules, some common ligands are given the following order of priority sequence :

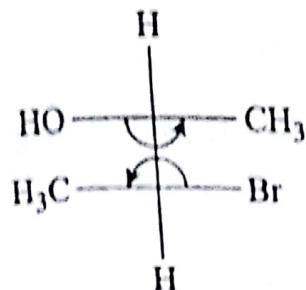
I, Br, Cl, SO_3H , SH, F, OCOR, OR, OH, NO_2 , NR_2 , NHR, NH_2 , COOR, COOH, COR, CHO, CH_2OH , CN, Ph, CR₃, CHR₂, CH₂R, CH₃, D, H.

On the basis of the above discussion, the designations *R* and *S* have been assigned to the following absolute configurations of some molecules as examples :

When a molecule contains two chiral centres, each chiral centre is assigned an *R* or *S* configuration according to the sequence and conversion rules. Thus, (+) tartaric acid is

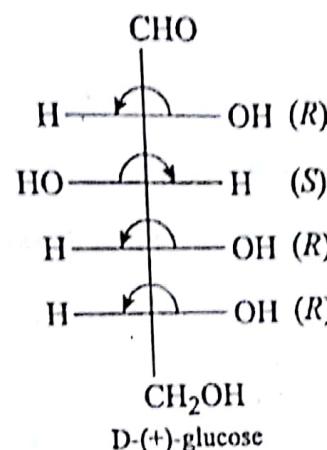


The group of lowest priority, i.e., H is on the horizontal line at both the chiral centres, hence the anticlockwise sequence of the remaining groups shows *R* configuration.

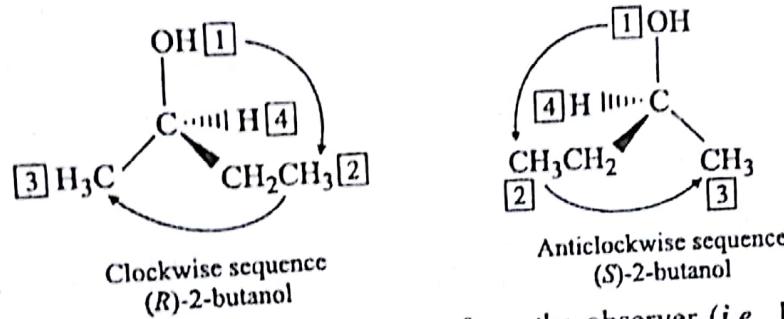


In 3-bromo-2-butanol, H is on the vertical line at the chiral centres, hence the anticlockwise sequence of the remaining groups gives S configuration.

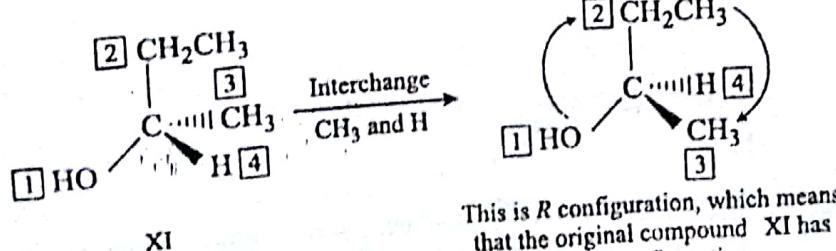
Applying the rule that if the group of lowest priority (H) is on the horizontal line then clockwise sequence gives S and anticlockwise sequence R configuration; the correct designation assigned to D-(+)-glucose is given on the next page :



The assignment of R and S configuration to both the enantiomers of 2-butanol represented by flying-wedge formula is shown below :



- If the group of the lowest priority is away from the observer (i.e., bonded by dashed line) and the priority sequence ($1 \rightarrow 2 \rightarrow 3$) is clockwise, then the configuration is assigned as R as shown above.
- If the group of the lowest priority is not bonded by dashed line (i.e., not away from the observer) then interchange a pair of groups so that the group with the lowest priority is bonded by dashed line. Now see the sequence ($1 \rightarrow 2 \rightarrow 3$), if it is clockwise then the configuration is assigned as S, and if anticlockwise R. This is because you have interchanged a pair of groups and now you are determining the configuration of enantiomer of the original molecule.



This is R configuration, which means that the original compound XI has the S configuration

hydrogens, so *t*-Bu has a much larger preference for the equatorial position than the other alkyl groups. Actually, the interactions between an axial *t*-butyl group and the axial hydrogen atoms are so severe that the *t*-Bu group virtually always stays in the equatorial position.

3.18 DIFFERENCE BETWEEN CONFORMATION AND CONFIGURATION

Conformation	Configuration
<ul style="list-style-type: none"> (i) Conformations of a molecule are the different spatial arrangements of its atoms and groups that arise due to the rotation of a part of the molecule about a single bond. (ii) Conformations have low energy barrier, which varies from 4.2 to 46 kJ per mole. (iii) Conformers are non-isolable. (iv) Conformations are easily interconvertible, they get converted even at room temperature. (v) Interconversions of conformations involve rotation of a part of a molecule about a single bond. (vi) A molecule could have an infinite number of conformations. 	<ul style="list-style-type: none"> (i) Configuration of a molecule is the spatial arrangement of atoms and groups about a rigid part of the molecule, i.e., about a double bond or ring and about a dissymmetric part of the molecule. (ii) Difference of energy between two configurations is more than 84 kJ/mole. (iii) Configurations are isolable. (iv) Configurations are not easily interconvertible. (v) Interconversions of configurations involve bond breaking and bond reforming processes. (vi) A molecule can have only one configuration, i.e., a different configuration is a different molecule.

VERY SHORT ANSWER QUESTIONS

- What is essential criterion?