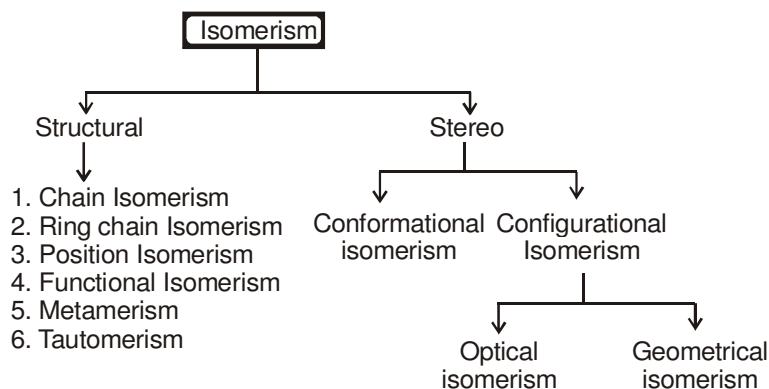


ISOMERISM

DEFINITION : Compounds having same molecular formula (M.F.) but differ in their properties are known as **isomers** and this phenomenon is known as **isomerism**.

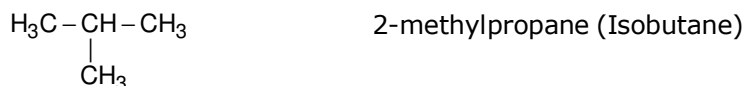
CLASSIFICATION :

STRUCTURAL ISOMERISM : Compounds having same M.F. and different in connectivity of atom (Structure is different)

CHAIN ISOMERISM

Compounds having same molecular formula but differing in the length of the principal chain.

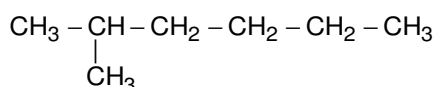
e.g.1 $\text{CH}_3 - \text{CH}_2 - \text{CH}_2 - \text{CH}_3$ butane (n - butane)
and



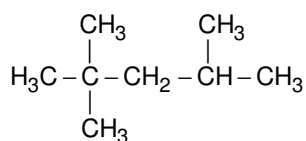
e.g.2 $\text{CH}_3 - \text{CH}_2 - \text{CH}_2 - \text{COOH}$ butanoic acid
and

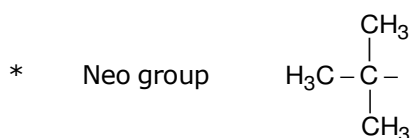


e.g. Isoheptane

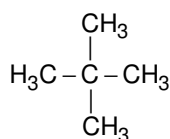


* Isooctane (exception of Iso group)

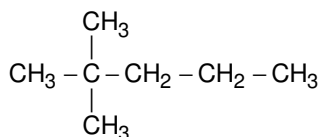




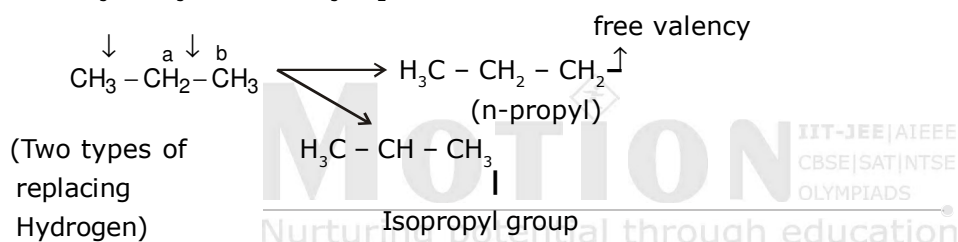
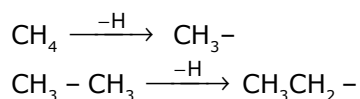
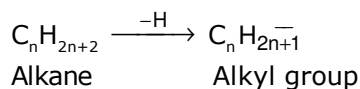
- * To prepare the neo compound firstly the above group ($\text{H}_3\text{C}-\text{C}-$) is written. After that required no. of carbon is added in the straight chain.
e.g. neopentane



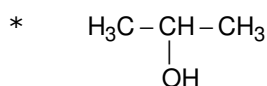
neoheptane



Alkyl Group :

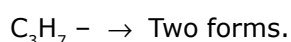


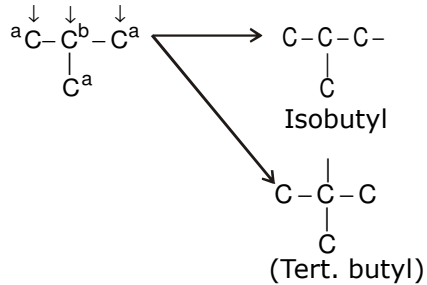
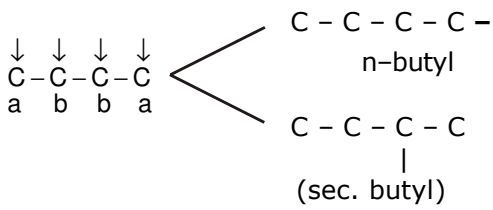
dark line (–) represents vacant valency where any group can be attached.



(Iso propyl alcohol)

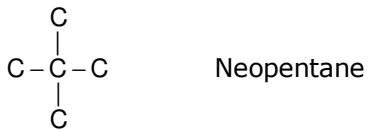
Thus we can conclude that



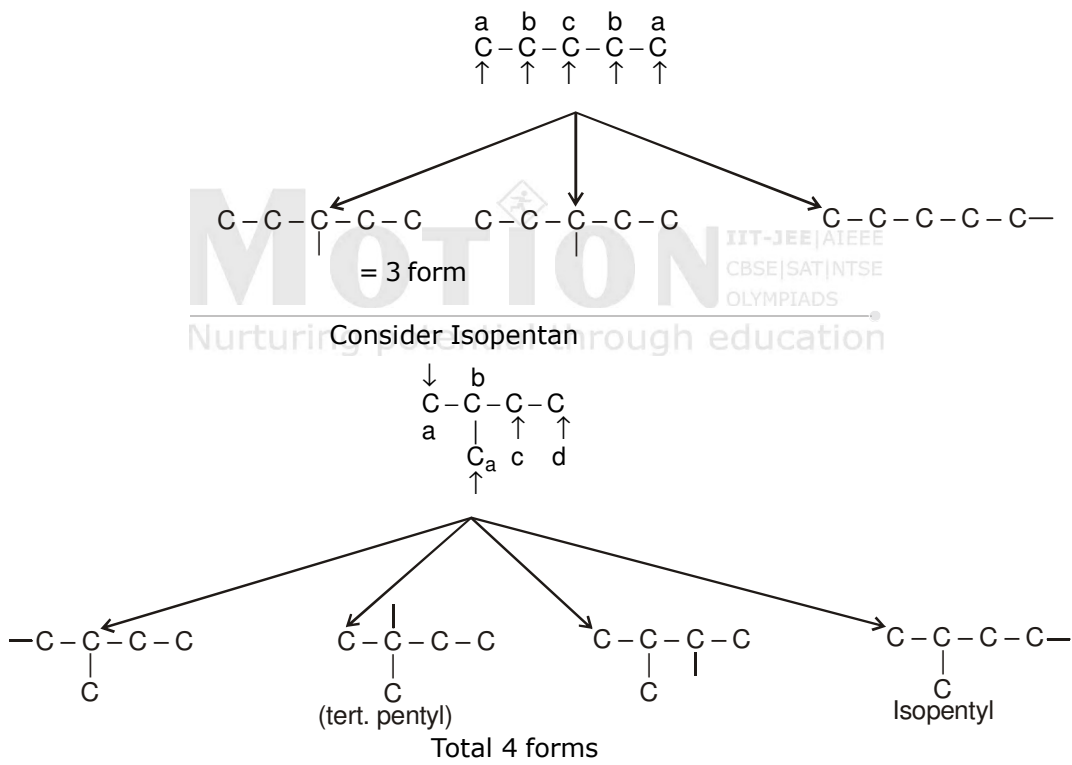


* $\text{C}_4\text{H}_9 - = 4$ forms.

* C_5H_{12} has its three forms
 $\text{C} - \text{C} - \text{C} - \text{C} - \text{C}$ n-pentane



* Consider n-pentane



Sol. a, b \longrightarrow chain isomers.
c, d \longrightarrow chain isomers.

b, c \longrightarrow position isomers.
d, e \longrightarrow position isomers.

* Monochlorination \longrightarrow Replace one H by Cl

Ex.3 How many monochloro derivative will be of C_4H_{10} (Only structural)

Sol. $C_4H_{10} \xrightarrow{Cl_2/h\nu} C_4H_9Cl$
 \downarrow
4 forms (product)

Ex.4 An alkane having molecular formula C_5H_{12} can give only one product on monochlorination. Find the IUPAC name of the alkane

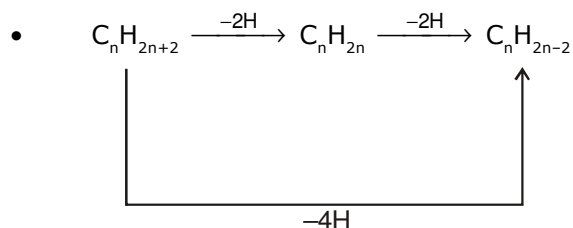
Sol.
$$\begin{array}{c} C \\ | \\ C - C - C \\ | \\ C \end{array}$$

(2, 2-dimethyl pentane)

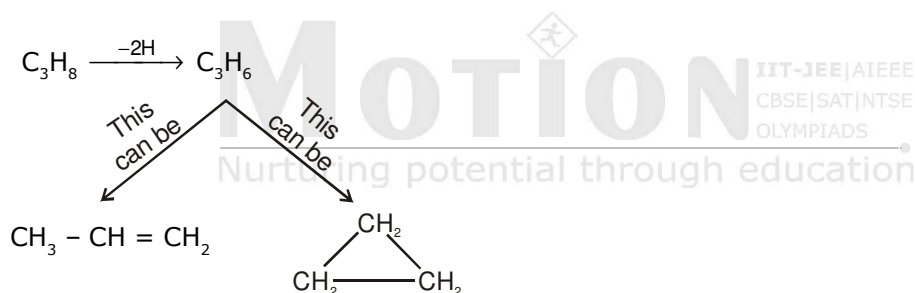
Ex.5 $C_5H_{10} \xrightarrow[h\nu]{Cl_2} \text{Single product (monochlorination)}$

what is the structure of C_5H_{10} ?

Sol. Cyclopentane

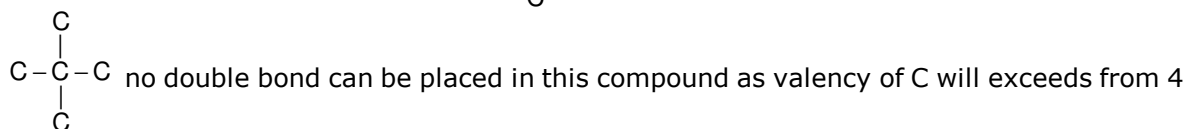
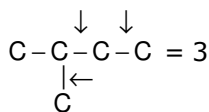
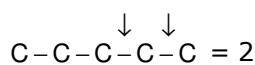


e.g.



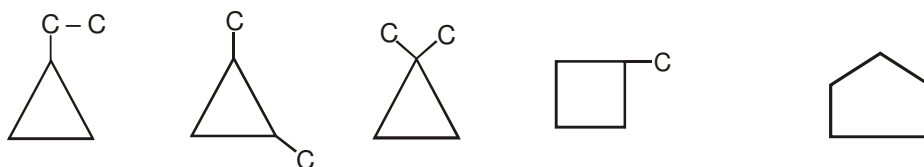
Ex.6 Find the total structural isomer of C_5H_{10} .

Sol. For solving these kinds of problem we should at once draw all possible structure of corresponding alkane and then we should check how many possibilities are there to put double bond.



Total open chain structural isomers = 5

* To form cyclic structural we should always start with 3 carbon ring.

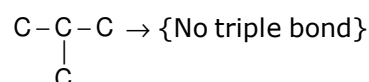


total structural isomers = 5 + 5 = 10

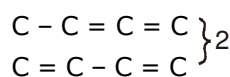
Ex.7 Find the total structural isomers of C_4H_6 .

Sol. Total unsaturation of $C_4H_6 = 2$

i.e. possibility = one triple bond, or 2 double bond or (one ring + one double bond)



for alkene,

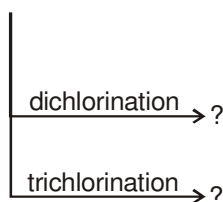


total open chain = 2 + 2 = 4

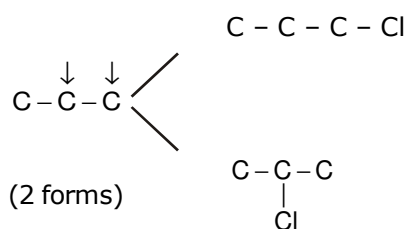
for cyclic



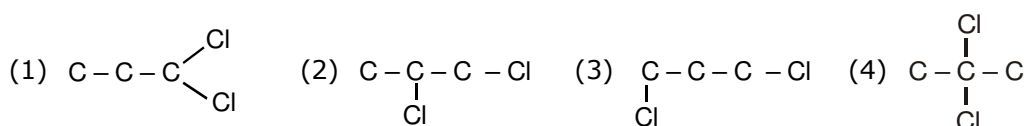
total structural isomers (cyclic + acyclic) = 9

Ex.8 C_3H_8 $\xrightarrow[\text{chlorination}]{\text{mono}}$? (Only structural in all)

Sol. For monochloroderivative,

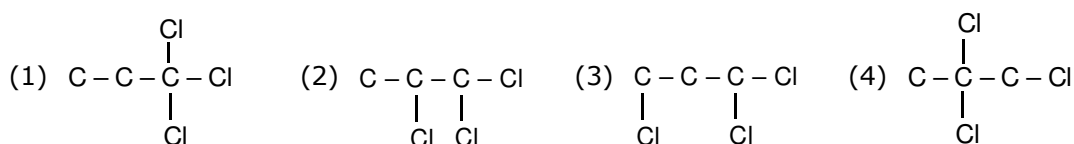


di-chloroderivative



Total dichloroderivative = 4

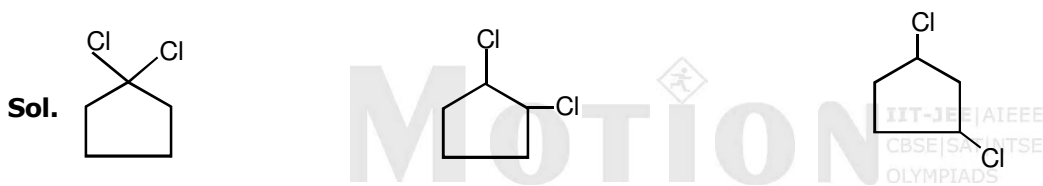
Trichloroderivative,



* To find di or trichloroderivative

We place two or three chlorine at last carbon and after that rotate one Cl by keeping the other two at the same the place.

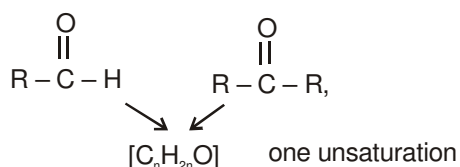
Ex.9 Find all the structural dichloroderivative of cyclopentane.

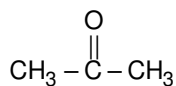
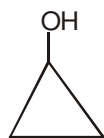
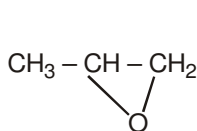


Total structural isomer = 3

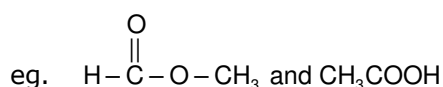
FUNCTIONAL ISOMERISM

Compound having same molecular formula but different in functional group are known as functional isomers.



e.g. C_3H_6O $CH_3 - CH_2CHO$  $CH_2 = CH - CH_2OH$ 

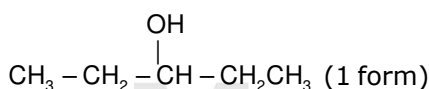
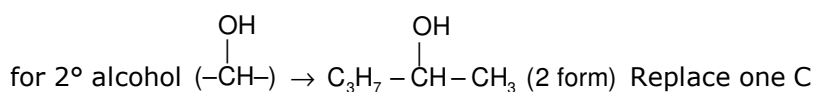
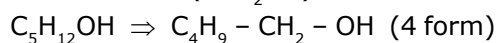
- * Aldehyde, Ketone, cyclic ethers, cyclic alcohol, unsaturated alcohol etc are functional isomers to each other.
- * Alcohol and ether functional isomers to each other.
e.g. CH_3CH_2OH , CH_3OCH_3
- * Acids and ester are functional isomers to each other.



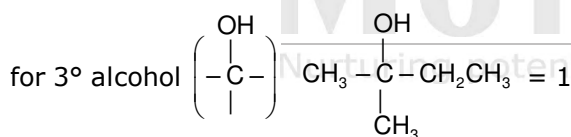
- * Cyanide and Isocyanide are functional isomer to each other but HCN and HNC are tautomers to each other.
- * 1° , 2° and 3° amine are functional isomer to each other.

Ex.10 How many primary, secondary and tertiary alcohol are possible for $C_5H_{12}O$? (Only structural)

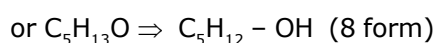
Sol. For 1° alcohol ($-CH_2OH$)



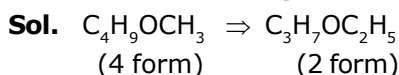
total = 3



total = 4 + 3 + 1 = 8



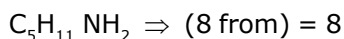
Ex.11 How many ethers are possible in $C_5H_{12}O$. (Only structural).



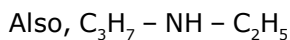
total = 6

Ex.12 How many 1°, 2° and 3° amine are possible for $C_5H_{13}N$ (Only structural).

Sol. For 1° amine ($-NH_2$)



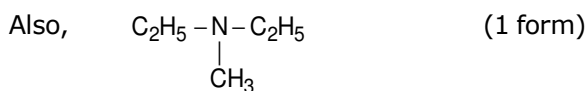
for 2° Amine, ($-NH-$) $C_4H_9 - NH - CH_3 \Rightarrow 4 \text{ forms}$



(2 form)

total form at 2° = 4 + 2 = 6

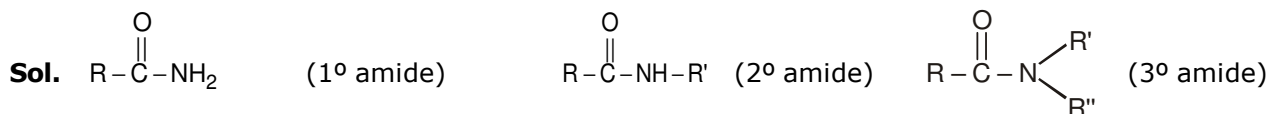
for 3° $\left(\begin{array}{c} -N- \\ | \end{array} \right)$



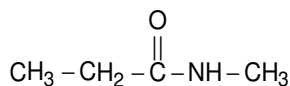
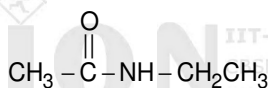
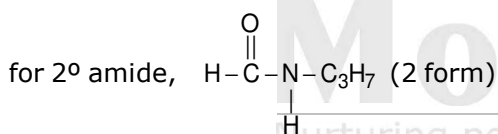
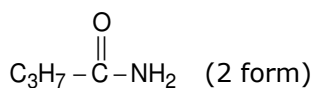
Total form of 3° = 2 + 1 = 3

Total no. of amines = 8 + 6 + 3 = 17

Ex.13 For molecular formula C_4H_9NO , how many amide will be there which will not form H-bond ? (Only structural)



for 1° amide



total 2° amide = 4

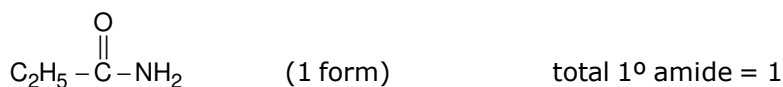
for 3° amide



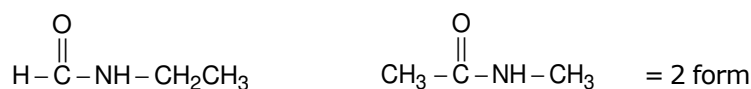
3° amide will not form H-bond hence there will be 2 amides which will not form H-bond.

Ex.14 Find all 1°, 2° and 3° amides for C₃H₇NO (Only structural)

Sol. For 1° amides



for 2° amide



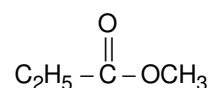
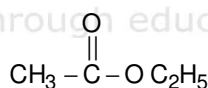
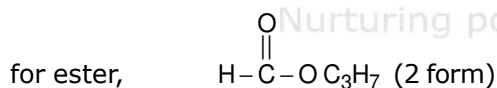
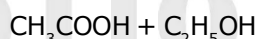
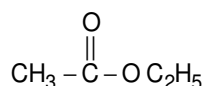
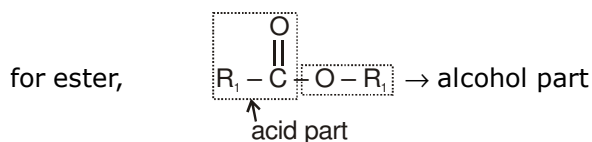
for 3° amide



total amides (1° + 2° + 3°) = 1 + 2 + 1 = 4

Ex.15 Find the total no. of acid and esters from C₄H₈O₂ (Only structural)

Sol. For acid, (–COOH) C₃H₇–COOH (2 form)



total esters = 4

Ex.16 C₄H₄O₄ may be (Only structural)

(i) Saturated dicarboxylic acid

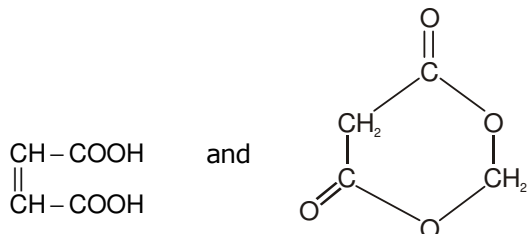
(iii) Cyclic diester

(ii) Unsaturated dicarboxylic acid

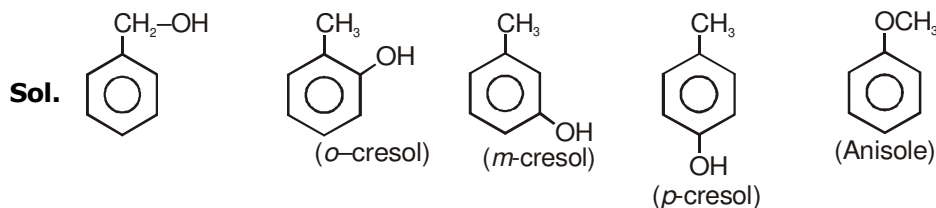
(iv) Saturated di aldehyde

Sol. Three unsaturation.

(ii) and (iii) is the Ans.

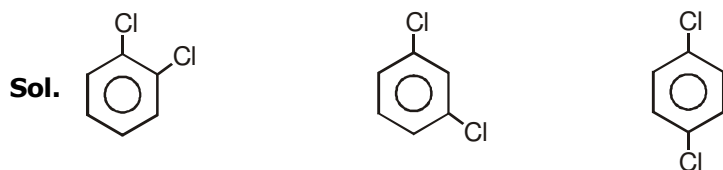


Ex.17 How many aromatic isomers will be possible for $\text{C}_7\text{H}_8\text{O}$ (Only structural)

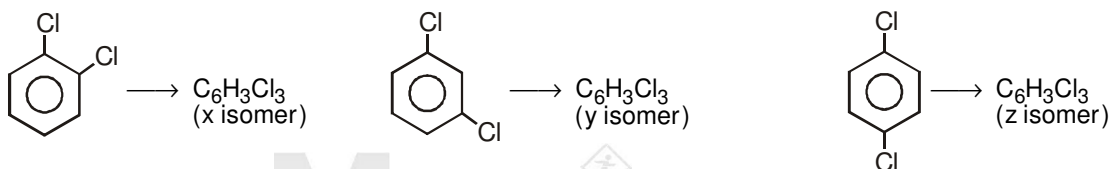


Total = 5

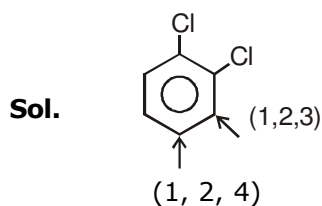
Ex.18 Find the possible dichloroderivative of $\text{C}_6\text{H}_4\text{Cl}_2$ (Only structural)



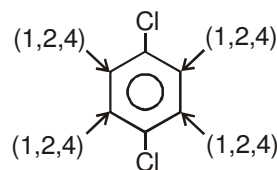
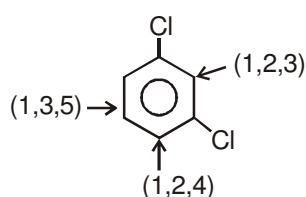
Ex.19 $\text{C}_6\text{H}_4\text{Cl}_2 \longrightarrow \text{C}_6\text{H}_3\text{Cl}_3$ (Only structural)



find the value of x, y, z



There are two possibilities placing Cl in place of H.



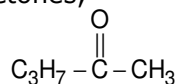
$$= 1$$

$$\therefore x = 2, y = 3, z = 1$$

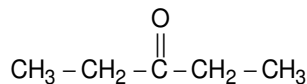
There are one possibilities of placing Cl, therefore z

Ex.20 Find the total carbonyl compound (aldehydes and ketones) formed by $C_5H_{10}O$ and also find the relation between carbonyl compounds which have same no. of α -hydrogen. (Only structural)

Sol. For ketones,



and



(2 form)

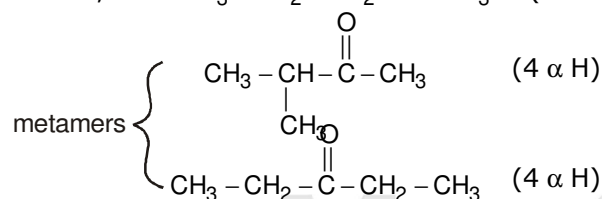
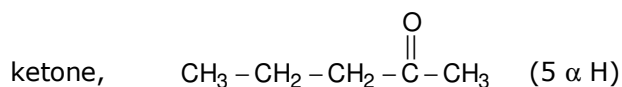
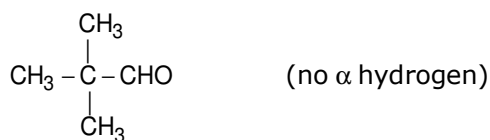
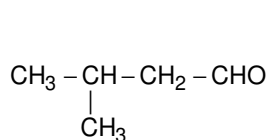
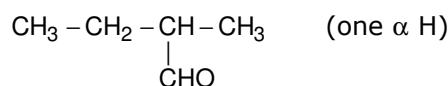
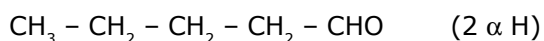
total ketones = 3



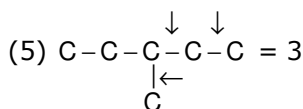
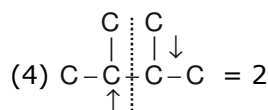
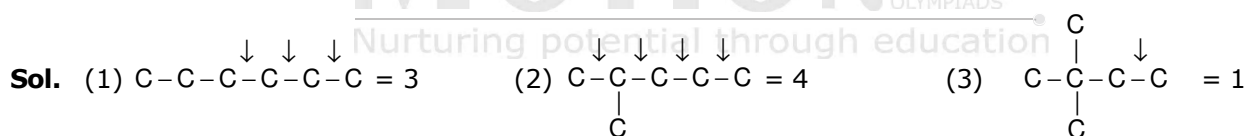
total aldehydes = 4

(4 forms)

total carbonyl compounds = 4 + 3 = 7

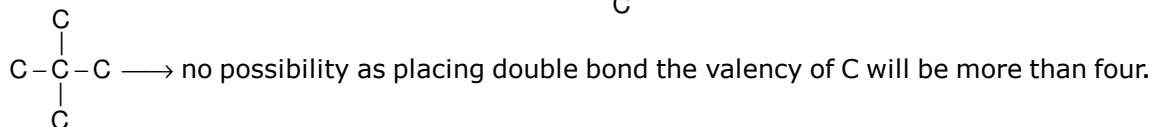
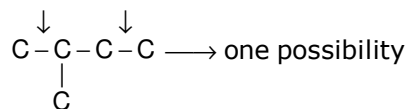
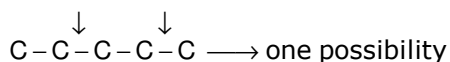


Ex.21 Find total acyclic structural isomer of C_6H_{12} (Only structural)

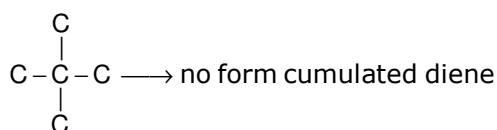
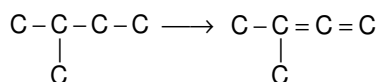
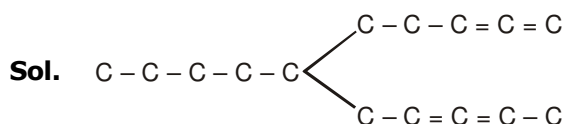


total = 13 isomers.

Ex.22 Find the total conjugated diene in C_5H_8 (Only structural)

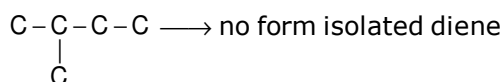
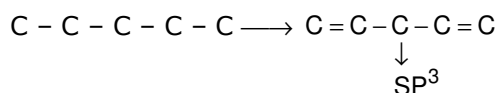


Ex.23 Find total cumulated diene in C_5H_8 . (Only structural)



total = 3

\Rightarrow Isolated dienes,

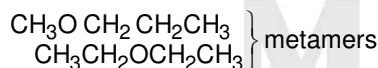


total = 1

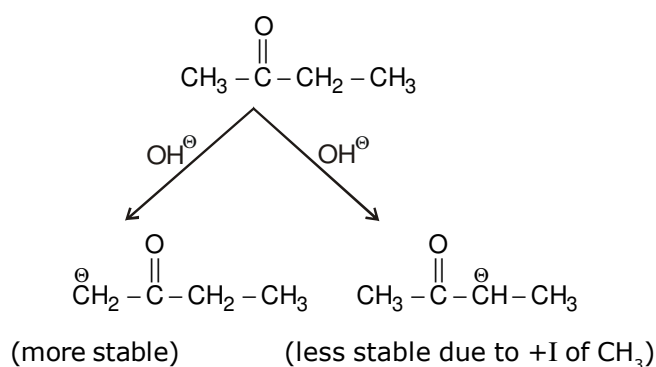
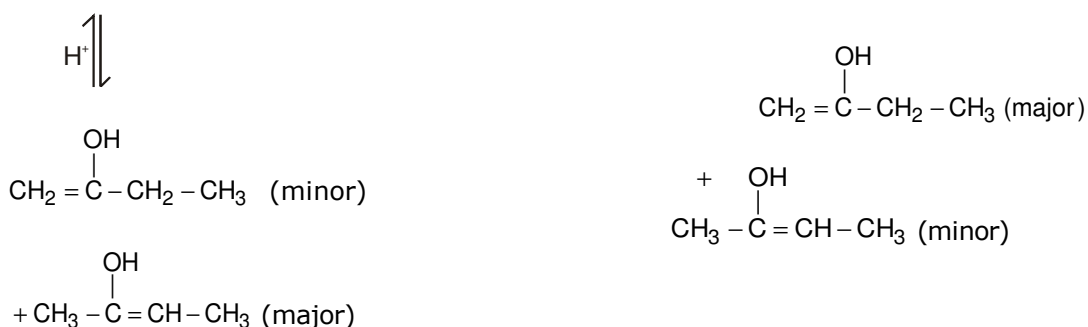
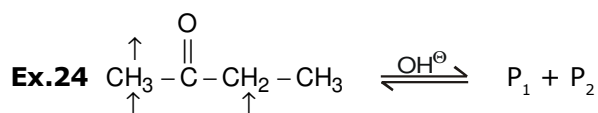
METAMERISM

This type of isomerism is found in those types of compounds which have polyvalent atoms or polyvalent functional group, e.g. ether, 2° amine, ester etc.

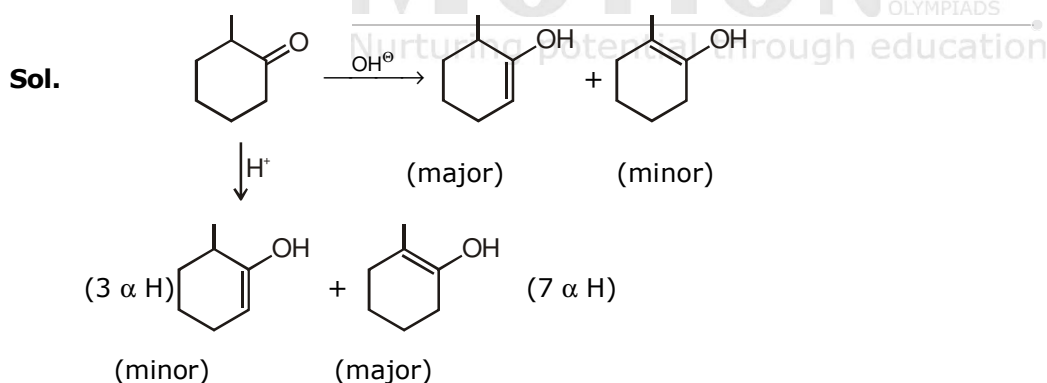
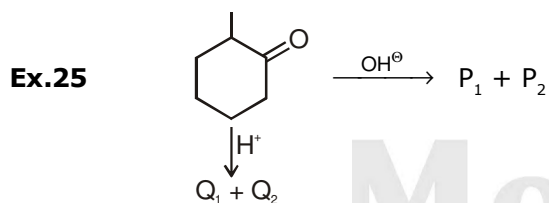
Compound having same molecular formula but differ from the nature of alkyl group directly attached with polyvalent atom or polyvalent functional group

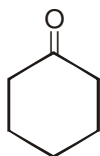
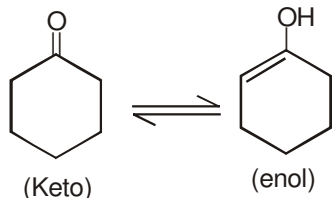


a & b are metamers



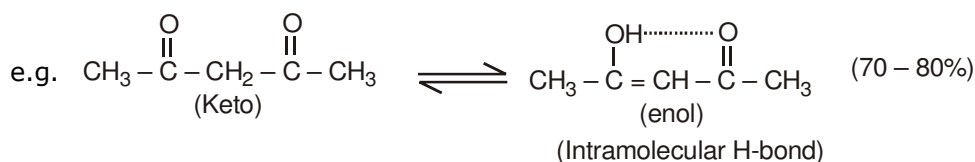
- * In case of base catalysed tautomerism the stability of carbanion is the deciding factor.
- * For acid catalysed tautomerism the stability at the product will be the deciding factor.



Ex.26 Write the enol form**Sol.**

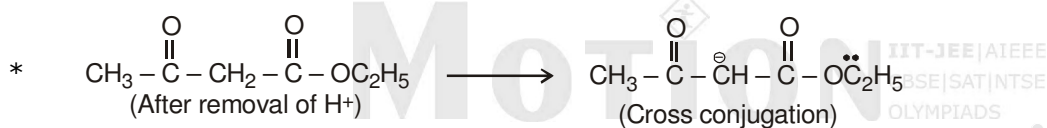
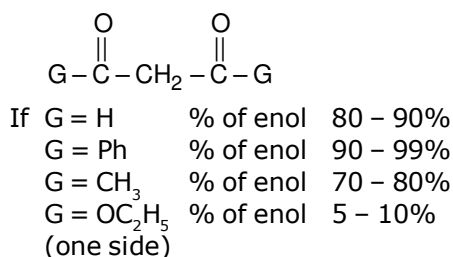
* Generally keto form is more stable than enol but in some cases the stability of enol form is greater than keto. This is due to

- | | |
|------------------------------|-------------------------|
| (i) Intramolecular H-bonding | (ii) Aromatic character |
| (iii) Extended conjugation | (iv) Steric factor |

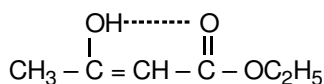
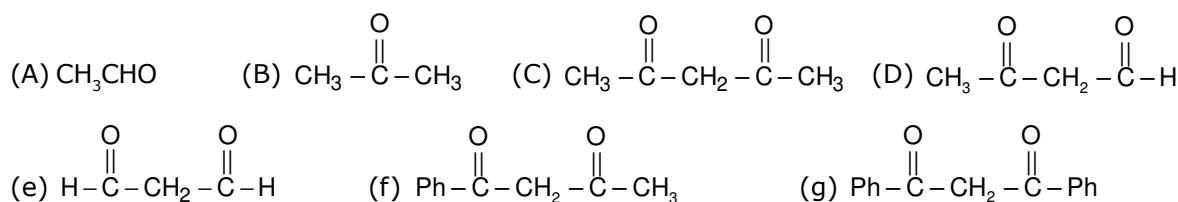


* Due to intramolecular H-bonding formation of 6 member ring takes place which is the cause of stability.

* This can be also summarised as



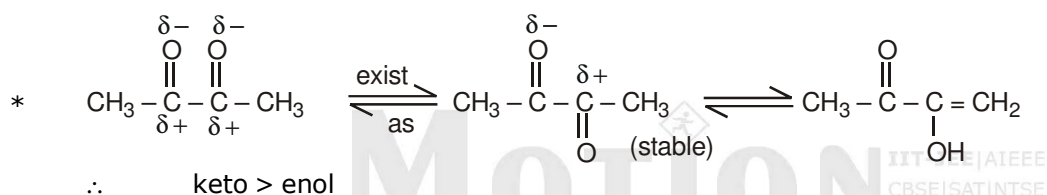
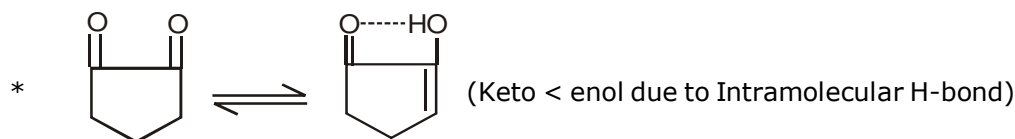
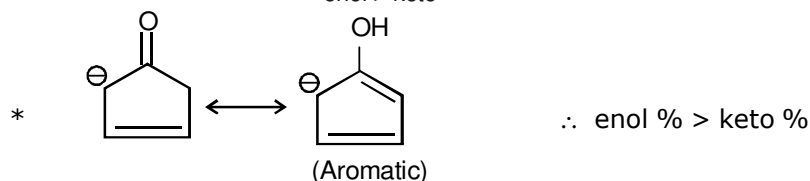
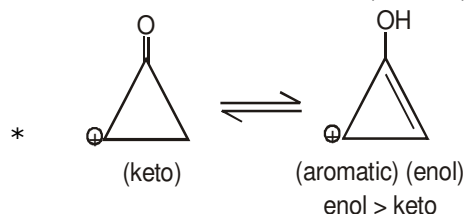
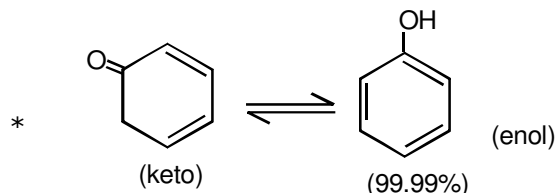
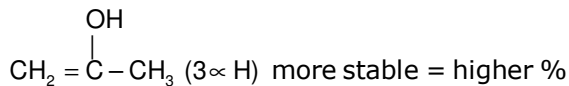
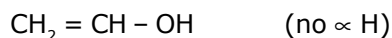
* Cross conjugation restricts the Resonance.

**Ex.27 Compare the enol percent.**

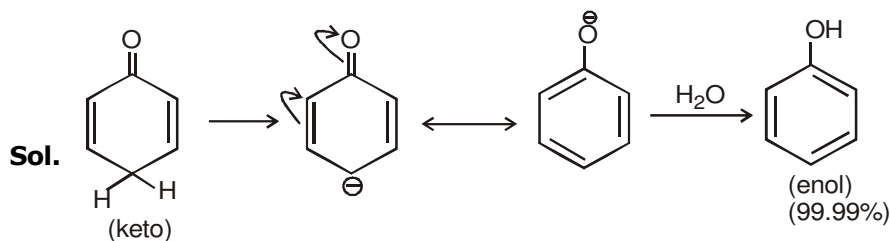
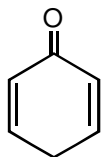
Sol. $g > f > e > d > c > b > a$

* In case of a and b

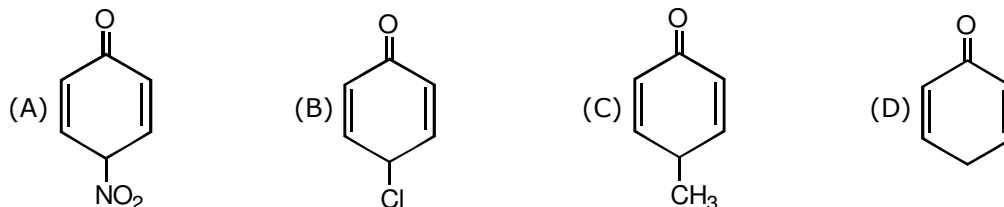
After forming enol form



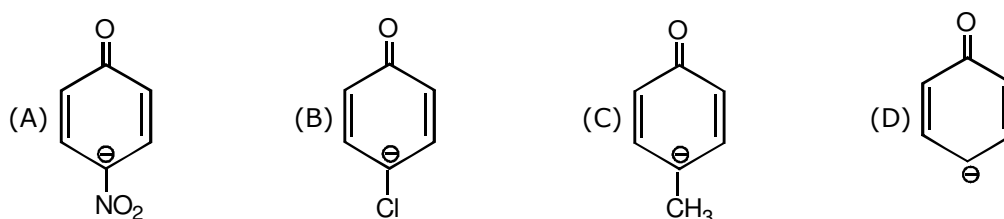
Ex.28 Find the enol form the given compound.



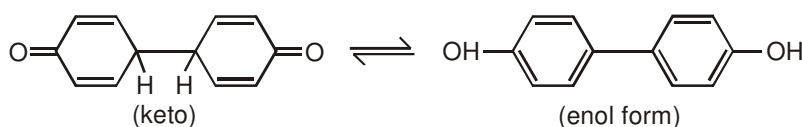
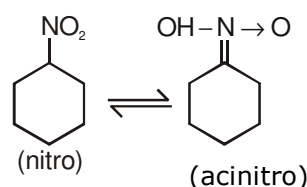
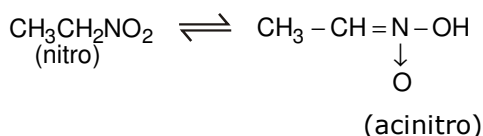
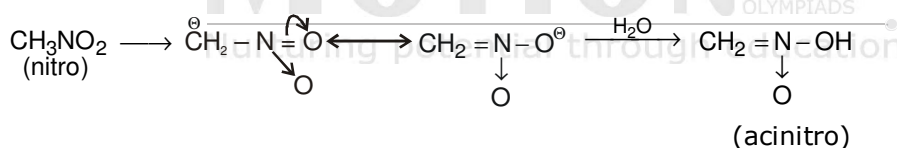
- * Above case is called paratautomerism.
Here γ -Hydrogen participate in tautomerism.

Ex.29 Compare the enol content

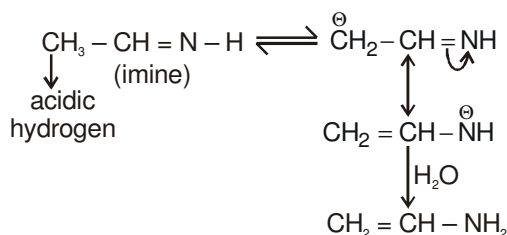
Sol. After removing H^+ (acidic-H) from the compounds



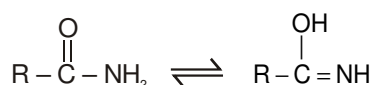
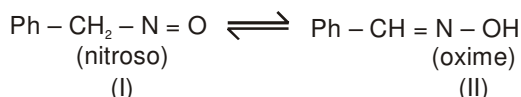
- * Enol percent \propto stability of carbanion
 $a > b > d > c$
* Formation of carbanion is one of step of from keto to enol. Therefore can be calculated as enol percent \propto stability of carbanion.

Ex.30 Find the enol form of**NITRO AND ACINITRO FORM**

- * $(CH_3)_3C - NO_2$ will not show nitro and acinitro form it has no α H w.r.t to NO_2 group.

IMINE AND ENAMINE

* For this type of tautomerism, there must be α H w.r.t. $(-\text{CH} = \text{NH})$ group.

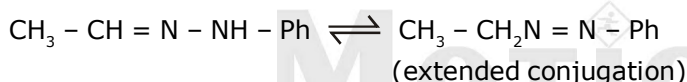
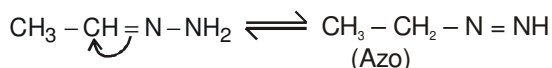
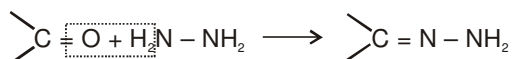
AMIDE AND IMIDOL**NITROSO AND OXIME FORM**

II > I (stability)

due to extended conjugation in (II)

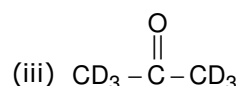
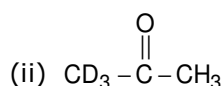
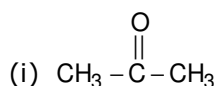
HYDRAZONE AND AZOFORM

NH_2NH_2 (Hydrazine)



Azo > Hydrazone (stability)

Ex.31 Compare enol percent.



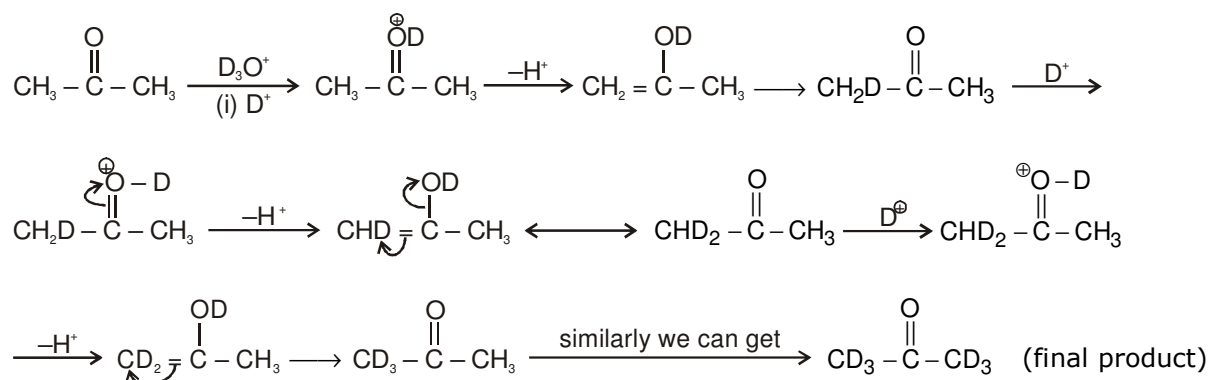
Sol. As we know $\text{C} - \text{D} > \text{C} - \text{H}$ (Bond strength)

$\Rightarrow \text{C} - \text{D}$ will not break easily.

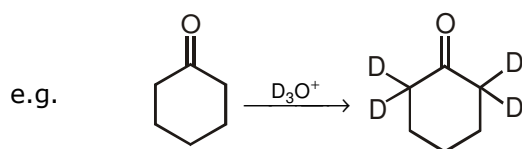
\Rightarrow Compound will have less tendency to come into enol form as $\text{C} - \text{D}$ bond breaking is one of the steps for conversion of keto into enol.

\Rightarrow enol percent will be less.

\Rightarrow (i) > (ii) > (iii) (enol content)

DEUTERIUM EXCHANGE REACTION**(Deuterium Exchange Tautomerism)**

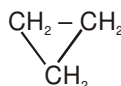
* To get the product directly replace all α -hydrogen w.r.t. carbonyl group by D (Deuterium)

**RING-CHAIN ISOMERISM**

If one isomer has open chain structure and the other has cyclic structure then isomers are known as ring-chain isomers and isomerism between them is known as ring-chain isomerism.

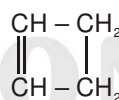
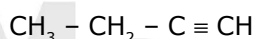
For examples :

(i) Alkene and cycloalkane, (C_nH_{2n})



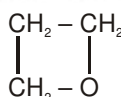
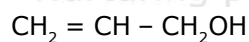
(ii) Alkyne and cycloalkene, ($\text{C}_n\text{H}_{2n-2}$)

C_4H_6 :



(iii) Alkenols and cyclic ethers, ($\text{C}_n\text{H}_{2n}\text{O}$)

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



Note : Ring-chain isomers are always functional isomers.

GEOMETRICAL ISOMERISM

Definition :

Isomers which possess the same molecular and structural formula but differ in the arrangement of atoms or groups in space due to restricted rotation are known as geometrical isomers and the phenomenon is known as geometrical isomerism.

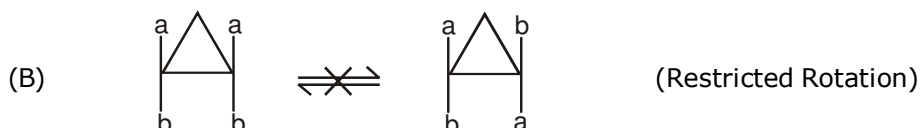
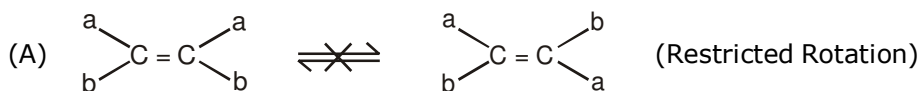
CONDITIONS OF GEOMETRICAL ISOMERISM

(I) Geometrical isomerism arises due to the presence of a double bond or a ring structure

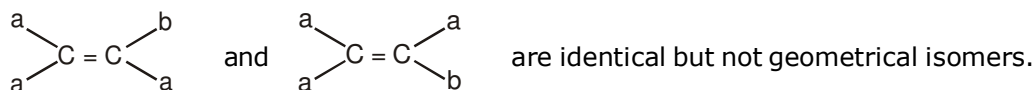
(i.e. $\text{>C}=\text{C}<$, $\text{>C}=\text{N}-$, $-\text{N}=\text{N}-$ or ring structure)

Due to the rigidity of double bond or the ring structure to rotate at the room temperature the molecules exist in two or more orientations. This rigidity to rotation is described as restricted rotation / hindered rotation / no rotation.

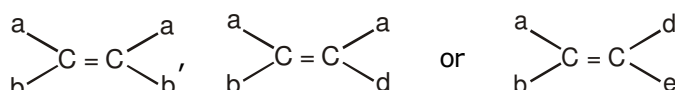
e.g.



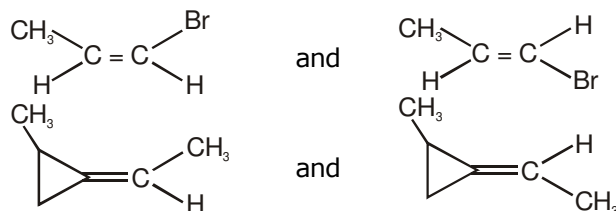
(II) Different groups should be attached at each doubly bonded atom. For example



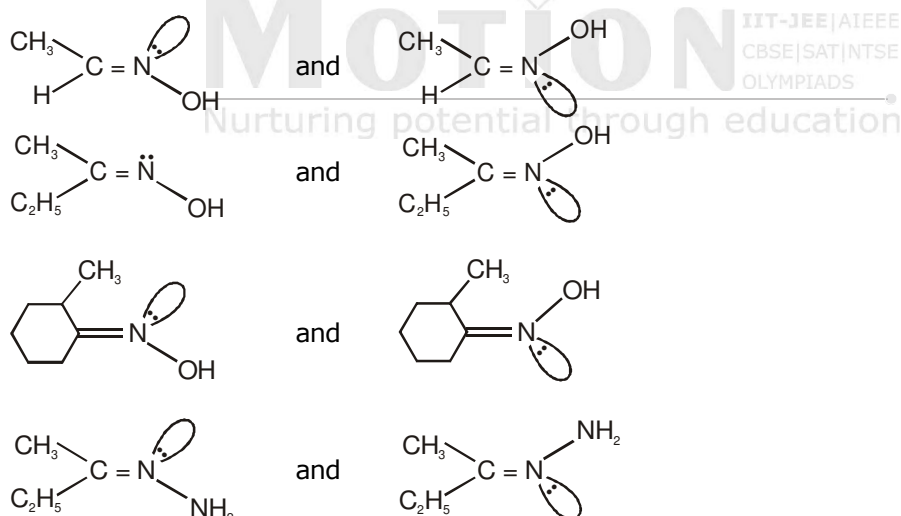
On the other hand, following types of compounds can exist as geometrical isomers :

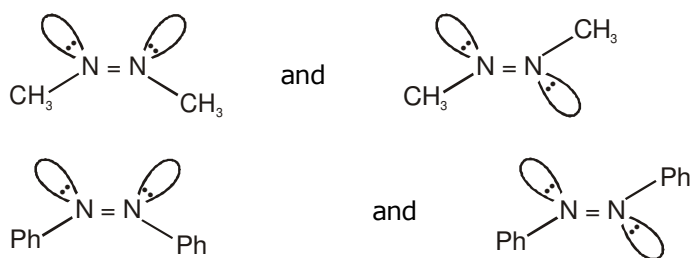
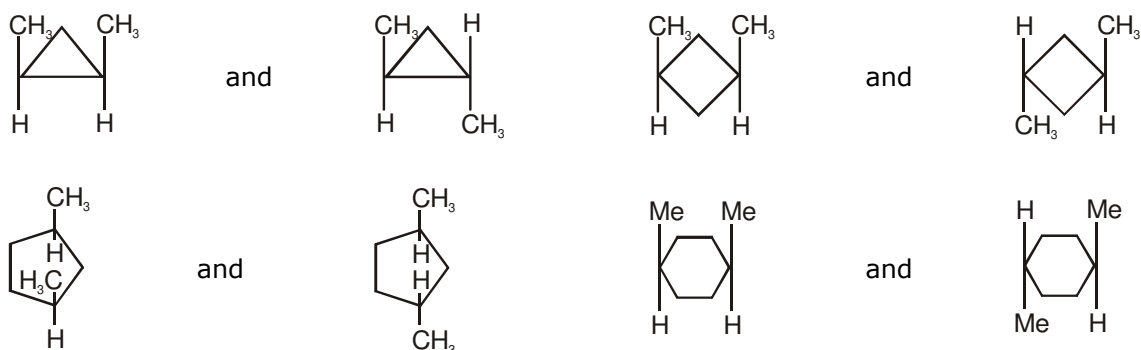
**Examples of Geometrical isomers :**

(I) Along $\text{>C}=\text{C}<$ bond

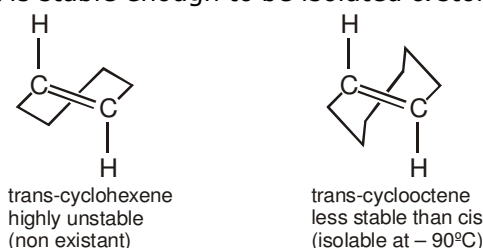


(II) Along $\text{>C}=\text{N}-$ bond



(III) Along $\text{N}=\text{N}$ bond(IV) Along σ bond of cycloalkane(V) Along $\text{C}=\text{C}$ in ring structures :

Usually in cycloalkenes double bond has its configuration. Their trans isomers do not exist due to large angle strain. But if the ring is large enough a trans stereoisomer is also possible. The smallest trans cycloalkene that is stable enough to be isolated & stored is trans-cyclooctene.



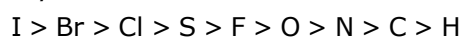
Configurational nomenclature in geometrical Isomerism

Configuration	Criteria	Remarks
cis / trans	Similarity of groups	If the two similar groups are on same side of restricted bond the configuration is cis otherwise trans.
E/Z	Seniority of groups	If the two senior groups are on same side of restricted bond the configuration is Z (Z = zusammen = together) otherwise E (E = entgegen = opposite).

Sequence rules : (Cahn - Ingold - Prelog sequence rules)

For deciding the seniority of groups following rules are applied :

Rule I : The group with the first atom having higher atomic number is senior. According to this rule the seniority of atom is :

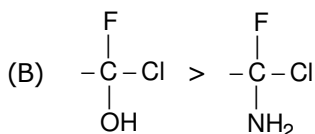


Rule II : The higher mass isotope is senior.

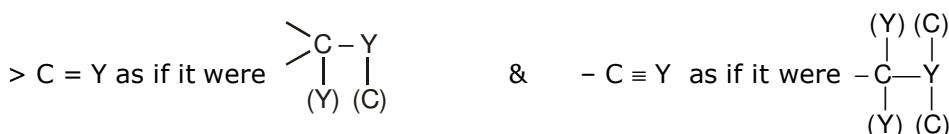


Rule III : If the first atom of group is identical then second atom is observed for seniority.

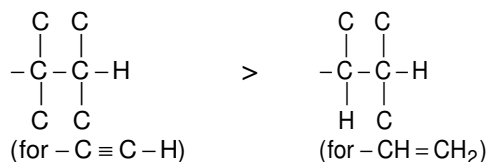
e.g. (A) $-\text{CH}_2\text{Cl} > -\text{CH}_2\text{OH} > -\text{CH}_2\text{NH}_2 > -\text{CH}_2\text{CH}_3 > -\text{CH}_3$



Rule IV : Groups containing double or triple bonds are assigned seniority as if both atoms were duplicated or triplicated that



e.g. for deciding seniority among $-\text{C} \equiv \text{CH}$, $-\text{CH} = \text{CH}_2$, their hypothetical equivalents are compared.



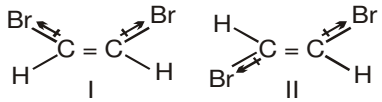
Rule V : Bond pair is senior to lone pair.

Number of Geometrical Isomers :

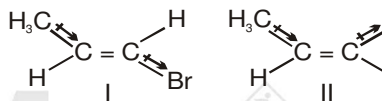
Number of geometrical isomers can be found by calculating the number of stereocentres in the compound. (stereocentre is defined as an atom or bond bearing groups of such nature that an interchange of any two group will produce a stereoisomer).

Nature of compound	No. of G.I. (n = no. of stereocentres)	Example	No. of Isomers	Isomers
(I) Compound with dissimilar ends	2^n	$\text{CH}_3 - \text{CH} = \text{CH} - \text{CH} = \text{CH} - \text{C}_2\text{H}_5$	4	I : (cis, cis) II : (trans, trans) III : (cis, trans) IV : (trans, cis)
(II) Compound with similar ends with even stereocentres	$2^{n-1} + 2^{\frac{n}{2}-1}$	$\text{CH}_3 - \text{CH} = \text{CH} - \text{CH} = \text{CH} - \text{CH}_3$	3	I : (cis, cis) II : (trans, trans) III : (cis, trans) ≡ (trans, cis)
(III) Compound with similar ends with odd stereocentre	$2^{n-1} + 2^{\frac{n-1}{2}}$	$\text{CH}_3 - \text{CH} = \text{CH} - \text{CH} = \text{CH} - \text{CH} = \text{CH} - \text{CH}_3$	6	I : (cis, cis, cis) II : (cis, cis, trans) ≡ (trans, cis, cis) III : (cis, trans, trans) ≡ (trans, trans, cis) IV : (trans, trans, trans) V : (cis, trans, cis) VI : (trans, cis, trans)

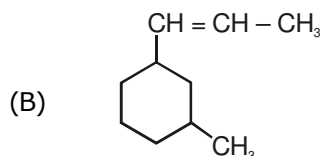
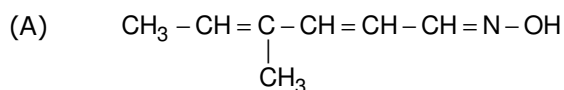
Physical Properties of Geometrical Isomers :

Physical properties		Remarks
Dipole moment	$I > II$	cis-isomer has resultant of dipoles while in trans isomer dipole moments cancel out
Boiling point	$I > II$	Molecules having higher dipole moment have higher boiling point due to larger intermolecular force of attraction
Solubility (in H_2O)	$I > II$	More polar molecules are more soluble in H_2O
Melting point	$II > I$	More symmetric isomers have higher melting points due to better packing in crystalline lattice & trans isomers are more symmetric than cis.
Stability	$II > I$	The molecule having more vander waal strain are less stable. In cis isomer the bulky groups are closer they have larger vander waals strain.

Table

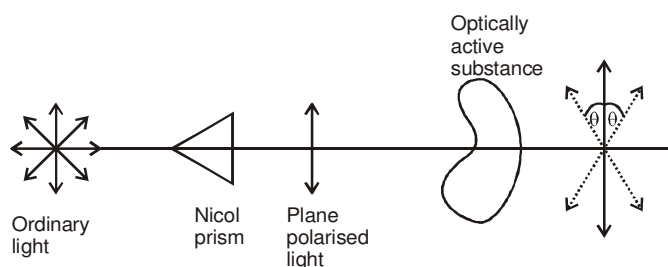
Physical properties	
Dipole moment	$I > II$
Boiling point	$I > II$
Solubility (in H_2O)	$I > II$
Melting point	$I > II$
Stability	$I > II$

Unsolved problem : Find the number of geometrical isomers in



Unsolved problem : Compare the physical properties (μ , b.p., m.p., solubility & stability) in the geometrical isomers of $\text{CH}_3 - \text{CH} = \text{CH} - \text{CN}$.

OPTICAL ISOMERISM



If rotation of light
is anticlock wise

⇓
laevo rotatory
(*l*-form)

If rotation of light
is clock wise

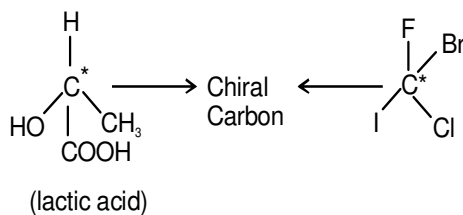
⇓
dextro rotatory substance
(*d*-form)

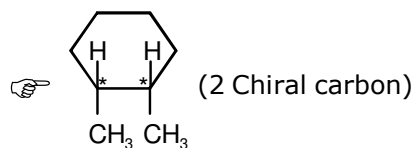
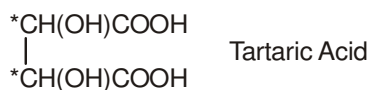
☞ If there is no rotation of light then substance is called optically inactive.

CHIRAL CARBON

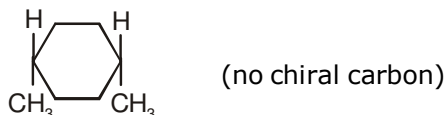
If all the four valencies of carbon are satisfied by four different atom or four different group atom then carbon is known as chiral carbon.

e.g.





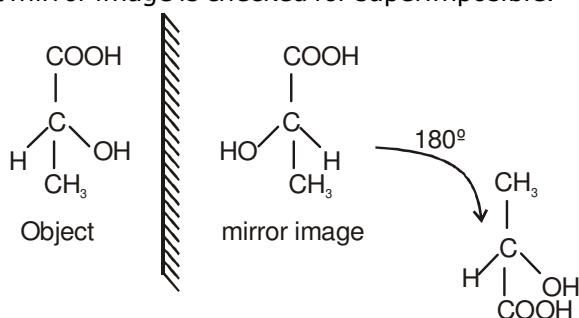
Chiral carbon ढूँढने के लिए पहले point of doubt check करना चाहिए



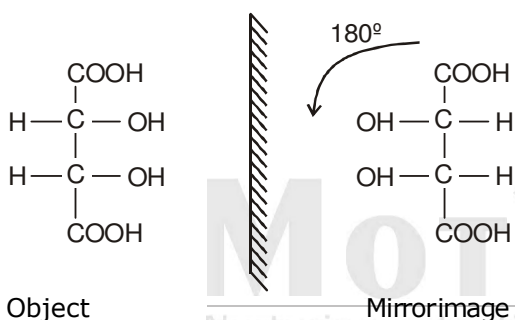
For optically active isomer the object and its mirror image must be non superimposable.

If image and object are superimposable then they are not optically isomer to each other.

To check, superimposable either of object or mirror image is rotated 180° along the mirror. After that mirror image is checked for superimposable.

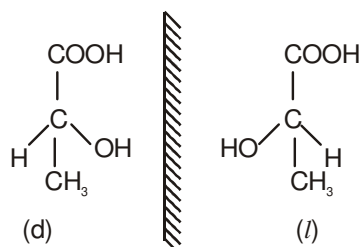


⇒



⇒ After 180° rotation, mirror image and object are identical. (mirror image of meso compound will be identical)

If the compound have only one chiral carbon then it will be certainly optically active.



← enantiomers →

Object and its nonsuperimposable mirror image are called enantiomer to each other

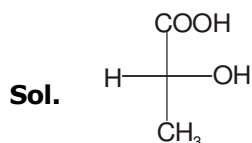
32. A and B are enantiomer to each other. If specific rotation of A is $+20^\circ$ and rotation of mix of A and B is -10° then find the percentage of A and B in the mixture?


Sol. Let x mol A
 (1-x) mol of B
 total rotational of A = $x \times 20$
 total rotational of B = $(1-x)(-20)$
 Total rotation of the mixture = -10
 $x \times 20 + (1-x)(-20) = -10$
 $20x - 20 + 20x = -10$
 $40x = 10 \Rightarrow x = \frac{10}{40} = 0.25$
 $\Rightarrow \% A = 25\%$
 $\therefore \% B = 75\%$

FISHER PROJECTION

By fisher projection three dimensional structure is converted into 2D.

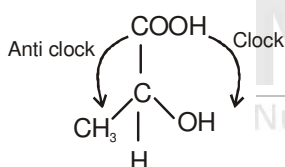
33. Write the Fisher projection of $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$



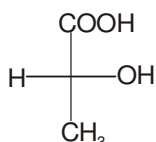
 Maximum carbon must be in vertical line.

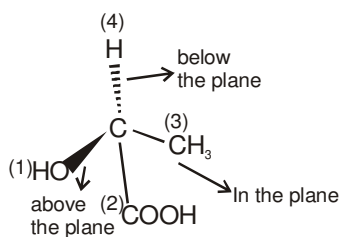
 Place higher priority carbon containing functional group on top of vertical line.

34. Write Fisher projection of



Sol. (i) Place higher priority carbon containing functional group on top of vertical line.
 (ii) Arrange other group according to its clock wise or anticlock wise position w.r.t. group on the top.

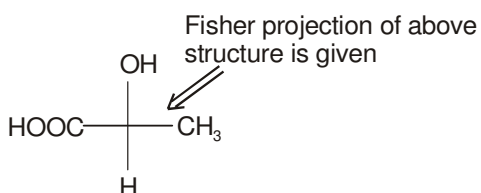
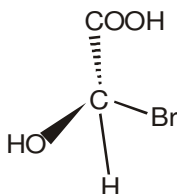
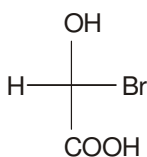


WEDGE DASH STRUCTURE

☞ केवल Fourth priority order को Cross कर सकते हैं, during checking of clock or anticlockwise.

☞ To draw Fisher projection of such structure

- (1) Dotted group is placed below
- (2) The group attached by dark line is placed on the top.
- (3) Remaining group are placed according to their clock wise or anticlock wise position w.r.t. group in dark line.

**35. Draw the fisher projection of****Sol.**

If fourth valency is not given then we assume it to be hydrogen

R AND S FORM

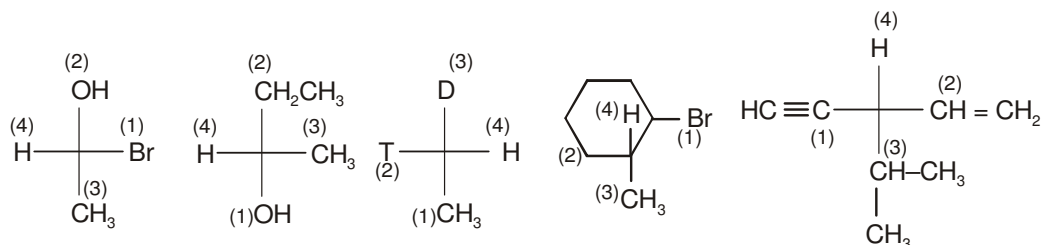
☞ R → Rectus → Right → Clock wise.

☞ S → Sinister → Left → Anticlock wise.

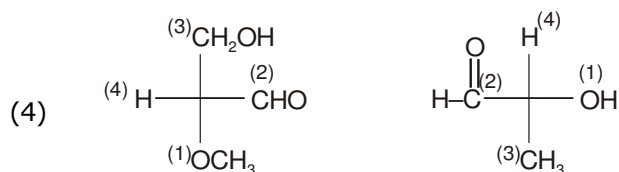
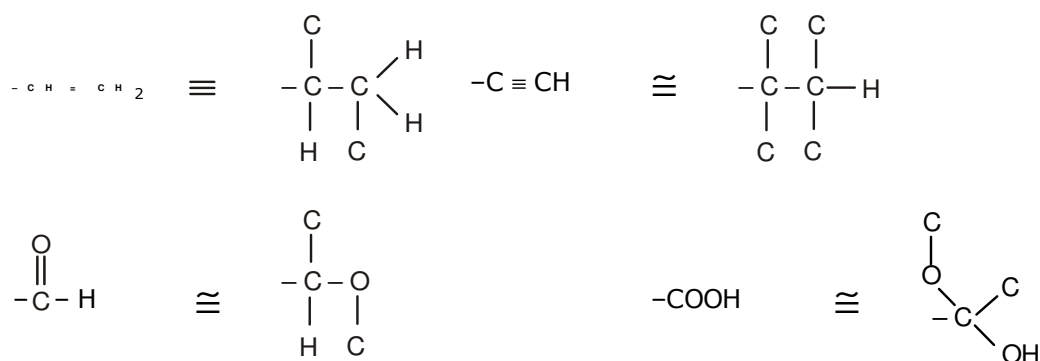
PRIORITY ORDER

☞ Higher the atomic number of the element, greater will be its priority.

e.g.

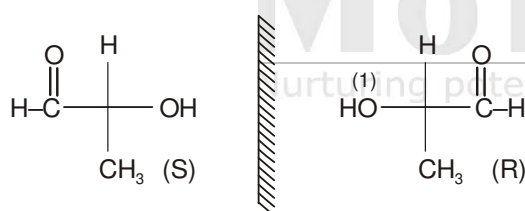


☞ In case of double bond (=) or triple bond (≡)



1 → 2 → 3 If clock wise ⇒ R

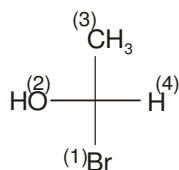
1 → 2 → 3 If Anti clock wise ⇒ S



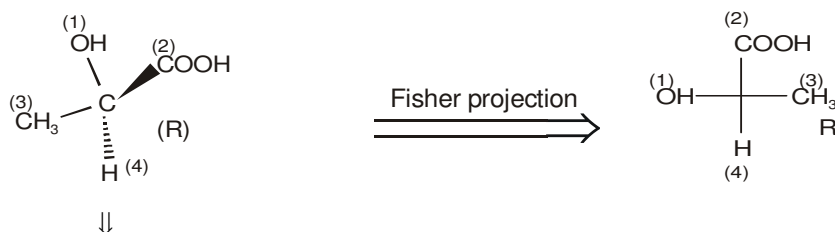
⇒ Mirror image of R is S

☞ If lowest priority element is in horizontal then exact order is obtained by reversing the form (i.e. it comes R then exact form will be S and vice versa)

e.g.



⇒ It comes as R but will be S form,



If lowest priority order element is in dotted then

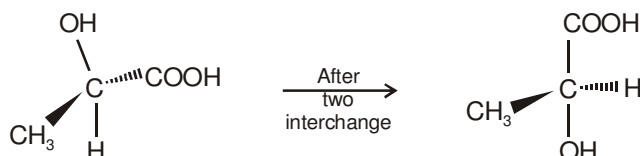
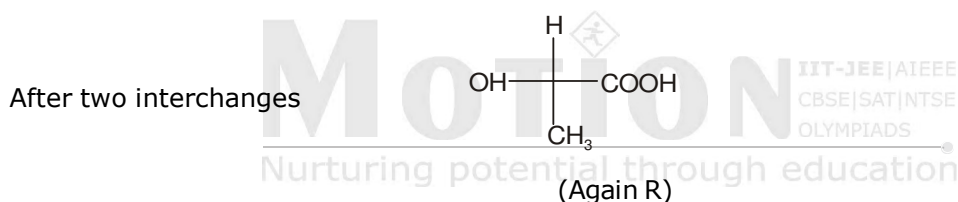
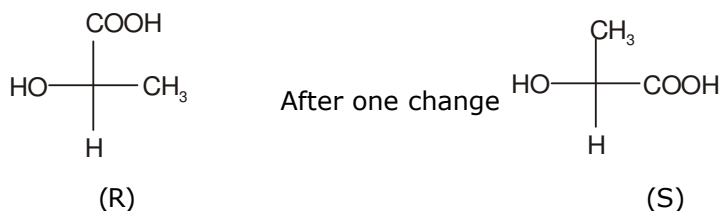
1 → 2 → 3 If clock wise ⇒ R

and if 1 → 2 → 3 If Anti clock wise ⇒ S

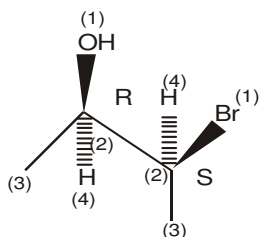
☞ If lowest priority element is not in dotted then we bring it in dotted by doing even number of inter changes (2,4 or 6) as by even no. of inter change, the configuration does not change.

☞ After odd number of change the configuration changes (If R then goes into S and vice versa).

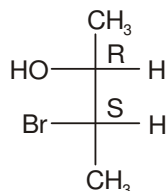
For Example:



Ex.36 Draw the Fisher projection of



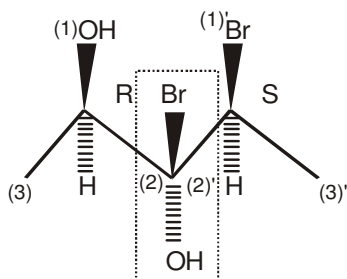
Sol.



☞ All the carbons are placed in vertical

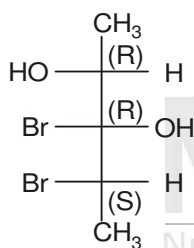
☞ Group attached to the chiral carbons are placed on any side. After that they are adjusted whether they are R or S form w.r.t chiral carbons.

Ex.37 Draw the Fisher projection of the following.



Wedge Dash formula

Sol.



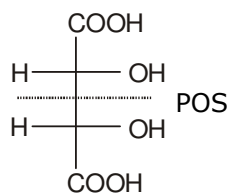
Fisher projection

RACEMIC MIXTURE

It is an equimolar mixture of R and S or *d* and *l*. Racemic mixture is optically inactive

☞ A compound is optically active due to

- (1) Absence of plane of symmetry (POS)
- (2) Absence of centre of symmetry (COS)



(meso form)

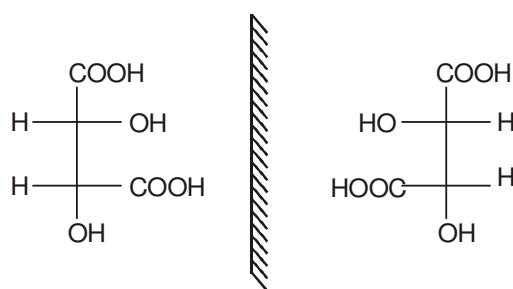
☞ POS is an imaginary plane where if we place a mirror, mirror image will exactly overlap the other half.

☞ For meso form, there must be at least two identical chiral carbon.
Identical carbon \Rightarrow Chiral carbons having identical group attached.

☞ If compound has POS then it will be certainly optically inactive and will be called meso form.

☞ After finding two identical carbons. We assign them as R or S. If first part is R and other is S then they will rotate the light in opposite direction but to equal extent the compound will be optically inactive

(meso form)

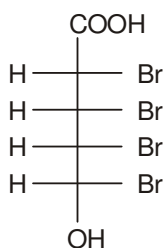


← Enantiomers →

☞ If a compound have 'n' different chiral carbon then total no. of optically active isomers = 2^n

No. of meso form = 0

e.g.



no. of different chiral carbon = 4

total optical isomer = $2^n = 2^4 = 16$

☞ There will be no meso as the compound does not have identical chiral carbon.

☞ If a compound has n identical chiral centre (symmetrical) \Rightarrow There must be symmetry from some where.

(i) If n is even

$$\text{optical isomer (a)} = 2^{n-1}$$

$$\text{mesoform (m)} = 2^{n/2-1}$$

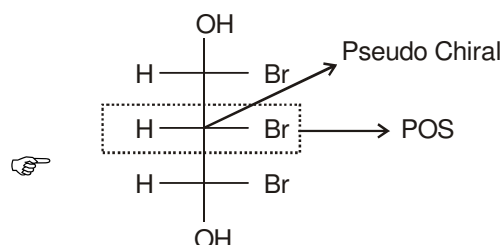
$$\text{total optical isomer} = a + m$$

(ii) If n is odd

$$a = 2^{n-1} - 2^{\frac{n-1}{2}}$$

$$m = 2^{\frac{n-1}{2}}$$

$$\begin{aligned} \text{Total optical isomer} &= 2^{n-1} - 2^{\frac{n-1}{2}} + 2^{\frac{n-1}{2}} \\ &= 2^{n-1} \end{aligned}$$



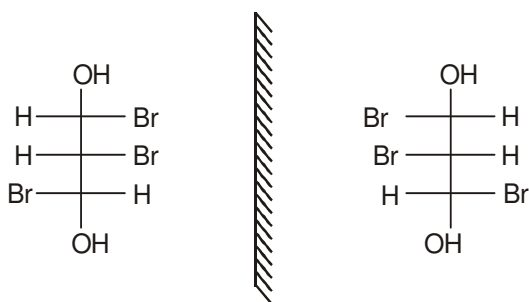
☞ When there is odd no. of identical carbon atom (i.e. symmetrical) then this compound will certainly contain pseudo chiral w.r.t. to which compound be symmetrical (i.e. POS)

☞ Other meso compound of the above compound will form by changing the place Br and H around Pseudo Chiral carbon.

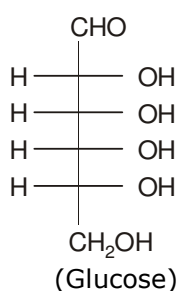


Total meso = 2

$$\begin{aligned} \text{optical} &= 2^{n-1} - 2^{\frac{n-1}{2}} \\ &= 2^{3-1} - 2^{\frac{3-1}{2}} \\ &= 2^2 - 2 \\ &= 4 - 2 = 2 \end{aligned}$$

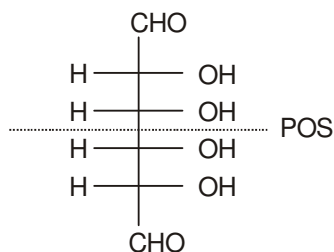


← Enantiomers →



Total no. of different chiral carbon = 4

Total optical isomer = $2^4 = 16$



Total no. of even chiral = 4

$$a = 2^{n-1} = 2^{4-1} = 2^3 = 8$$

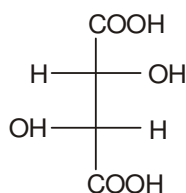
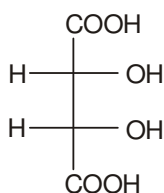
$$m = 2^{\frac{n}{2}-1} = 2^{\frac{4}{2}-1} = 2^{2-1} = 2^1 = 2$$

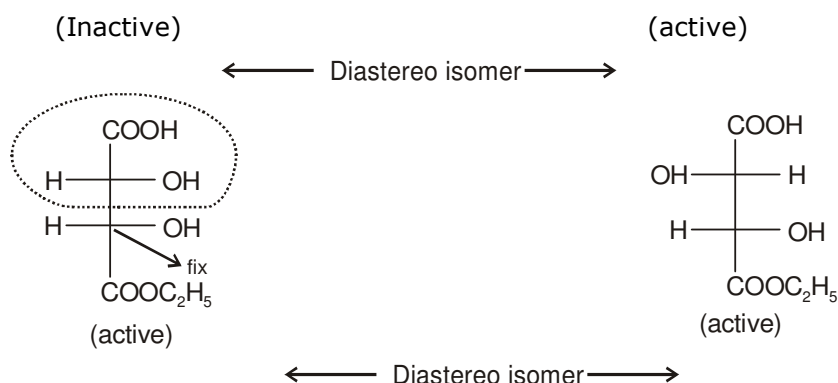
Total isomer = $8 + 2 = 10$

DIASTEREO ISOMERS



For single chiral centre, there is no diastereoisomer. The stereoisomer which are not related as object and mirror image. They may be optically active or optically inactive.



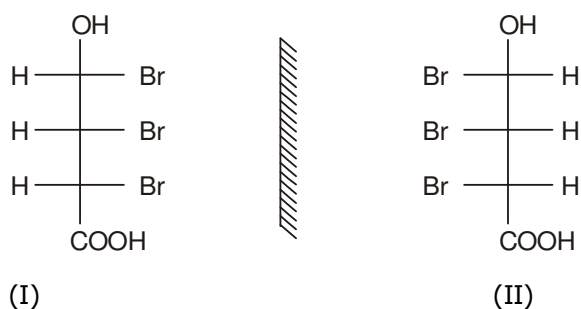
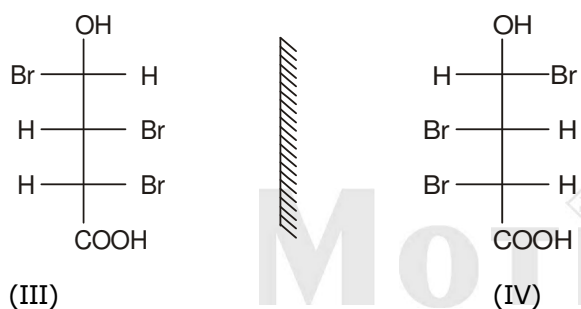


Fix one chiral carbon

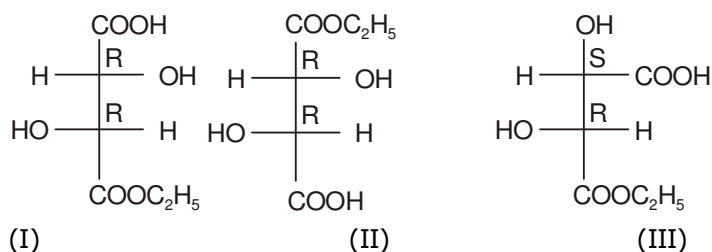
After one inter change

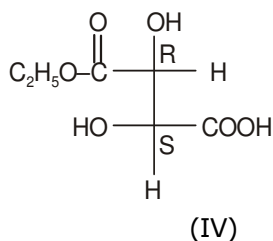
If (R, R) → (R, S)

For compound having 3 chiral carbon to get diastereoisomer, fix two chiral carbon and one interchange with left carbon or fix one chiral carbon and inter change with other two,

Total isomer = $2^3 = 8$ 

(I) and (III), I and (IV), (II) and (III), (II) and (IV) are diastereoisomers.

Ex.38

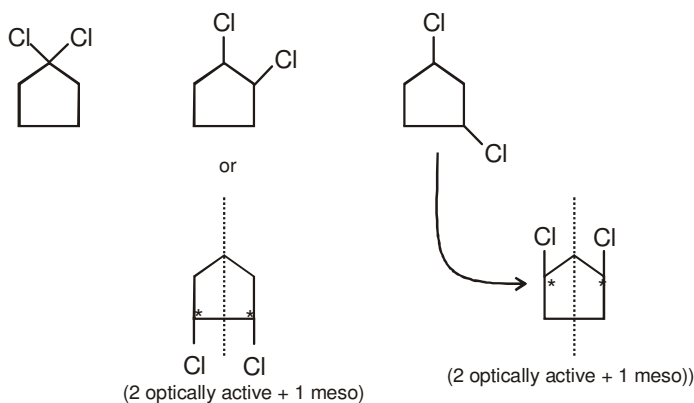


What are the relation among the above compounds?

Sol. I and II are identical III and IV are identical
 II and III are diastereo isomer I and IV are diastereo isomer

Ex.39 Find total isomers obtained by dichlorination of cyclopentane?

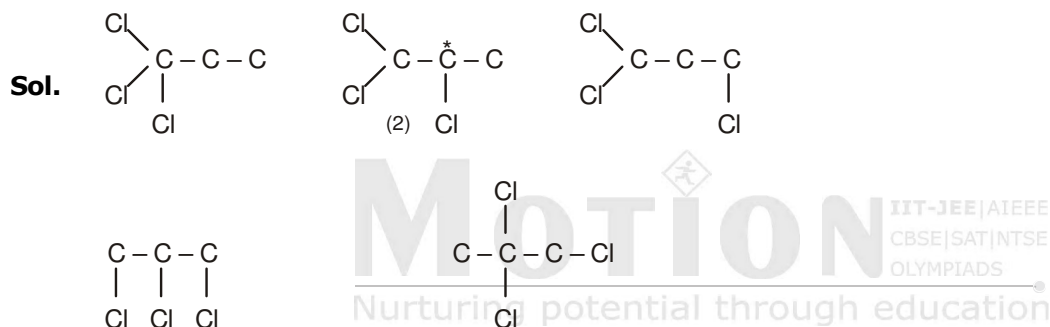
Sol.



Total isomers = 3 + 3 + 1 = 7

Optically active isomers = 6

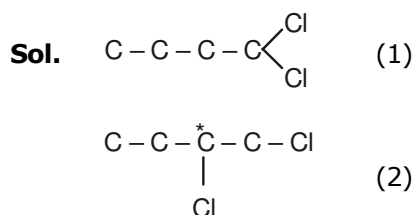
Ex.40 Find the total isomers obtained by trichlorination of propane.

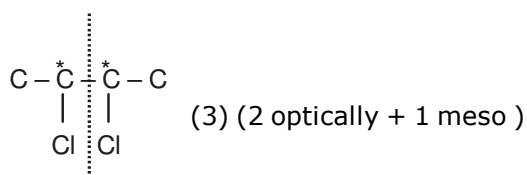
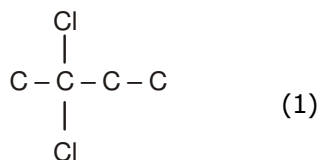
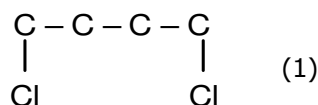
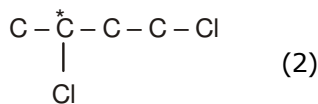


Total isomers = 6

optically isomers = 2

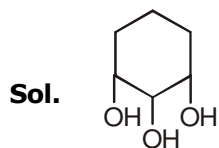
Ex.41 Find total isomers obtained by dichlorination of n-butane





Total isomers = 10 (6 optically active + 1 meso + 3 structural)

Ex.42 How many stereoisomers of 1,2,3-cyclohexanetriol

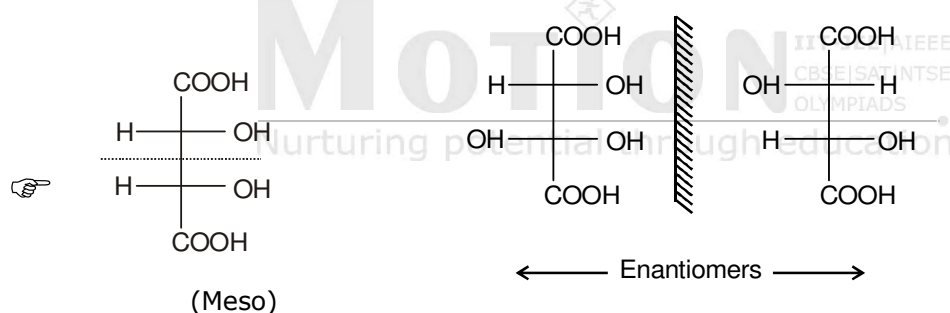


No. of Chiral carbon = 3 (identical) symmetrical)

$$a = 2^{n-1} - 2^{\frac{n-1}{2}} = 2^{3-1} - 2^{\frac{3-1}{2}} = 4 - 2$$

$$m = 2^{\frac{n-1}{2}} = 2^{\frac{3-1}{2}} = 2$$

$$\text{total stereoisomers} = 2 + 2 = 4$$



☞ Mesoform is optically inactive due to internal compensation and racemic mixture is optically inactive due to external compensation.

Ex.43 A and B are enantiomer of each other. Specific rotation of A is 20° . Rotation of mixture of A and B = -5° what is the percentage of racemic part?

Sol. x mol A, 1-x mol B

$$x \times 20 + (1 - x)(-20) = -5$$

$$20x - 20 + 20x = -5$$

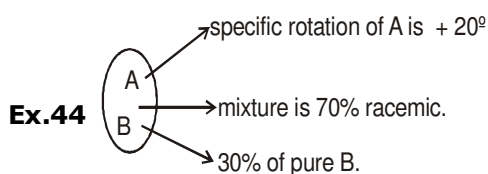
$$40x = 15 \Rightarrow x = \frac{3}{8} = 0.375$$

$$\text{moles of A} = \frac{3}{8}$$

$$\text{moles of B} = 1 - \frac{3}{8} = \frac{5}{8}$$

$\frac{3}{8}$ moles of A and $\frac{5}{8}$ moles of B will form racemic mixture.

$$\text{Enantiomer excess or optical purity} = \frac{5}{8} - \frac{3}{8} = \frac{2}{8} = \frac{1}{4}$$

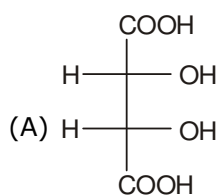


What is rotation of mixture?

Sol. Rotation will be due to B only,
 $= 0.3 \times (-20^\circ)$
 $= -6^\circ$

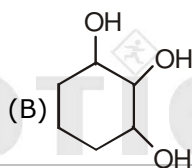
Chiral compound \rightarrow optically active compound

Ex.45 Which of the following compound is Chiral (Optically active)?



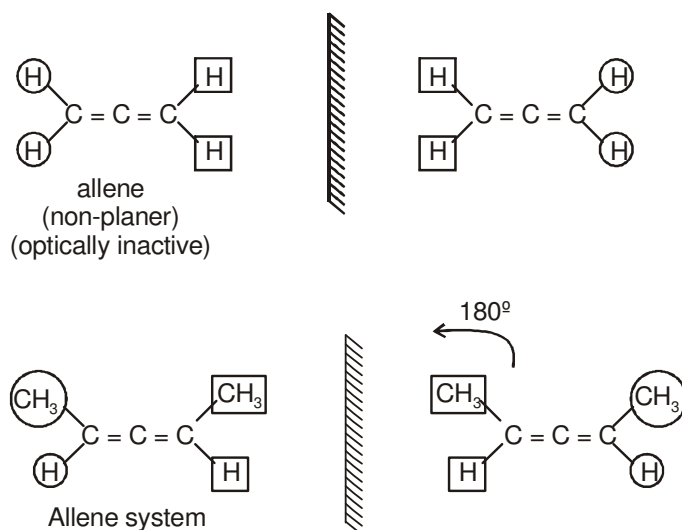
(C) Both

Ans. (D)

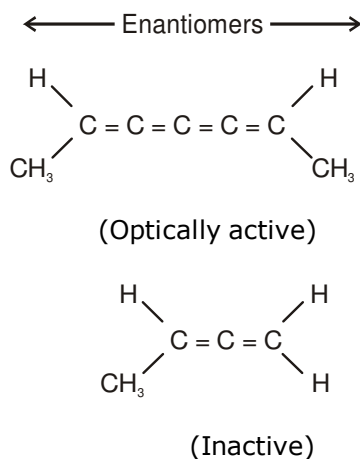


(D) None

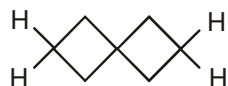
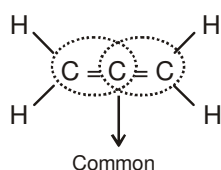
ALLENE SYSTEM



They are non superimposable mirror image

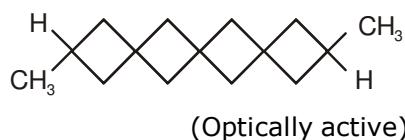


SPIRO COMPOUNDS

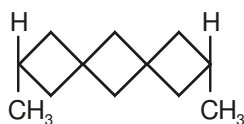


If no. of rings are even \Rightarrow optically active

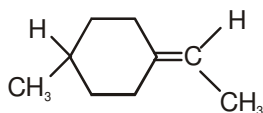
If no. of rings are odd \Rightarrow Inactive



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(Optically Inactive)



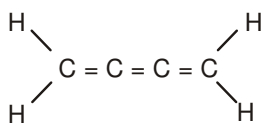
(Optically active)



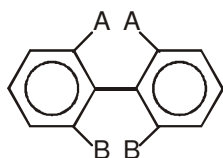
This is the even no of double bond case.



For optical activity, the carbons at extreme position must have different group attached.



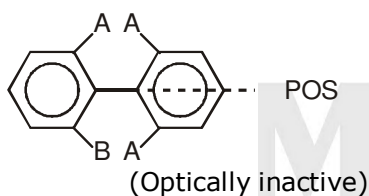
Planer compound

Always have POS \therefore Optically inactive**BIPHENYLS**

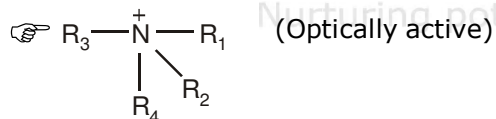
If biphenyl contain bulky group at its ortho position (only) then due to repulsion the planarity of compound disappears and its mirror image is non superimposable.



In the biphenyls none of the two ring must have symmetry.

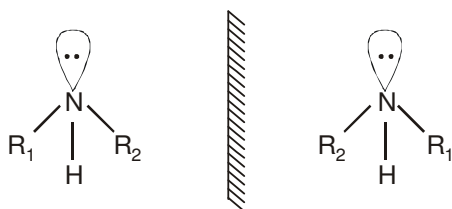


(Optically inactive)



(Optically active)

In 2° Amines.



Optically inactive due to formation of racemic mixture.

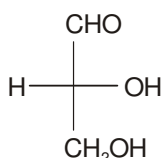
☞ Order of flipping in amines $1^\circ > 2^\circ > 3^\circ$

D-Form :- For compound having one chiral carbon

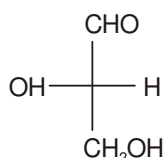
(a) If OH is right side \rightarrow D

(b) If OH is left side \rightarrow L

(**Note** \rightarrow All the carbon must be in vertical having highest O. N. Carbon on the top)

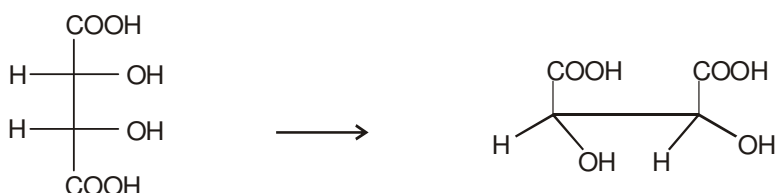


D-form



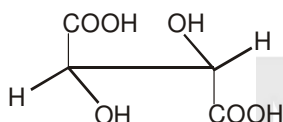
L-form

CONVERSION OF FISHER PROJECTION IN SAWHORSE STRUCTURE

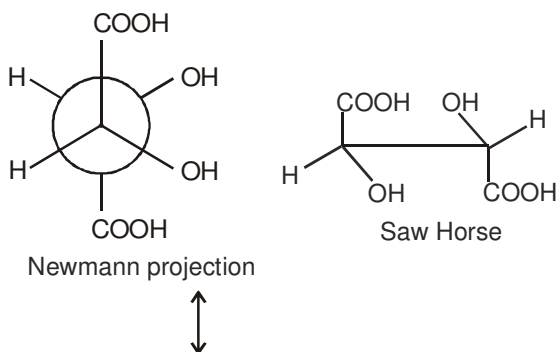


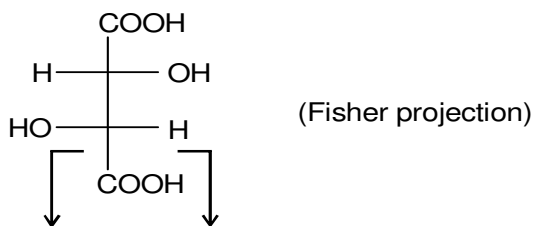
☞ सबसे पहले, First Chiral Carbon को As it is लिख लेते हैं। फिर अगर दोनों Vertical वाले group, same side में हैं, तो दूसरे chiral carbon के, Respect में बाकी दोनों group जैसे लगे हैं वैसे ही लगा देंगे जैसे ऊपर वाले example में दूसरे chiral में, Left में H और Right में OH हैं तो उसे वैसे ही Place कर देंगे।

☞ और दोनों Vertical में situated group को opposite में place करेंगे तो दूसरे वाले Chiral से attached बाकी दोनों group का side reverse कर देंगे i.e. left वाले group को Right में और Right वाले group को left में place कर देंगे।
The above Fisher projection can also be written in Saw Horse form as follows

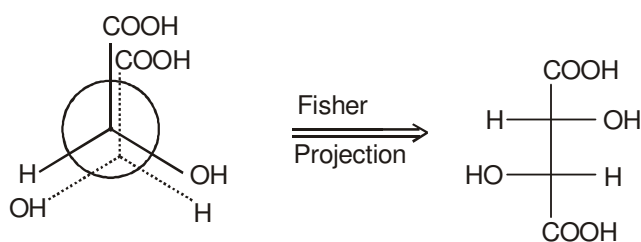


CONVERSION OF NEWMANN PROJECTION IN TO SAWHORSE PROJECTION





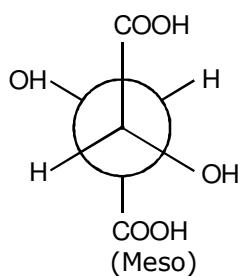
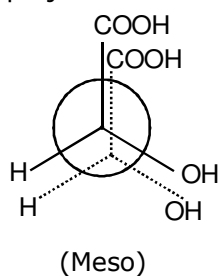
(OH और OH opposite)
करके इसलिए लिखे गये हैं क्योंकि Newmann projection
में COOH ओर COOH opposite में हैं।



Above example में दोनों COOH, same side में हे। इसलिए second chiral carbon में के respect में लगे group का place बदला नहीं जायेगा।



If all the identical groups are same side or in exactly opposite direction to each other in Newmann projection then compound will be meso.

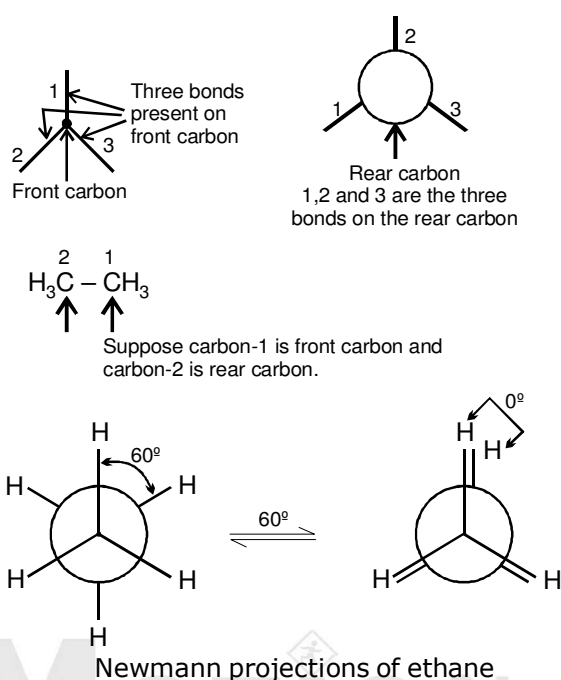


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CONFORMATIONAL ISOMERS**Conformational Isomerism in Alkanes**

Different spatial arrangements of the atoms that result from **restricted** rotation about a single bond are called conformations. Different conformations are also called conformational isomers or **conformers**.

When an ethane molecule rotates about its carbon-carbon single bond, two extreme conformations can result : the **staggered conformation** and the **eclipsed conformation**. An infinite number of conformations between these two extreme conformation is also possible . There are several ways to represent on paper the three dimensional conformation that, occur as a result of rotation about a single bond. **Wedge-and-dash** structures, **Sawhorse** projections and **Newmann** projections are all commonly used methods. But here we will use only Newmann projections. In a Newmann projection you will look down the length of a particular carbon-carbon single bond. The carbon that is in the front, is represented by the point at which three bonds intersect and the carbon that is in the back is represented by a circle. The three lines emanating from each of the carbons represent the carbon's other three bonds.



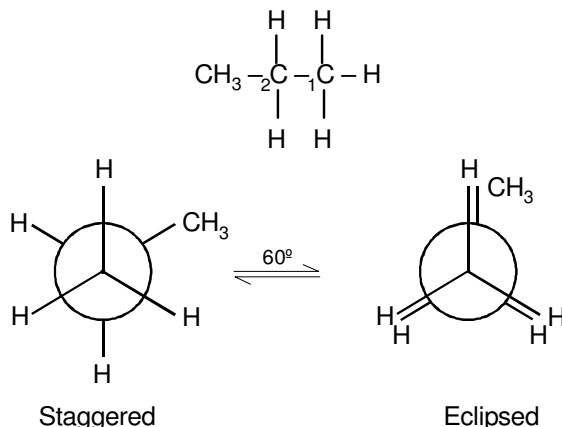
Staggered conformations : A conformation with a 60° dihedral angle is known as staggered conformation.

Eclipsed conformation : A conformation with a 0° dihedral angle is known as eclipsed conformation.

The electrons in a carbon-hydrogen bond will repel the electrons in another carbon-hydrogen bond if the bonds get too close to each other. The staggered conformation, therefore, is the most stable conformation because the carbon-hydrogen bonds are as far away from each other as possible. The eclipsed conformation is the least stable conformation, because in no other conformation are the carbon-hydrogen bonds closer to one another. In staggered conformation the distance between the hydrogen nuclei is 2.55 \AA . but, they are only 2.29 \AA apart in the eclipsed conformation. The rotational barrier in ethane is 2.9 Kcal/mole . This rotational barrier can be described in terms of the change in potential energy of the molecule as a function of the change in dihedral angle. The extra energy of the eclipsed conformation is called **torsional strain**. Torsional strain is the name given to the repulsion felt by bonding electrons of one substituent as they pass close the bonding electrons of another substituent. The energy barrier between staggered and eclipsed conformation in ethane molecule is 2.9 Kcal/mole (12 kJ/mole). This barrier is more than RT ($\approx 0.6 \text{ Kcal/mole}$) at room temperature (energy for free rotation) and less than $16\text{--}20 \text{ Kcal/mole}$ (energy barrier for frozen rotation). Hence the rotation

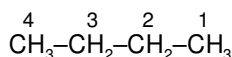
about carbon-carbon single bond is neither completely free nor frozen but only restricted.

- Note :** (i) For free rotation energy barrier is 0.6 Kcal/mole.
(ii) For restricted rotation energy barrier is in between > 0.06 and < 16 Kcal/mole.
(iii) For frozen rotation energy barrier is ≥ 16 Kcal/mole.
Similarly propane has also two conformations.

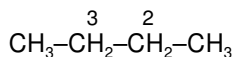


In this case, out of six substituents on two C's (carbon -1 and carbon-2) five, are hydrogens and one is CH_3 group.

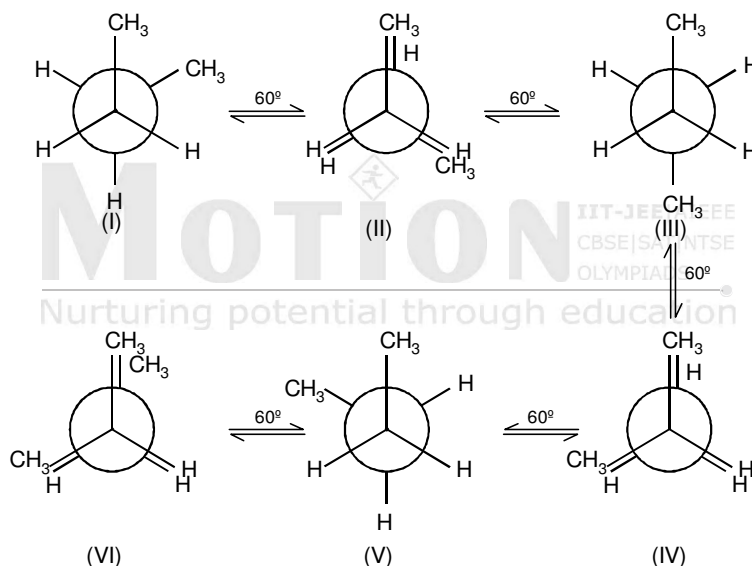
Butane has three carbon-carbon single bonds and the molecule can rotate about each of them



If rotation will be about C - 2 and C - 3 bond then conformation will be symmetrical.



For conformational analysis treat butane as the derivative of ethane. Out of six substituents four are hydrogens and two are methyl groups Different conformations of butane are obtained by rotation.



Butane has three staggered conformers (I, III and V) .

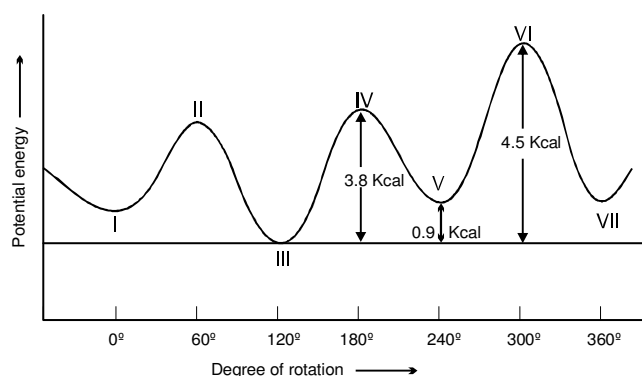
Conformer -(III), in which the two methyl groups are as far apart as possible, is more stable than the other two staggered conformers (I and V). The most stable of the staggered conformers is called the **anti conformer** (in anti conformation the angle between two methyl groups is 180°) and the other two staggered conformers are called gauche conformers. (anti in Greek for "opposite of" gauche in French for " left"). In gauche conformation the angle between two methyl groups is 60° .

In the anti conformer, the largest substituents (CH_3 and CH_3) are opposite to each other; in the gauche conformer, they are adjacent. Two gauche conformers have the same energy but each is 0.9 Kcal/mole less stable than the anti conformer.

Anti and gauche conformers do not have the same energy because of the steric strain. **Steric strain** or **steric hindrance** is the strain put on a molecule when atoms or groups are large in size and due to this they are too close to each other, which causes repulsion between the electrons of atoms or groups. There is more steric strain in the gauche conformer than in the anti because the two methyl groups are closer together in the gauche conformer. Steric strain in gauche conformer is called gauche interaction.

The eclipsed conformer in which the two methyl groups are closest to each other (VI) is less stable than the other eclipsed conformers (II and IV). All these eclipsed conformers have both torsional and steric strain. Torsional strain is due to bond-bond repulsion and steric strain is due to the closeness of the eclipsing groups.

In general steric strain in the molecule is directly proportional to the size of the eclipsing groups. Eclipsed conformer (VI) is called the fully eclipsed conformer (angle between two methyl groups is zero) whereas (II) and (IV) are called eclipsed conformers. The energy diagram for rotation about the C-2-C-3 bond of butane is shown in the **Fig.**

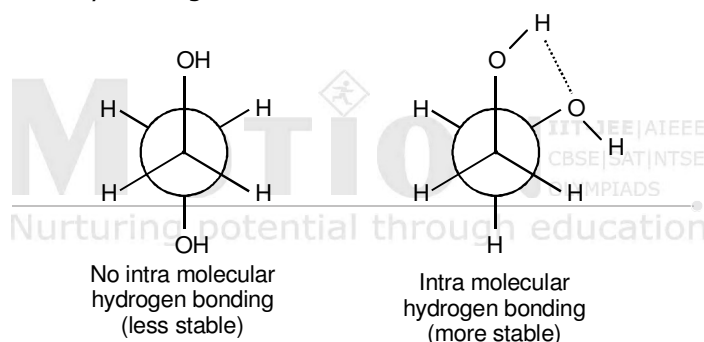


Thus the relative stabilities of the six conformers of n-butane in decreasing order is as follows:

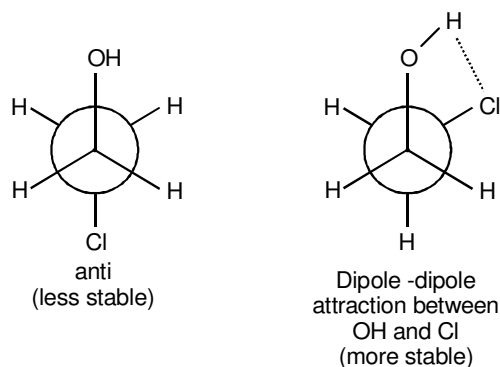
Anti > gauche > eclipsed > fully eclipsed
(III) (I) and (V) (II) and (IV) (VI)

Thus molecules with carbon-carbon single bonds have many interconvertible conformers. Conformers cannot be separated because they rapidly interconvert.

Although anti conformation is more stable than the gauche conformation but in some cases gauche conformation is more stable than the anti because of the intramolecular hydrogen bonding which is geometrically possible only in the gauche conformation.

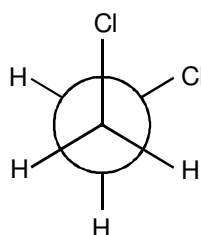


In ethylenechlorohydrin also gauche conformation is more stable than the anti conformation due to the dipole-dipole attraction between OH and Cl which is geometrically possible only in the gauche conformation.



Ex.46 Write Gauch conformation of the compound $\text{CH}_2\text{Cl} - \text{CH}_2\text{Cl}$?

Sol. Gauch conformation of the given compound is:



(i) Mole fraction of anti and gauch form : Mole fraction of stable conformers (i. e., mole fraction of anti and gauch can be calculated if dipole moment of anti and gauch form is known.

$$\mu_{\text{ob}} = \mu(\text{anti}) \times x_a + \mu(\text{gauch}) \times x_g$$

where x_a = mole fraction of anti form and

x_g = mole fraction of gauch form.

Suppose

$$\mu_{\text{ob}} = 1.00$$

$$\mu_g = 5.55$$

Then x_a can be calculated as follows :

$$\mu_{\text{ob}} = \mu_a \times x_a + \mu_g \times x_g$$

$$1 = 0 \times x_a + 5.55 x_g$$

\therefore

$$x_g = \frac{1}{5.55} = 0.18$$

Sum of mole fraction of $x_a + x_g = 1$

$$x_a = 1 - x_g = 1 - 0.18 = 0.82$$

(ii) relative amounts of anti and gauch conformers

The anti conformer of n-butane is more stable than the gauch may about 900 Kcal/mole (i.e., 0.9 Kcal/mole). This is energy barrier between anti and gauch.

Thus $\text{gauch} \rightleftharpoons \text{anti}$, $\Delta H = -900 \text{ cal/mole}$.

Suppose at room temp ΔG is negligible.

So

$$\Delta G = -RT \ln K_{\text{eq}}$$

$$K_{\text{eq}} = \frac{[\text{anti}]}{[\text{gauch}]}$$

and

$$\ln K_{\text{eq}} = \frac{-\Delta G}{RT} = \frac{-900 \text{ cal/mole}}{1.99 \text{ cal/moleK} \times 298 \text{ K}} = 1.52$$

The ratio of K_{eq} is $4.57 \approx 4.6$, which means that about 82% mole $\left(\frac{4.6 \times 100}{5.6}\right)$ of the molecule are in the anti conformation and 18% in the gauche conformation at any one time.

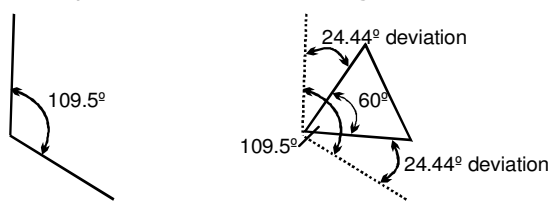
STABILITY OF CYCLOALKANES

Compounds with three and four membered rings are not as stable as compounds with five or six membered rings.

The German chemist Baeyer was the first to suggest that the instability of these small ring compounds was due to angle strain. This theory is known as Baeyer-Strain theory.

Baeyer strain theory was based upon the assumption that when an open chain organic compound having the normal bond angle 109.5° is converted into a cyclic compound, a definite distortion of this normal angle takes place leading to the development of a strain in the molecule.

Baeyer assumed that cyclic rings are planar. Assuming that the rings are planar, the amount of strain in various cycloalkanes can be expressed in terms of angle of deviation (d).



$$d = \frac{1}{2} \left[109.5 - \frac{2(n-2)}{n} \times 30 \right] \text{ or } d = \frac{1}{2} [109.5 - \alpha]$$







where n = number of carbon-carbon bonds in cycloalkane ring

α = inner bond angle in the cycloalkane ring.

$$\text{Angle strain} \propto d \propto \frac{1}{\text{inner angle}}$$

$$\text{Stability} \propto \frac{1}{d} \propto \text{inner angle } (\alpha)$$

Now let us take the case of three to eight membered cyclic compounds.

					
cyclopropane $\alpha = 60^\circ$ $d = 22.44^\circ$	cyclobutane $\alpha = 90^\circ$ $d = 9.4^\circ$	cyclopentane $\alpha = 108^\circ$ $d = 0.44^\circ$	cyclohexane $\alpha = 120^\circ$ $d = -5.16^\circ$	cycloheptane $\alpha = 128.6^\circ$ $d = -9.33^\circ$	cyclooctane $\alpha = 135^\circ$ $d = -12.46^\circ$

The positive and negative values of (d) indicate whether the inner angle is less than or more than the normal tetrahedral value.

Baeyer thus predicted that a five membered ring compound would be the most stable. He predicted that six membered ring compounds would be less stable and as cyclic compound became larger than five membered ring they would become less and less stable.

Contrary to what Baeyer predicted, however, cyclohexane is more stable than cyclopentane. Furthermore, cyclic compounds do not become less and less stable as the number of side increase. Thus Baeyer strain theory is applicable only to **cyclopropane, cyclobutane and cyclopentane**.

The mistake that Baeyer made was to assume that all cyclic compounds are planar. In real sense only cyclopropane is planar and other cycloalkanes are not planar. Cyclic compounds **twist** and **bend** in

order to achieve a final structure that minimises the three different kinds of strain that can destabilise a cyclic compound.

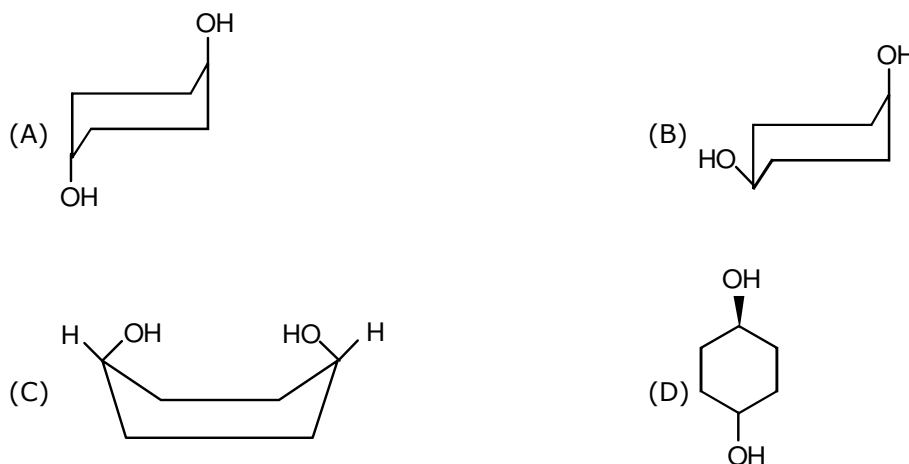
1. **Angle strain** is the strain that results when the bond angle is different from desired tetrahedral bond angle of 109.5° .
2. **Torsional strain** is caused by repulsion of the bonding electrons of one substituent with bonding electrons a nearby substituent.
3. **Steric strain** is caused by atoms or groups of atoms approaching each other too closely.

Ex.47 According to Baeyer-strain theory which compound has minimum angle strain?

- (A) *n*-butane (B) cyclopentane (C) cyclopropane (D) cyclohexane

Sol. (B)

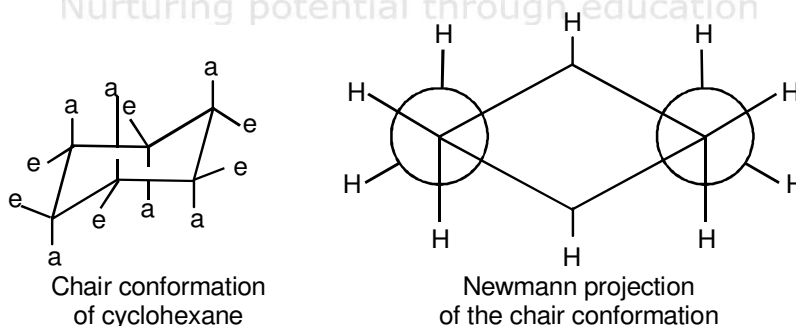
Ex.48 Which form of trans 1,4-cyclohexane diol is most stable?



Sol. (C)

CONFORMATION OF CYCLOHEXANE

Despite Baeyer's prediction that six-membered cyclic compound would be the most stable, the six membered cyclic compound is the most stable. Six membered cyclic compound are most stable because they can exist in a conformation that is almost completely free of strain. This conformation is called the **chair conformation**. In a chair conformation of cyclohexane all bond angles are 111° which is very close to the 109.5° and all the adjacent carbon-hydrogen bonds are staggered.



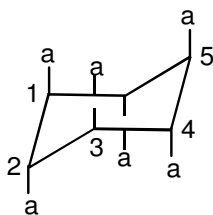
⇒ Each carbon in chair conformation has an axial bond and an equatorial bond.

⇒ Axial bonds are perpendicular to the plane of the ring and equatorial bonds are in the plane of the ring.

⇒ If axial bond on carbon-1 is above the plane of the ring then axial bond on carbon-2 will be below the plane of the ring. Thus

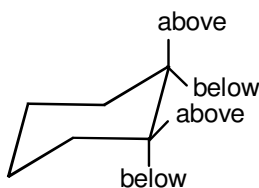
C - 1, C - 3 and C - 5 axial bonds are above

C - 1, C - 4 and C - 6 axial bonds are below



⇒ Thus C - 1 axial and C - 2 axial are trans to each other. Similarly C - 1 and C - 5 axials are cis to each other.

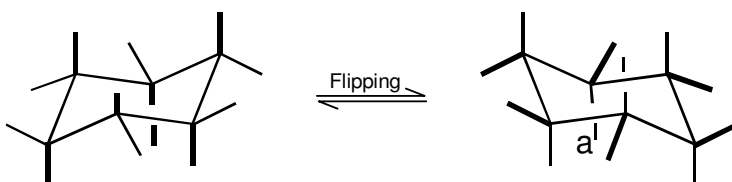
⇒ If axial bond on carbon - 1 will be above the plane then equatorial bond on this carbon will be below the plane.



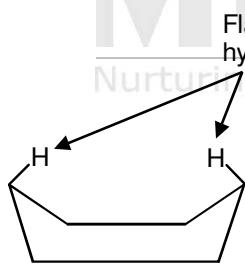
(i) Thus C - 1 equatorial and C - 2 equatorial will be cis

(ii) C - 1 axial and C - 2 equatorial will be cis

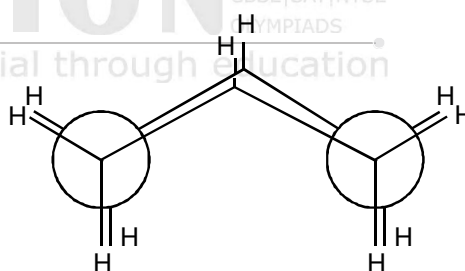
⇒ As a result of rotation about carbon-carbon single bonds cyclohexane rapidly interconverts between two stable chair conformations. This interconversion is known as ring-flip. When the two chair forms interconvert, axial bonds become equatorial and equatorial bonds become axial.



⇒ Cyclohexane can also exist in a boat conformation. Like the chair conformation, the boat conformation is free of angle strain. However, the conformation is less stable than the chair conformation by 11 Kcal/mole. Boat conformation is less stable because some of the carbon-hydrogen bonds in boat conformation are eclipsed.



Boat conformation of cyclohexane

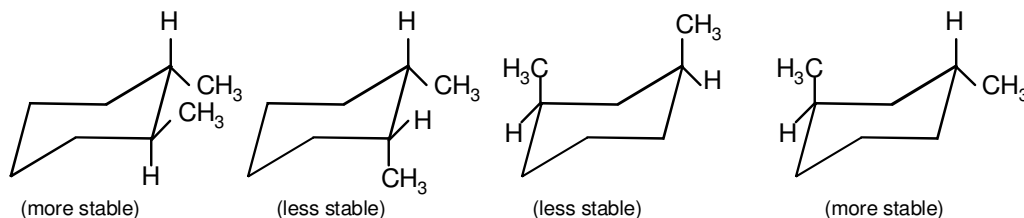


Newman projection of the boat conformation

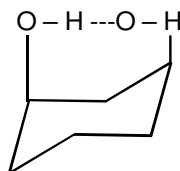
The boat conformation is further destabilised by the close proximity of the flagpole hydrogens. These hydrogens are 1.8 Å apart but the van der Waal's radii is 2.4 Å. The flagpole hydrogens are also known as trans nuclear hydrogens.

When one hydrogen of cyclohexane is placed by a larger atom or group, crowding occurs. The most

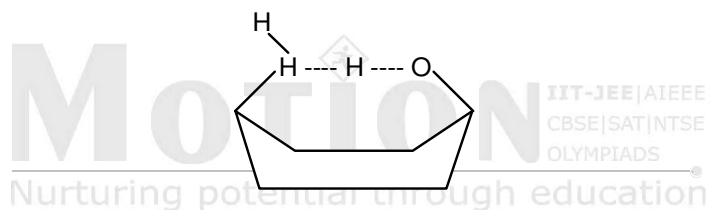
severe crowding is among atoms held by the three axial bonds on the same side of the molecule; the resulting repulsive interaction is called 1,3-diaxial interaction. This causes steric strain in the molecule. Thus, monosubstituted cyclohexane will assume chair conformation in which the substituent occupies an equatorial position. Similarly in disubstituted cyclohexanes the chair conformation containing both the substituents in equatorial positions will be the preferred conformation. In general, the conformation with bulkier substituent in an equatorial position will be the preferred conformation. For examples:



cis-1,3-cyclohexanediol has shown to have diaxial rather than the diequatorial orientation. This is because of the stabilisation orientation. This is because of the stabilisation of the diaxial form by intramolecular hydrogen bonding which is not possible in the diequatorial form.



The preferred conformation of the cyclohexane ring is the chair form, but when intramolecular hydrogen bonding is possible between groups in 1 and 4 positions the molecule assumes a boat conformation rather than the chair conformation in which this hydrogen bonding is not possible.



SOME IMPORTANT TERMINOLOGY

Asymmetric carbon : The carbon which is attached with four different groups of atoms is called asymmetric carbon.

Asymmetric molecule : If all the four substituents attached to carbon are different, the resulting molecule will lack symmetry. Such a molecule is called asymmetric molecule. Asymmetry of molecule is responsible for optical activity in such organic compounds.

Achiral molecule : A molecule that is superimposable on its mirror image. Achiral molecules lack handedness and are incapable of existing as a pair of enantiomers.

Axial bond : The six bonds of a cyclohexane ring (below) that are perpendicular to the general plane of the ring, and that alternate up and down around the ring.

Boat conformation : A conformation of cyclohexane that resembles a boat and that has eclipsed bonds along its two sides.

Chair conformation : The all-staggered conformation of cyclohexane that has no angle strain or torsional strain and is therefore, the lowest energy conformation.

Chiral molecule : A molecule that is not superimposable on its mirror image. Chiral molecules have handedness and are capable of existing as a pair of enantiomers.

Chirality : The property of having handedness.

Configuration : The particular arrangement of atoms (or groups) in space that is characteristic of a given stereoisomer.

Conformatoin : A particular temporary orientation of a molecule that results from rotations about its single bonds.

Conformational analysis : An analysis of the energy changes that a molecule undergoes as its groups undergo rotation (sometimes only partial) about the single bonds that join them.

Conformer : A particular staggered conformation of a molecule.

Connectivity : The sequence, or order, in which the atoms of a molecule are attached to each other.

Diastereomers : Stereoisomers that are not mirror images of each other.

Dextrorotatory : Those substances which rotate the plane of polarisation of light towards right are called dextrorotatory. Currently, dextro and laevo rotations are represented by algebraic signs of (+) and (-) respectively.

Eclipsed conformation : A temporary orientation of groups around two atoms joined by a single bond such that the groups directly oppose each other.

Enantiomers : Stereoisomers that are mirror images of each other. enantiomers rotate the plane of polarised light to the same extent but in opposite direction.

Equatorial bond : The six bonds of a cyclohexane ring that lie generally around the "equator" of the molecule.

Levorotatory : A compound that rotates planepolarized light in a counterclockwise direction.

Meso compound : An optically inactive compound whose molecules are achiral even though they contain tetrahedral atoms with four different attached groups. A meso-compound is optically inactive due to internal compensation.

Optically active substances : Those substances which rotate the plane of polarisation of plane-polarised light when it is passed through their solution are called optically active substances. This phenomenon is called optical activity.

Plane of symmetry : An imaginary plane that bisects a molecule in a way such that the two halves of the molecule are mirror images of each other. Any molecule with a plane of symmetry will be achiral.

Plane-polarized light : Ordinary light in which the oscillations of the electrical field occur only in one plane. It is obtained by passing a monochromatic light (light of single wavelength) through a Nicol prism.

Polarimeter : A device used for measuring optical activity.

(R-S) System : A method for designating the configuration of tetrahedral stereogenic centres.

Racemic form (racemate or racemic mixture) : An equimolar mixture of enantiomers. A racemic mixture is optically inactive due to external compensation.

Racemisation : The process of conversion of an enantiomer into racemic mixture is known as an racemisation.

Retention : If in an optically active molecule that relative configuration of the atoms groups around a chiral centre remains the same before and after the reaction, the reaction is said to proceed with retention of configuration.

Relative configuration : The relationship between the configuration of two chiral molecules. Molecules are said to have the same relative configuration when similar or identical groups in each occupy the same position in space. The configuration of molecules can be related to each other through reactions of known stereochemistry, for example through reactions that cause no bonds to a stereogenic center to be broken.

Resolution : The process by which the enantiomers of a racemic form are separated.

Ring flip : The change in a cyclohexane ring (resulting from partial bond rotations) that converts one ring conformation to another. A chair-chair ring flip converts any equatorial substituent to an axial substituent and vice versa.

Ring strain : The increased potential energy of the cyclic form of a molecule (usually measured by heats of combustion) When compared to its acyclic form.

Specific rotation : Specific rotation is defined as the number of degrees of rotation observed when the concentration of optically active substance is 1 g cm^{-3} and length of polarimeter tube is 1 decimetre (dm) for D-line of sodium vapour lamp at 25°C .

Stereogenic center : An atom bearing group of such nature that an interchange of any two groups will produce a stereoisomer.

Steric hindrance : An effect on relative reaction rates caused when the spatial arrangement of atoms or groups at or near the reacting site hinders or retards a reaction.

Torsional strain : The strain associated with an eclipsed conformation of a molecule; it is caused by repulsions between the aligned electron pairs of the eclipsed bonds.