

# Stereochemistry

## Isomers

Constitutional

Stereoisomer

Conformation

Configuration

↓  
Sawhorse formula.  
Newman projection.

↓  
Geometrical Isomerism  
Optical Isomerism

Optical

Geometrical

Enantiomerism

Diastereomeres

Cis

Trans

Compound containing  
one chiral atom.

Compounds containing  
2 chiral central atoms

\* **Isomers** - Chemical compounds that have identical chemical formula but differ in props and arrangement of ~~materials~~ atoms in the molecule are called isomers

→ A molecule can be several types of isomer at same time, depending on which molecule ~~are~~ you are comparing to

→ Eg:-  $CH_4$ ,  $C_2H_6$ ,  $C_3H_8$  do not show any isomerism as they doesn't have a sufficient no. of carbon atom.

→ No. of C atoms ↑ No. of possible isomers ↑

Some molecular formula

→ **Constitutional Isomers**:- Structure Isomers that share same molecular formula but diff. bonding patterns. (Only IUPAC named numbering are

~~2 Stereoisomers~~



$C_6H_{12}$

Cyclohexane



$C_6H_{12}$

1-hexene



$C_6H_{12}$

2-hexene

→ Stereoisomers:- Molecule which have same connectivity but a different arrangement of their atoms in space.

→ Two Types

### Conformational

① Stereoisomers which differ in relative position of some of atoms in the space due to rotation about a sigma bond are called conformational.

② Interconversion of these molecule do not require breaking & remarking of covalent bond.

③ Can interconvert at room temp.

③ Energy is ~~more~~ less than 60KJ

### Configurational

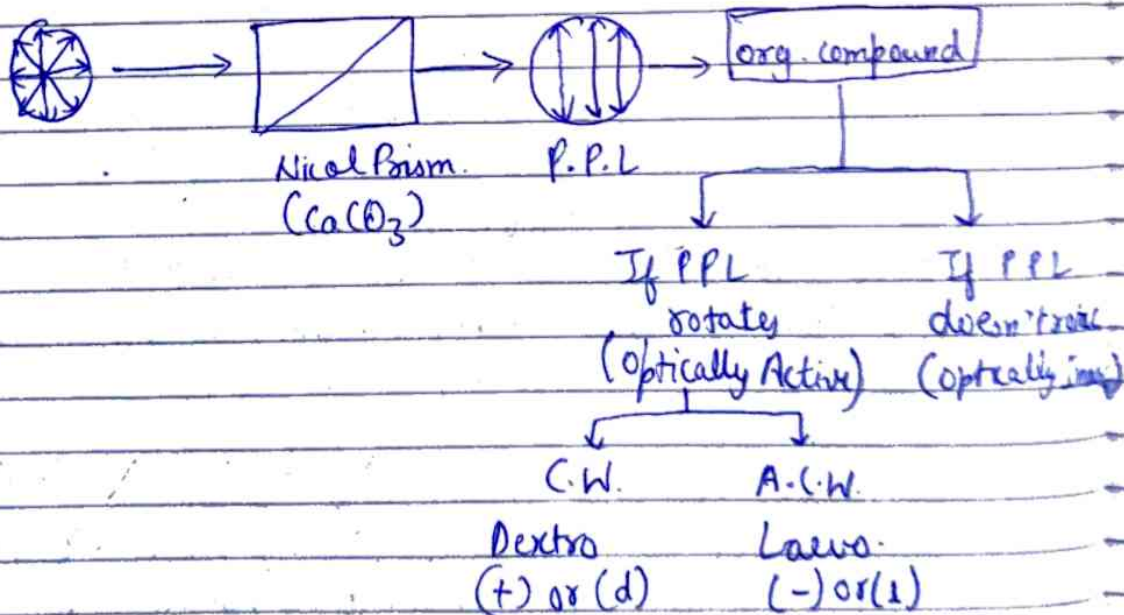
① which arise due to a some sort of rigidity within the molecule and which can be interconverted by breaking and remarking of covalent bond not by rotation about a sigma bond.

② Those which can't be interconvert at room temp.

③ Energy is more than 60KJ

\* Optical Isomerism.

→ Polarimeter Exp.





→ Condition for ~~Exhibition~~ Exhibition of C.I.

POS (Plane of Symmetry)

COS (Centre of Symmetry)

POS ✓ COS X O.I.A

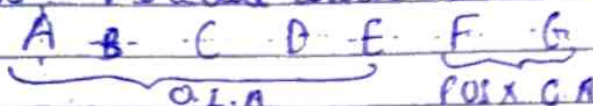
POS ✓ COS ✓ O.I.A

POS X COS ✓ O.I.A

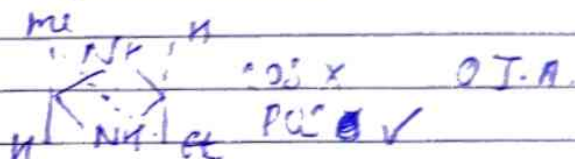
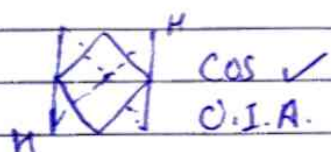
POS X COS X O.I.A

Always check POS first

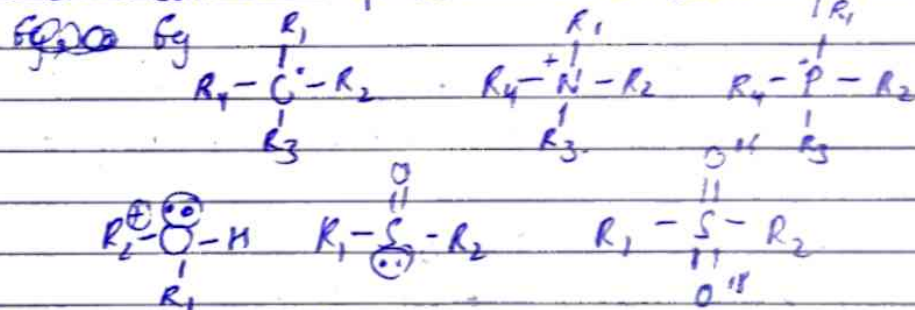
→ POS - molecule which divides into 2 equal halves



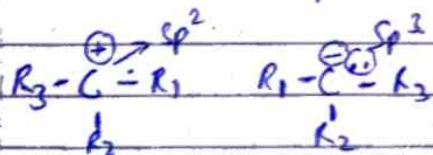
→ COS :- Diagonally opp line khecks to same grp rule and there should be symmetry



→ Chiral center:-  $sp^3$  atom attached with four diff. grps



• Chiral Carbon-  $sp^3$  C atom attached with 4 diff grps

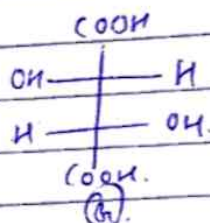
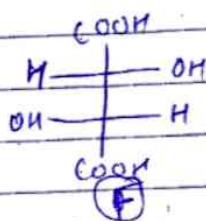
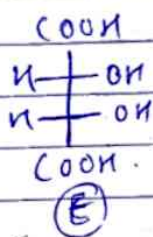
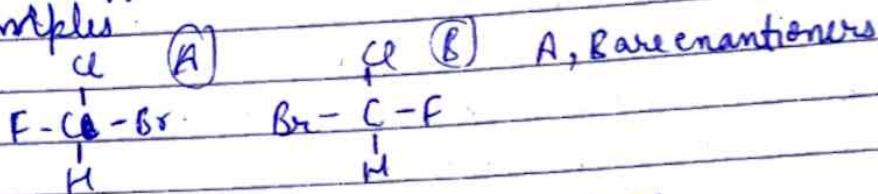


→ Molecules that are superimposable with their mirror image are 'achiral' while which do not superimose are 'chiral'

→ Racemic modification

- Enantiomers → Two isomers which are mirror images of each other but are not superposable are called enantiomers and have enantiomeric relationship.
- Have same phy and chemical prop except they turn P.L. to equal degree but in opp. direction.
- Diastereomers: Isomers which are not mirror images of each other. Diff. Chem and phy props. Can be separated

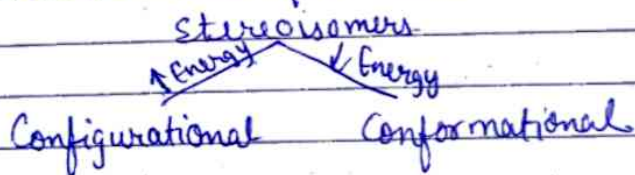
Examples



(F) & (G) are enantiomers

(A) & (E) & (F), (E) & (G) are diastereomers

- Stereoisomers: Classification on basis of energy barrier



- \* Racemic modification: Equimolar mixture of two enantiomers of chiral molecule. Also known as racemic mixture or racemate. Denoted by prefix (+) or (dl) - before the name of compound.
- Racemic modification is optically inactive due to external compensation i.e. (+) rotation of one enantiomer is compensated by (-) rotation of other.
- Process by which an optically active substance is transformed into corresponding racemic modification is known as racemization. Eg:- tartaric acid.



The reverse process by which a racemic modification is separated into 2 enantiomers is called resolution.

Page No.

Date

→ Thermodynamic Prop.

When racemate is formed, there is  $\Delta S$  of mixing.

$$\Delta S = -R X_1 \ln X_1 - R X_2 \ln X_2$$

$$= -R \ln \frac{1}{2} = R \ln 2$$

$$= 6 \text{ J mol}^{-1} \text{ degree}^{-1}$$

as  $\Delta S$  is ~~pos~~ +ve and at 300K,  $\Delta G$  is -ve, this means racemisation is thermodynamically stable & a spontaneous process.

→ Classification of racemic mixture (nature of packing in crystal lattice)

① Racemic conglomerate  $\rightarrow A \begin{bmatrix} + \\ + \end{bmatrix} + B \begin{bmatrix} - \\ - \end{bmatrix} \rightarrow AB$ . Crystal lattice is formed entirely from enantiomers of like <sup>chirality</sup>.

② Racemic compound  $\rightarrow A \begin{bmatrix} + \\ - \end{bmatrix} + B \begin{bmatrix} - \\ + \end{bmatrix} \rightarrow AB$

Crystal unit contain equal no. of (+) or (-) enantiomers

③ Pseudoracemate  $\rightarrow A \begin{bmatrix} + \\ + \end{bmatrix}$  or  $B \begin{bmatrix} - \\ - \end{bmatrix} \rightarrow AB$ .

Crystal unit is formed indiscriminately from both enantiomers

④ Quasiracemates  $\rightarrow$  Mixture of two similar but distinct compounds in which one is left handed and another is right handed. They are chemically different but sterically similar.

Eg:- (+) Chlorosuccinic acid (-) Bromosuccinic acid

→ Optical rotation:- measurement of rotation of P.P. in degree. Depends upon  $T$ ,  $\lambda$ , conc. of length of tube.

$$[\alpha]_D = \frac{\text{Obs. Rotation}}{c \times l} \quad \begin{matrix} c \rightarrow \text{gm/mL} \\ l \rightarrow \text{dm} \end{matrix}$$

Example. Enantiomers of 2 butanol

Obs. rotation  $\approx 4.05^\circ$  anticlockwise.

conc  $\rightarrow 6 \text{ gm} / 40 \text{ mL}$ ,  $l = 200 \text{ mm}$ .

$$[\alpha]_D = \frac{-4.05}{\frac{6}{40} \times 2} = -13.5^\circ$$

## → Optical purity

$$O_p = \frac{[\alpha]_{\text{obs}}}{[\alpha]_{\text{max}}} \times 100$$

$$\text{enantiomeric excess} \text{ or } ee = \frac{R-S}{R+S} \times 100$$

Q.  $[\alpha]_{\text{max}} = 23.1^\circ [S]$

$[\alpha]_{\text{obs}} = 9.2^\circ$

$$O_p \text{ or } ee = \frac{9.2}{23.1} \times 100 = 40\%$$

$$40\% S + 60\% R \&S.$$

$$S = 70\%, R = 30\%$$

Q.  $R:S = 95:5$

$$O_p \text{ or } ee = \frac{95-5}{95+5} \times 100 = 90\%$$

## ★ Separation of enantiomers.

### ① Mechanical separation.

#### ★ Enantiomers

- ① Have same phy. prop like B.P, M.P etc.
- ② They cannot be separated by phy methods like distillation.
- ③ Have same chem prop with achiral reagent.
- ④ Have diff chem prop with chiral reagent.

#### Distereomers

- ① Have diff. phy prop like B.P, M.P etc.
- ② Can be separated.
- ③ Chem prop. are similar
- ④ GI are known as diastereomers

## ★ Separation of enantiomers

### ① Mechanical Separation & Crystallisation method.

- Applicable only to racemic conglomerates.
- by Normal crystallisation can be separated as but require bigger crystal size to be picked from hand & check rotation by dissolving it.



- tedious method & not much practical application

## ② Resolution through formation of diastereomers

- Same enantiomers have common phy. props. So they cannot be separated by methods like crystallization or any other like distillation or chromatography.
- Diastereomers have diff. phy. props., so they can be separated easily by crystallisation and after separation on hydrolysis can get <sup>up</sup> ~~racemate~~ <sup>pure</sup> enantiomers.
- These facts can be used to achieve resolution of ~~racemate~~ <sup>racemate</sup>.
- Reaction of racemates with an enantiomerically pure chiral reagents gives a mixture of diastereomers which can be separated.

## ③ Resolution through formation of molecular complexes:-

- To separate enantiomers, we can make complexes of them by adding suitable complexing agent which can form easily and decompose easily.
- It should selectively complex only to one type of compound, so that both can be separated one by complexing & one left behind.
- Eg:- amides of (-) malic acid and of tartaric acid

## ④ Resolution by chromatography

There are 4 conditions for resolution

- Formation of diastereomeric mixtures by derivatisation with optically active reagents and separation by classical chromatography using achiral adsorbent
- Direct resolution of racemic mixture using chiral adsorbent materials either as solid or liquid stationary phase
- Direct resolution on an achiral solid phase using a mobile chiral liquid phase.

direct resolution using an achiral solid stationary phase modified by a chiral reagent

- (5) Resolution by chemical transformation.  
Resolution can also be done with the help of micro-organisms or enzymes, which are often stereoselective in their reactions.  
Eg:- Ammonium salt of (+) - tartaric acid is fermented by yeast, natural (+) form is completely consumed leaving behind the ammonium salt of (-) ~~tartrate~~ <sup>tartaric</sup> acid.

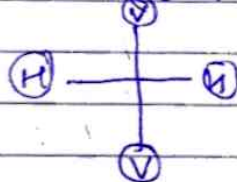
### \* Absolute configuration (R & S)

Case 1:- In Fischer Projection formula.

R  $\rightarrow$  Rectus (Clockwise)

S  $\rightarrow$  Sinister (Anticlockwise)

(CIP rule)



# (4) is on vertical.

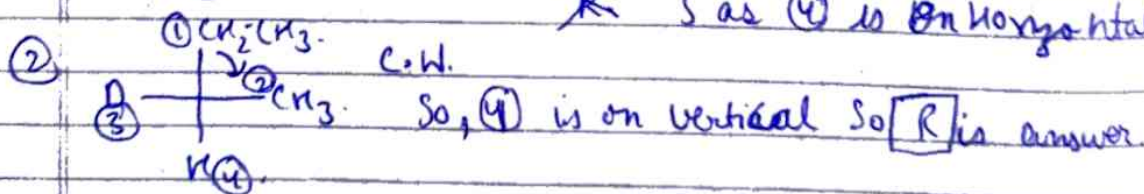
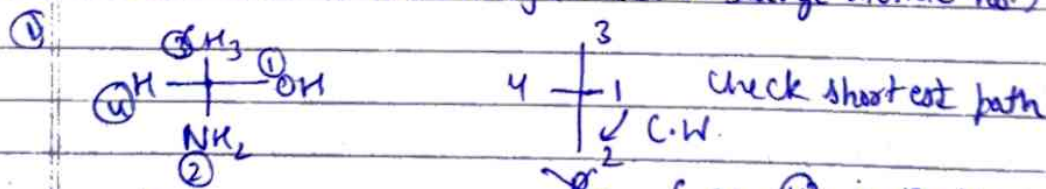
R  $\rightarrow$  R

S  $\rightarrow$  S

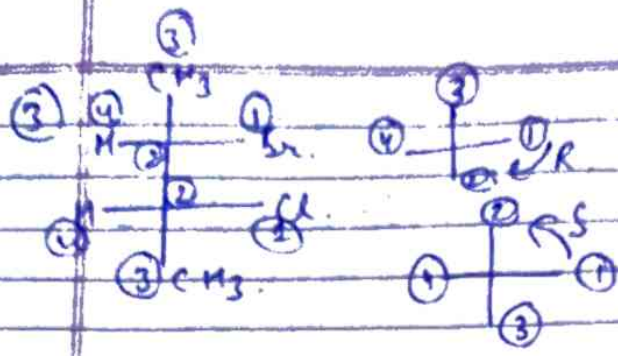
# (4) is on Horizontal.

R  $\rightarrow$  S, S  $\rightarrow$  R.

- Q Find R.S. (Numbering is acc to large atomic no.)



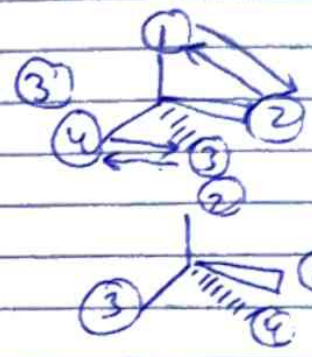
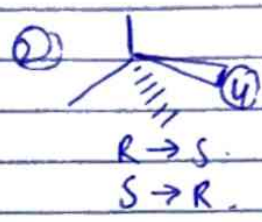
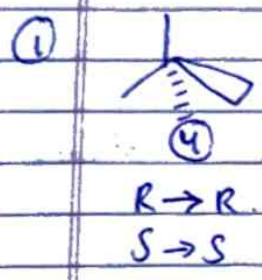




as 4 is on horizontal,  
~~R~~ [S] is answer

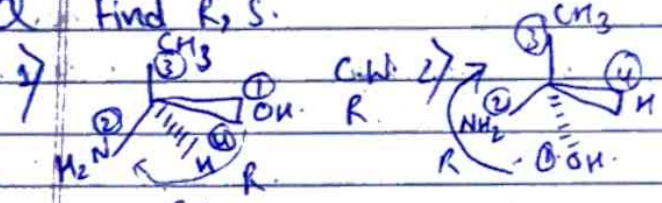
as 4 is on horizontal,  
 R is answer

Case 2:- In solid dash wedge.

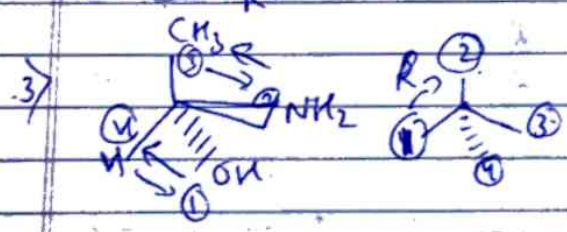


R → R, S → S

Q. Find R, S.



as 4 is on dash (solid)  
 R → S



R is answer

\* Relation b/w compounds

Case 1 In one chiral carbon → O.A

Identical  
 OR

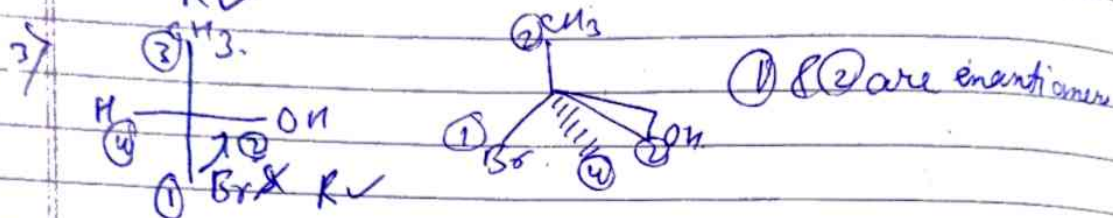
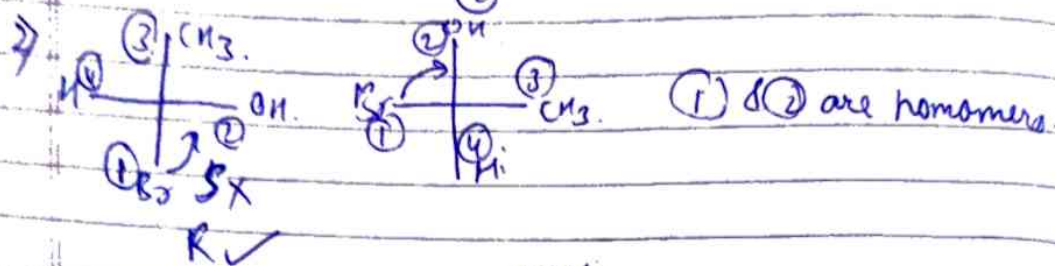
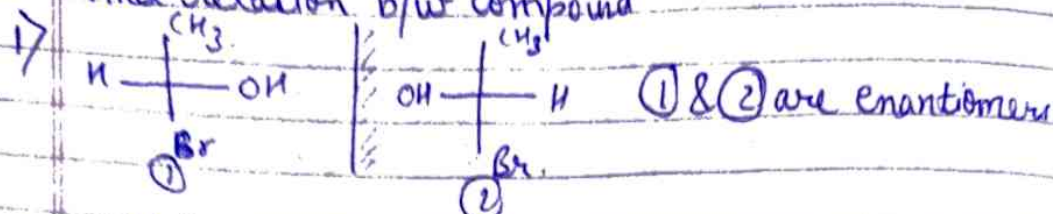
Enantiomer

non super imposable images

Homomer  
 ② ②  
 R R  
 S S

① ② ① ②  
 R S S R

Q Find relation b/w compound



Case 2 In 2 chiral carbon.

Identical.  
Same.

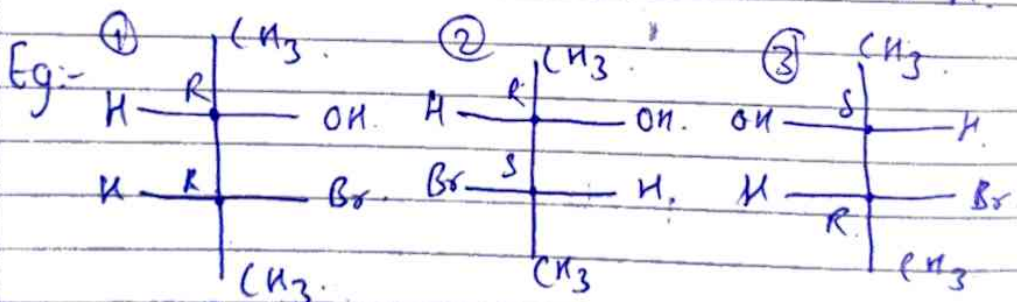
Enantiomer.  
non super... mirror images

Diastereomer  
non mirror image

R R  
R R  
S S  
S S

R S  
R S  
S R  
S R

R R  
R S  
S S  
S R



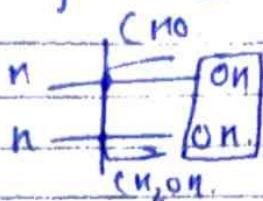
② & ③ are enantiomer.

① & ② Diastereomers as R R  
R S

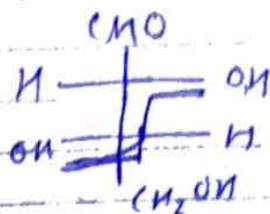
① & ③ are diastereomers



## \* Erythro & Threo.



Erythro.



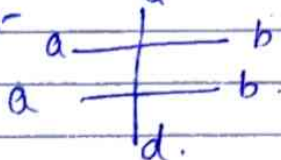
Threo.

\* Elements of Symmetry:- It helps to decide whether a molecule or object is chiral or not.

→ When molecule has a plane of symmetry (POS) or a COS or an axis of symmetry (AOS), it is superimposable on its mirror image and is achiral.

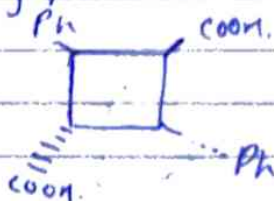
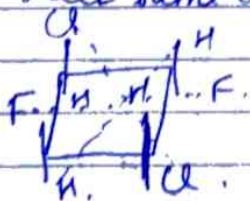
① POS:- ~~the~~ Plane which divides a molecule into 2 equal halves which are related as an object and mirror image is known as POS.

For Eg:-



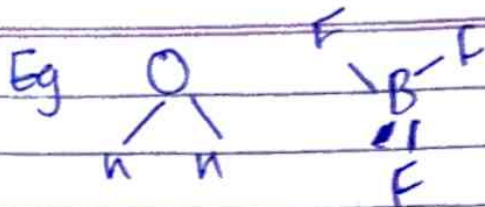
② COS:- Point in a ~~an~~ molecule from which if lines are drawn on one side and extended an equal distance on other side. Meet same atoms or groups.

Eg:-



③ Unit of symmetry:- If a molecule is rotated by an angle  $360^\circ$  about an imaginary axis passing through it, molecule is converted into a second molecule which is identical in all aspects.

$$C_n = \frac{360^\circ}{n}, \quad C_1 = \frac{360^\circ}{1} = 360^\circ$$

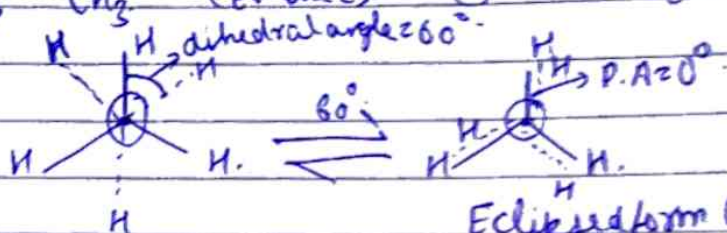


\* Conformation - ~~Isomers~~ <sup>Isomers</sup> can be interconverted

\* Conformation - Isomers can be interconverted into each other by free rotation around  $\sigma$ -bond. (C-C)

①  $\text{CH}_3$  - ②  $\text{CH}_3$  (Ethane). ① is denoted by  $\cdot$ , ② is denoted by  $\odot$

Newman  
Projection  
Formula



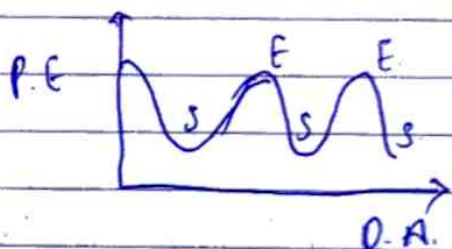
Staggered form (at  $60^\circ, 180^\circ, 300^\circ$ )

Stability,  $S > E$

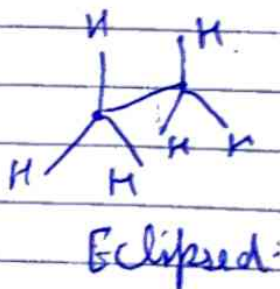
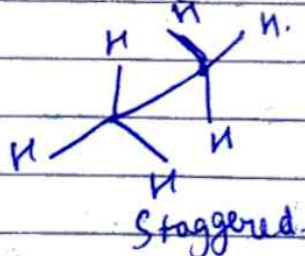
Energy,  $S < E$

Eclipsed form (at  $0^\circ, 120^\circ, 240^\circ$ )

Total conformers =  $\infty$   
Conformers b/w staggered and eclipsed are called  
Skew form



Sawhorse



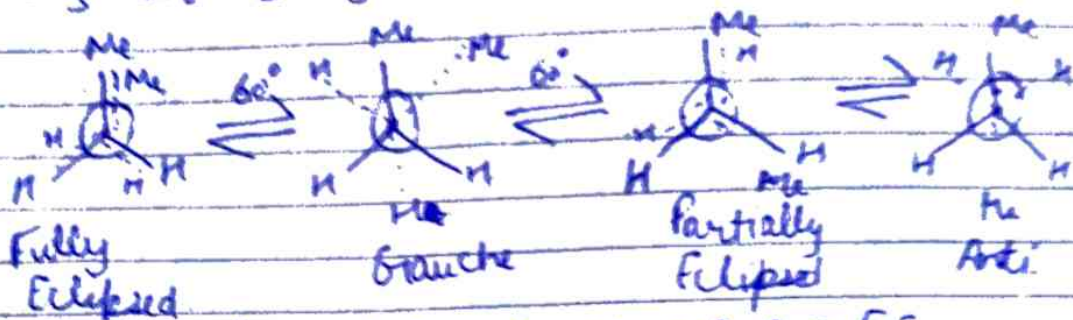


②

Butane



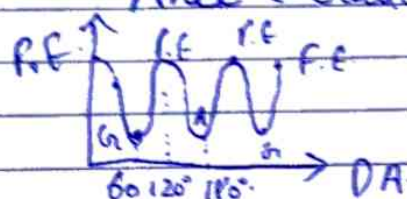
①  $\rightarrow \cdot$  , ②  $\rightarrow \text{C}$



Stability  $\text{Anti} > \text{Gauche} > \text{P.E} > \text{F.E}$

Energy

$\text{Anti} < \text{Gauche} < \text{P.E} < \text{F.E}$



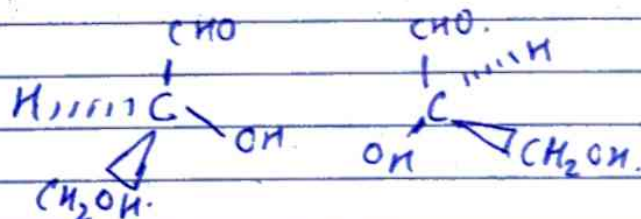
★ Projection formula.

17) Flying wedge representation:- In this representation, 3 types of lines are used in a standard way to indicate 3D structure in a 2D picture.

→ Solid wedge (thick line)

→ Solid line (—)

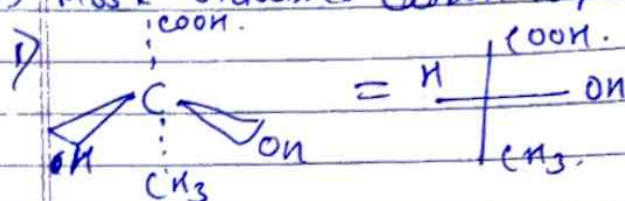
→ Dashed line (---)



Flying wedge representation of 2 forms of glyceraldehyde

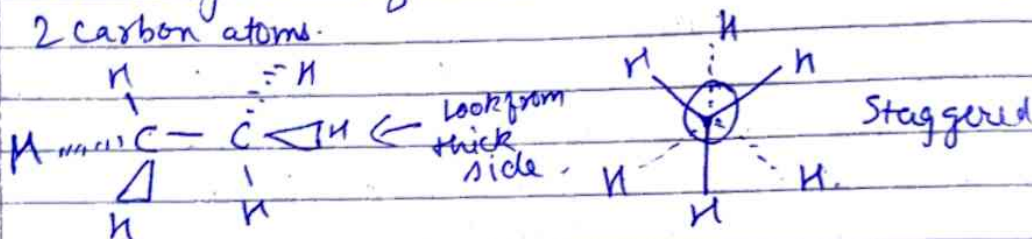
## 2) Fischer Projection

- hold the molecule in such a way that central carbon lies in the plane.
- Groups on carbon held at top and bottom must be inclined the plane (represented by dotted lines in wedge diagram)
- Groups on carbon at left and right must be inclined above the plane (represented by thick lines in wedges)
- Most oxidised carbon kept at top.



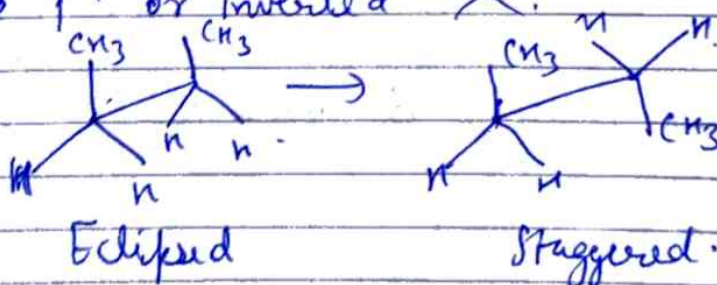
## 3) Newman Projection

- Obtained by looking at molecule along the bond joining 2 carbon atoms.



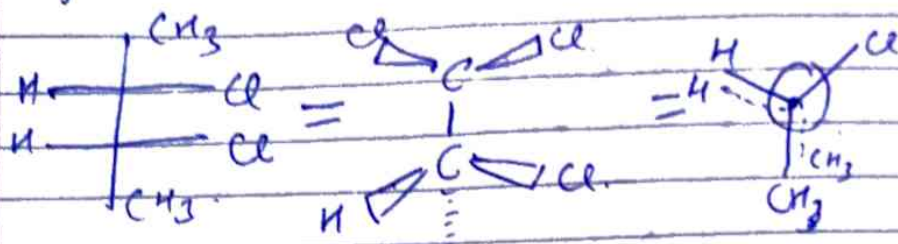
## 4) Sawhorse Projection

- Obtained by looking at the molecule, at a small angle to bond joining 2 carbon atoms.
- These bonds at each carbon are drawn in shape 'Y' or inverted 'Y'.



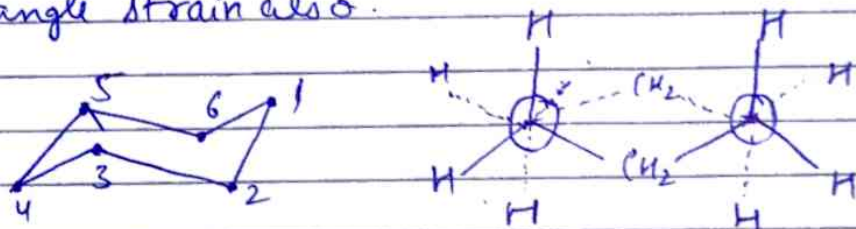


# \* Projection conversion.

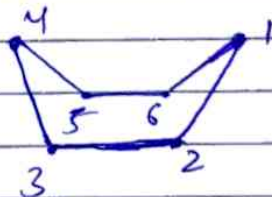


## \* Conformers of Cyclohexane

- ② The twisting about C-C bond results in formation of different conformations of cyclohexane are--
- ① Chair conformation:- Most stable. as it is free from torsional strain. B. A  $\approx 109.5^\circ$  and free from angle strain also.



- ② Boat conformation:- Twisting about C-C ~~bond~~ single bond of chair form results in formation of boat conformation



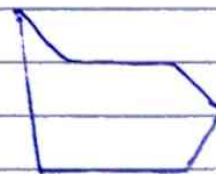
Boat

③



Twist Boat

④



Half chair.

Stability  $C > T.B > B > H.C$

Energy  $C < T.B < B < H.C$

- T.B is optically active.

