Module-2

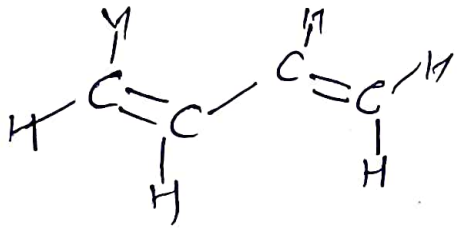
Organic structure & Reactivity

Conjugated Molecules

Resonance effect

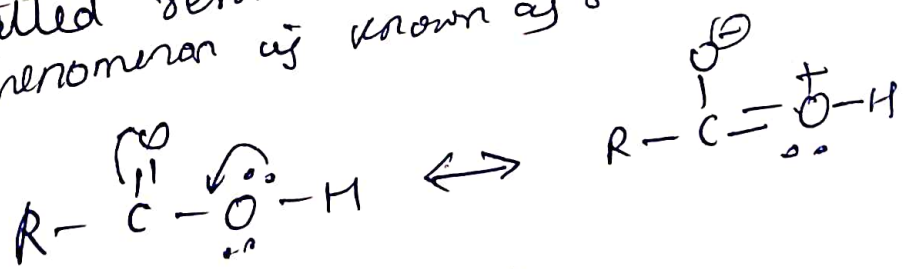
If two double bonds in a molecule are separated by a single bond, they are said to be in conjugation & the molecule having such bonds are called conjugated molecules.

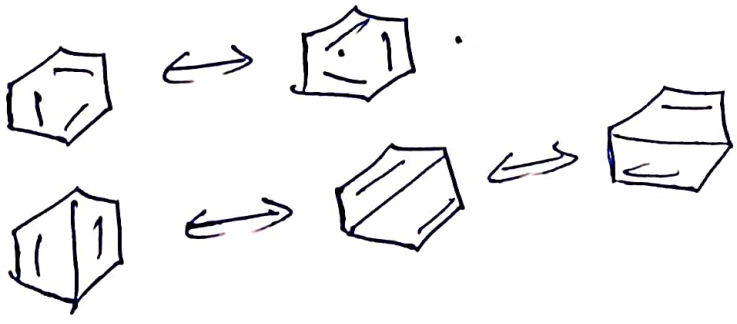
eg. 1,3-butadiene



* Robinson & Ingold stated that such compd exists in two or more forms none of which can explain all the properties of the molecule under investigation. they are called mesomerism.

* If a compd having a certain molecular formula can be represented by different structural formulae which differ only in arrangement of $\bar{e}$ pairs & not of atoms such like structures are called resonating or canonical structures & phenomenon is known as resonance..





Cond^ns for Resonance

i) The resonating structures must differ only in position of the electron pairs & not of atomic nuclei

ii) The resonating structures must have the same no of paired & unpaired e^-.

iii) The energies of various R.S. must be either same or nearly the same.

iv) All RS do not contribute equally towards RH.

Effects of Resonance

1. **Stability** : Reso. energy of RH. ↓ Stability ↑

2. **Bond length** : Reso. causes change in BL

C–C is 154 pm

C=C is 134 pm

C–C for benzene is 139 pm

Aromaticity

Huckel's rule :- $(4n+2)$ rule.

$n = 0, 1, 2, 3, \ldots$

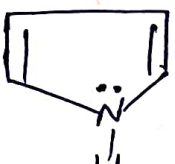
Monocyclic planar systems which contain $(4n+2)\pi$ e^-s possess aromaticity

(i) Monocyclic

eg:

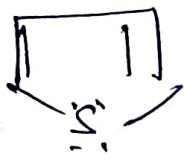
Benzene

$6\pi e^-$ $(4n+2)$ ✓



Pyrrole

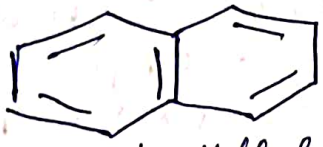
Furan



Thiophene

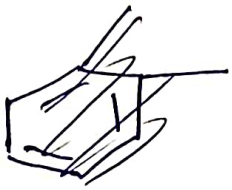
$8\pi e^-$ $(4n+2)$ ✗

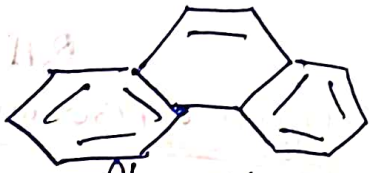
(ii) fused ring system



Naphthalene
(10 π e)

anthracene
(14 π e

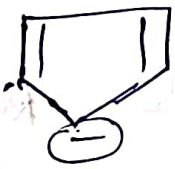




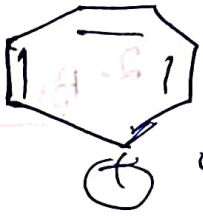
Phenanthrene

(iii)

2 π e⁻



6 π e⁻



6 π e⁻

Isomerism :-

Compounds having same molecular formula & molecular mass but having different characteristics are called isomers. This phenomenon is called isomerism. The relative position of different atoms or groups in these isomers is different & causes the difference in properties.

Somers

Structural Isomerism
↓
Molecules differ in structural arrangement of atoms or groups

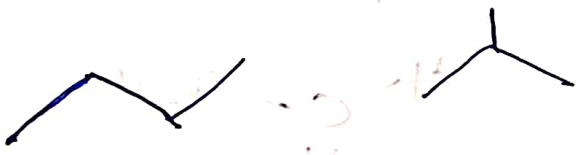
Stereoisomerism.
↓
isomers have same structural arrangement but differ in arrangement of atoms or groups in space

Isomers

- Structural Isomerism
  - chain isomer
  - Position Isomer
  - Functional Isomer
  - Metamers
  - Tautomers
- stereoisomerism
  - Geometrical isomer
  - optical isomer
  - conformational isomer.

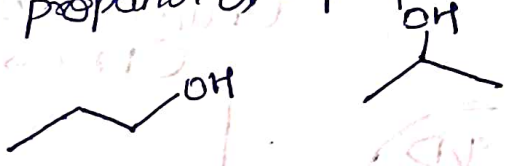
Chain

n-butane & Isobutane (C_4H_{10})



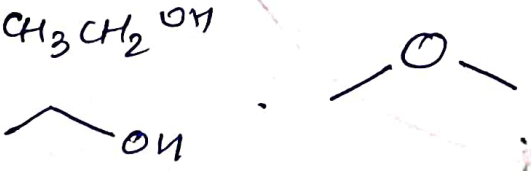
Position

1 propanol & 2 propanol (C_3H_8O)

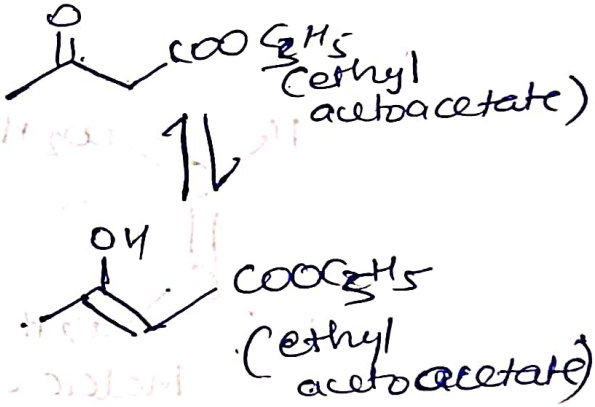


Functional

Ethyl alcohol & Dimethyl ether (C_2H_6O)



Tautomer



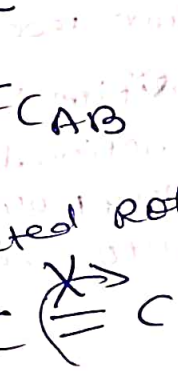
Geometrical Isomerism

↳ Arises due to restriction or hinderence in C–C double bond

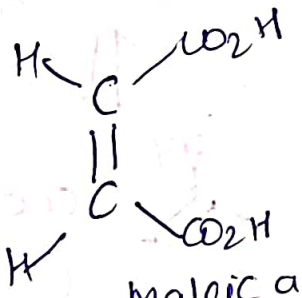
⇒ C = C

⇒ $C_{AB} = C_{AB}$

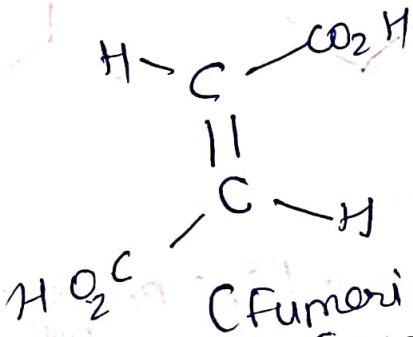
⇒ Restricted Rotation



- Cis / Trans.
  - Same
  - opposite



Maleic acid (Cis)

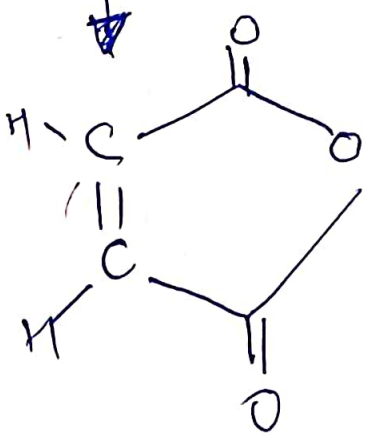


Cfumaric acid (Trans)

M = 98

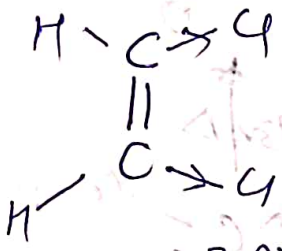
Δ 453K

Δ 573K



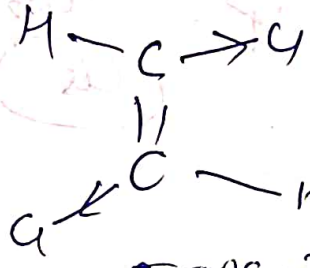
Determination of configuration

① From Dipole moment measurement



Cis-2-Dichloroethane

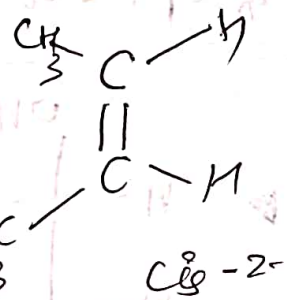
$\mu = 1.85\ D$



Trans-2-dichloroethane

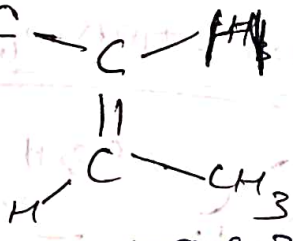
$\mu = 0\ D$

② From Boiling Pt



Cis-2-butene

bp. 277K

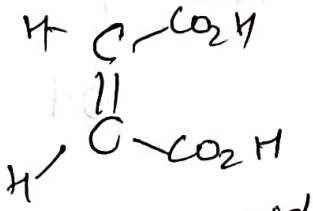


Trans-2-butene

bp 274K

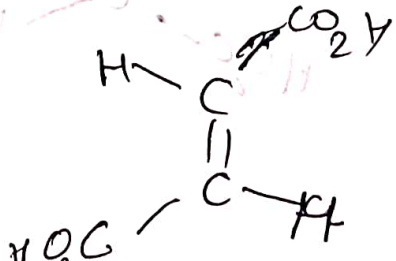
BP ∝ DM

③ Melting Pt



Maleic acid (Cis)

MP = 403K



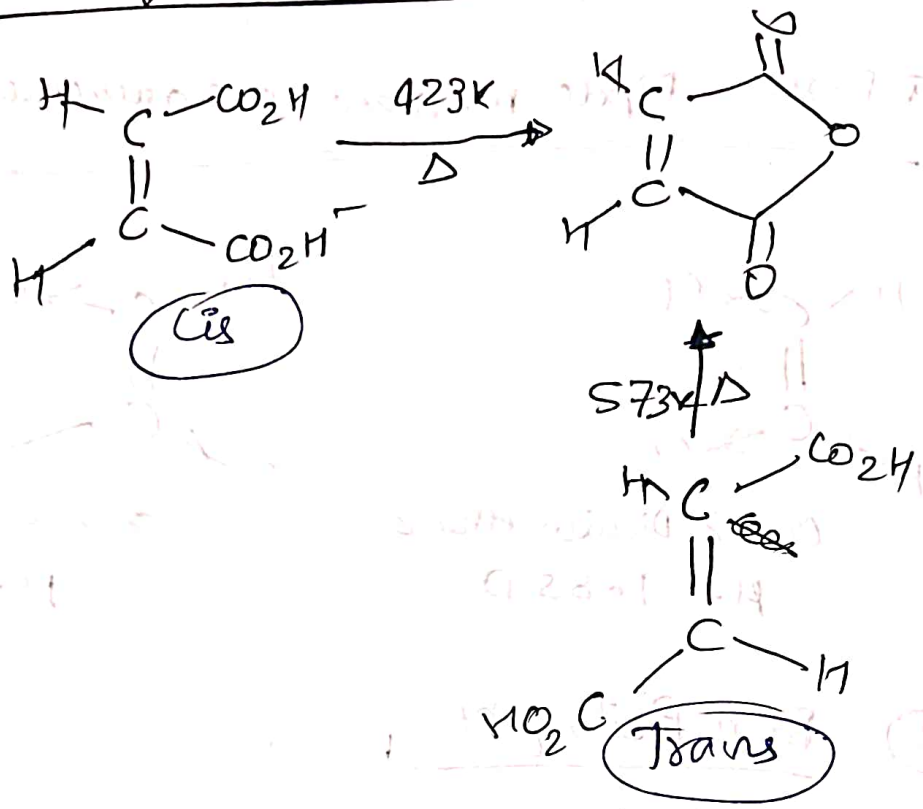
Fumeric acid (Trans)

MP = 575K

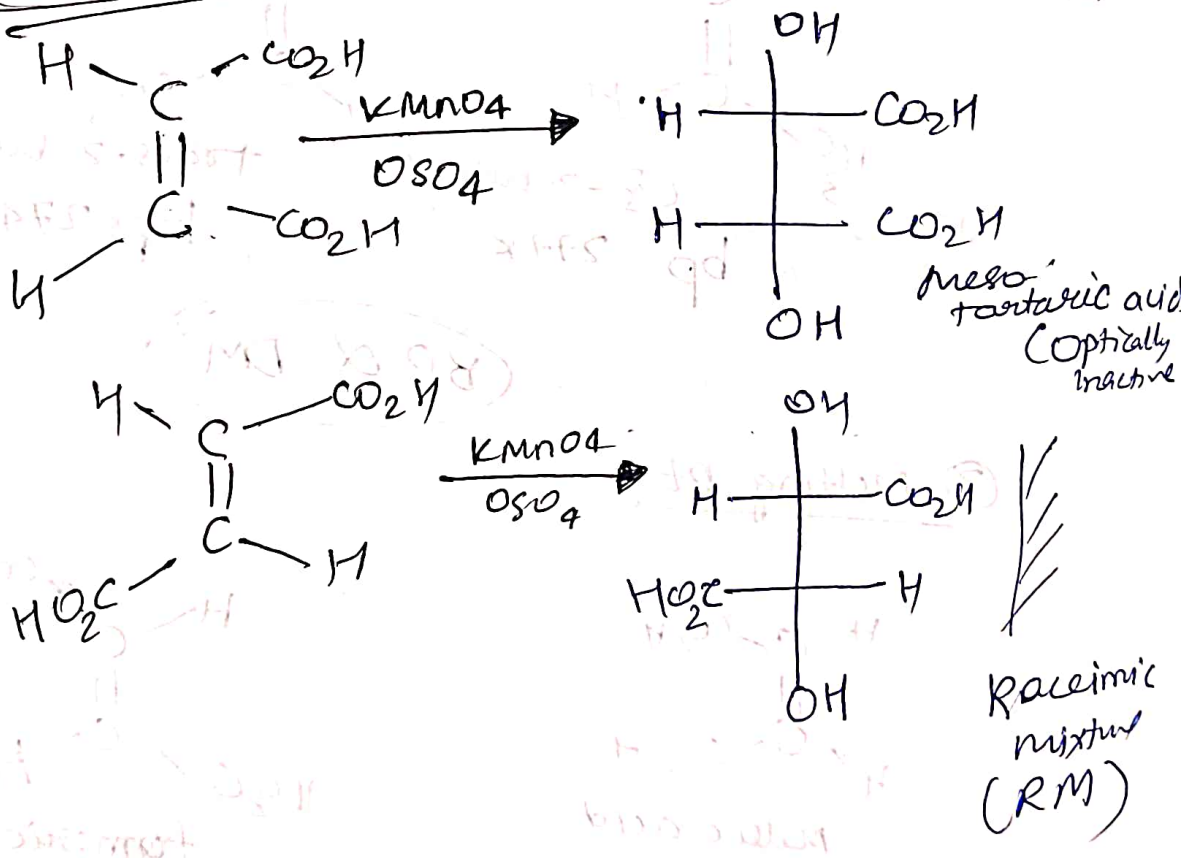
due to better packing efficiency [Inter-molecular forces]

Trans has high MP.

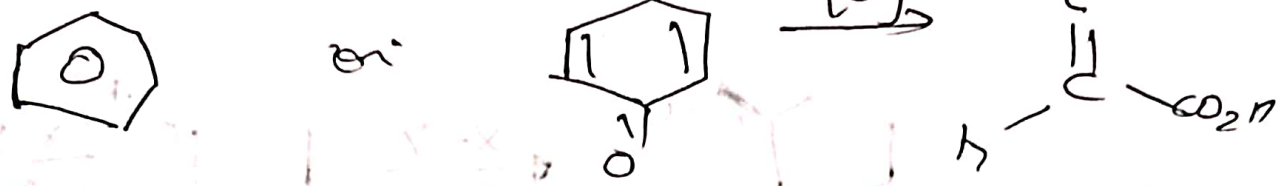
④ Formation of cyclic compd :-



⑤ Formation of type of optical isomers



(6) from MOP



E-Z designations of G I

$C_{AB} = C_{DE}$

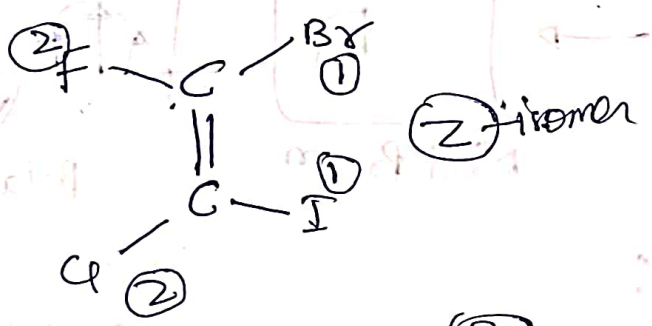
(CIP)

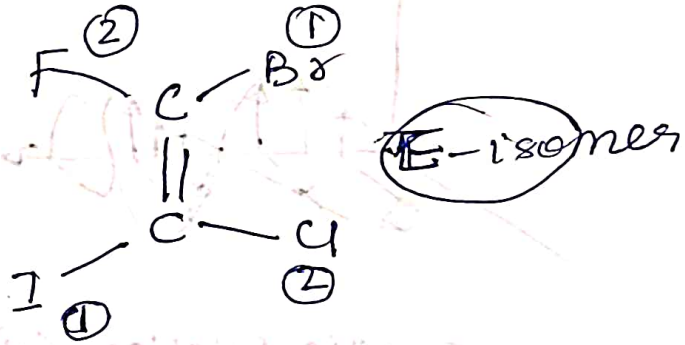
Cahn Ingold Prelog

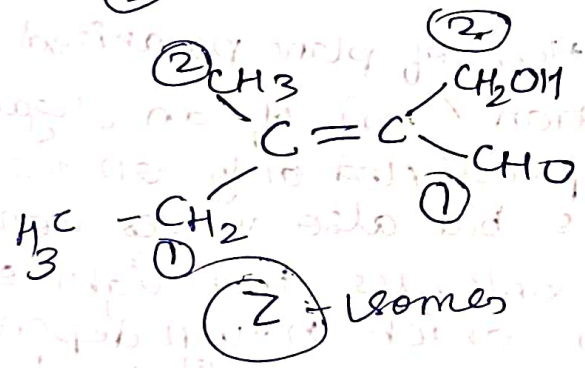
E : Enemy (Entegen or opposite)

Z : zusammen (together).

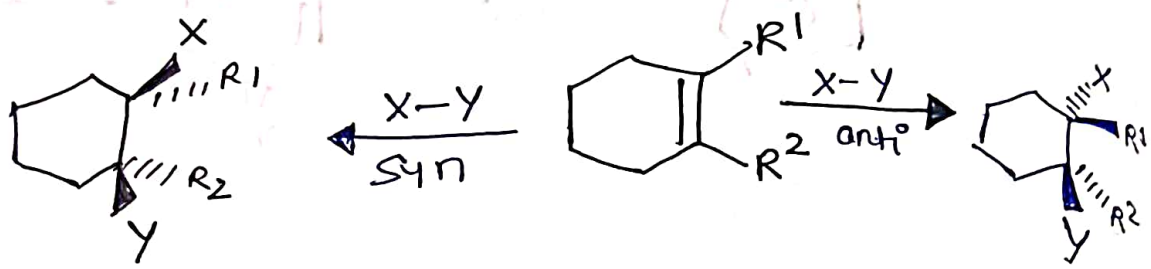
Priorities ✓ same as R·S =



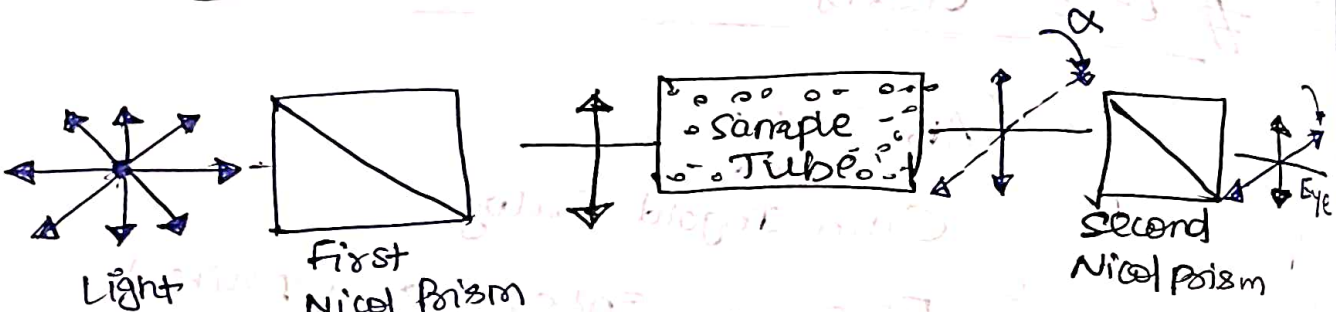


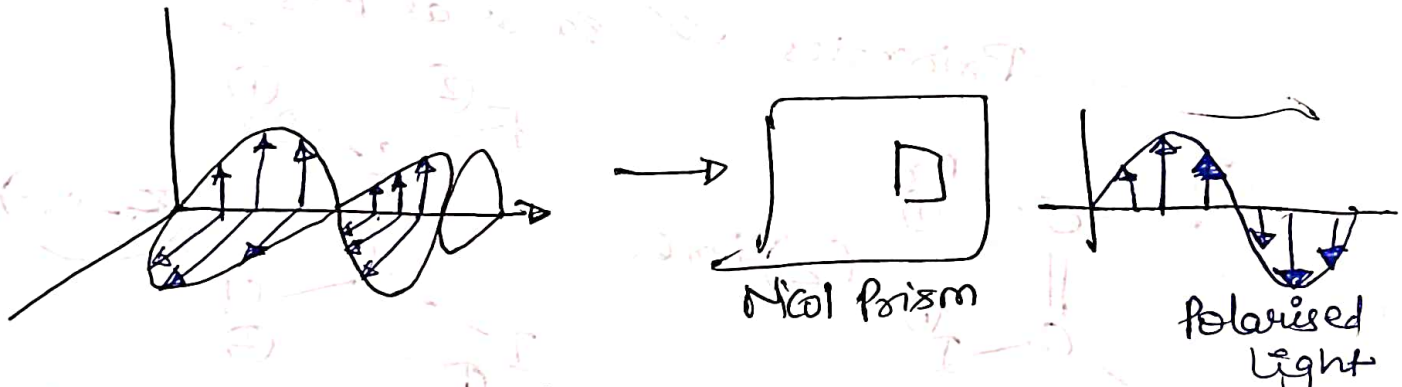


Syn anti:



optical Isomerism





Specific Rotation (α):

The angle of rotation of plane polarised light or optical rotation (om) of an organic substance depends not only on the kind of molecules but also varies considerably with the no of molecules that light encounters in its path which in turn depends on the concentration of the sol^{n} used & Length of polarimeter tube containing it.

Special rotation (α) depends on

- Molecule
- Concn
- Path length
- Temperature
- Wave length
- Nature of solvent

$$[\alpha]_{\lambda}^{t} = \frac{\alpha}{l \times c}$$

l : Length of Polarimeter

α observed rotation

c : concn

$l = 1$ decimeter

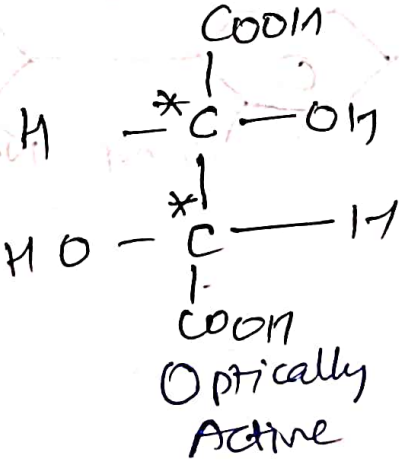
$c = 1$ gm/mL

$[\alpha]_{\lambda}^{1} = \alpha$

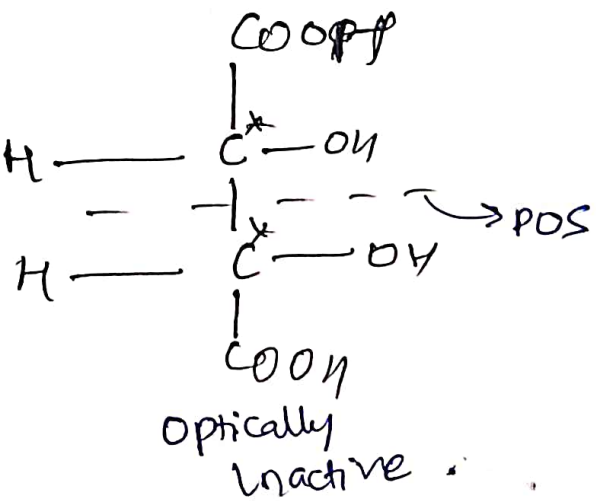
= chiral

→ do not possess POS.

→ An object which is non-superimposable on its mirror image is called chiral object.



Optically Active



optically Inactive.

No. of optical isomers

- Symmetric
  - odd: $\left[2^{n-1} - 2^{\frac{(n-1)}{2}}\right] + \left[2^{\frac{(n-1)}{2}}\right]$
  - even: $2^{n-1} + 2^{p-1}$, $p = \frac{n}{2}$
- Asymmetric: 2^n

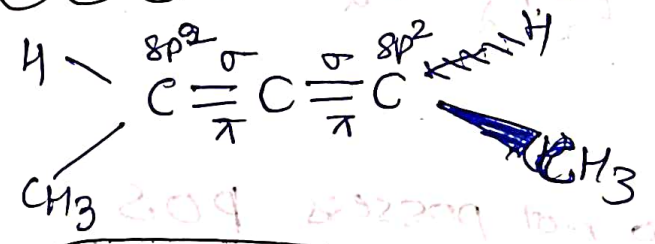
Tartaric acid

$CH(OH)COOH$ $CH(OH)COOH$

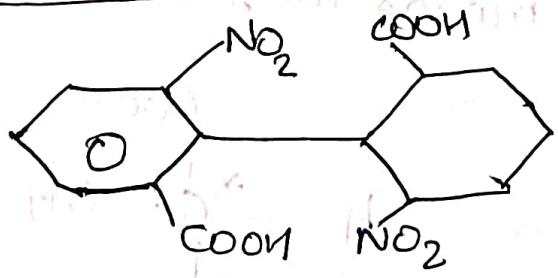
$2^2 = 4$

Optically Active / No chiral 'C'

* Substituted allene



* Substituted biphenyl



Enantiomer — Non-superimposable mirror image

Diastereomers — Non-superimposable Non-mirror image

Properties of Enantiomers :-

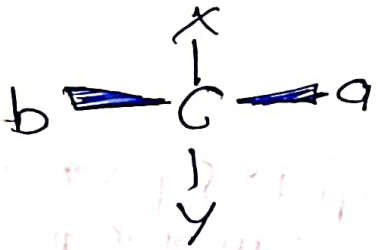
(1) Identical physical properties differ in optical properties

(2) Have identical chemical properties except towards optically active reagents

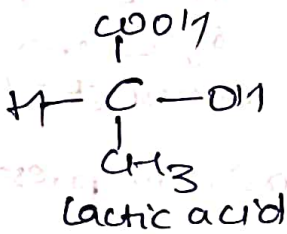
(3) When equal amt of enantiomers are mixed it produces optically inactive mixture (Racemic mixture)

Fischer Projection formula :-

(i)

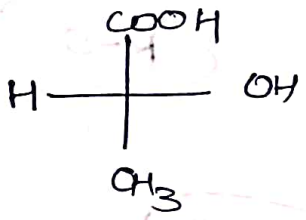


(ii)

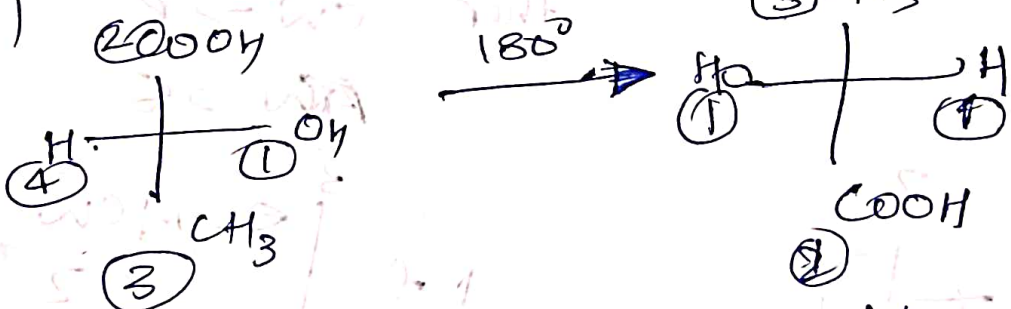


Lactic acid

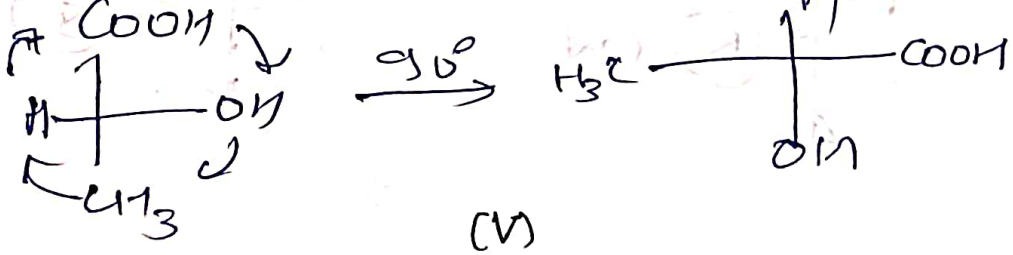
or



(iii)

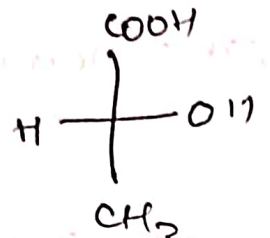


(iv)



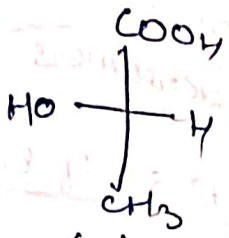
(v)

(V)



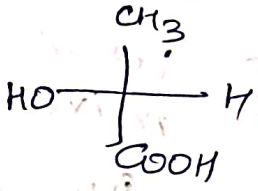
(−) lactic acid

1st Interchange



(+) Lactic acid

2nd Interchange



(−) Lactic acid

Absolute configuration

R → Rectus (Right)

S → Sinister (Left)

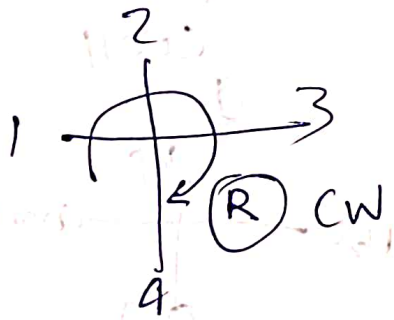
R-S

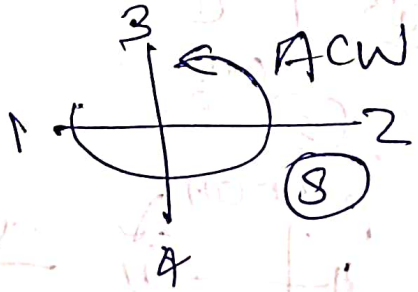
Step-1 By set of sequence rule we give the priority order of atom or group connected through C-C

Step-2 If minimum priority present on Vertical Line

then CW → R

ACW → S

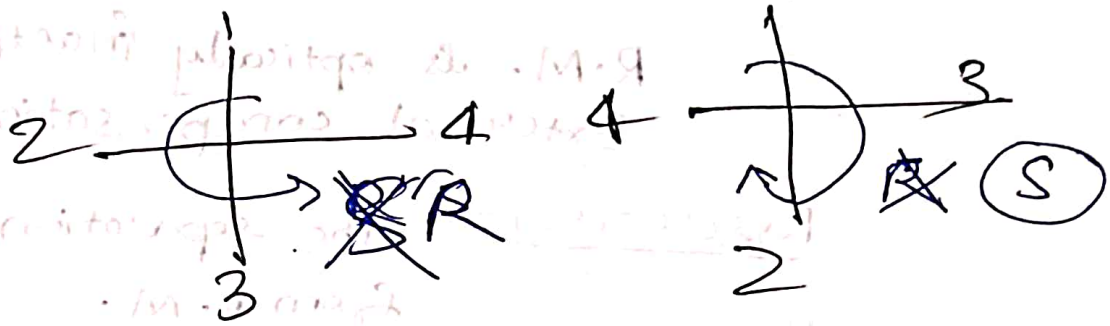




If Minimum priority group present on horizontal line then

CW → ~~X~~ S

ACW ⇒ ~~X~~ R



one chiral carbon

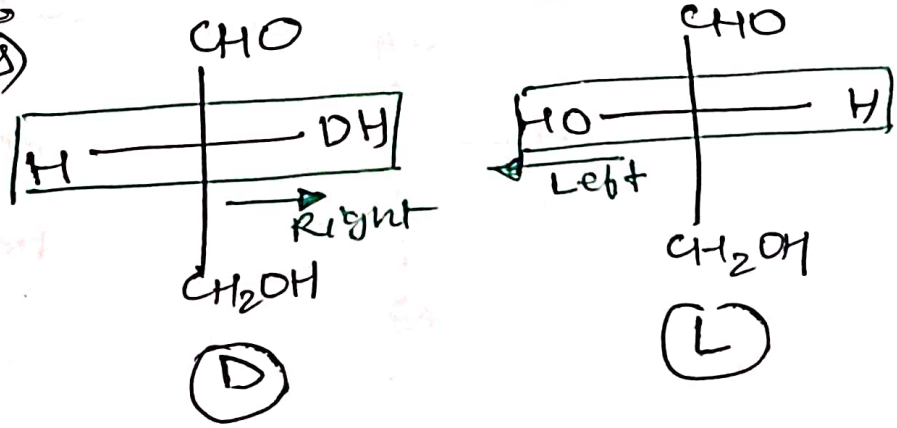
comp1	comp 2	Answer
R	S	E
R	R	I
S	S	I
S	R	E

In two chiral carbons

comp 1	comp 2	Answer
(R, R)	(R, S)	D
(R, S)	(S, R)	E
(R, R)	(R, R)	I

D/L configuration

(Carbohydrates)



Racemic Mixture – The mix of d & l form

d ⫷ l $\theta = 0°$

+50° −50°

R.M. is optically inactive due to External compensation.

Resolution → The separation of d and l from R.M.

How to find total no. of optical isomers

Case-① If symmetry is not present

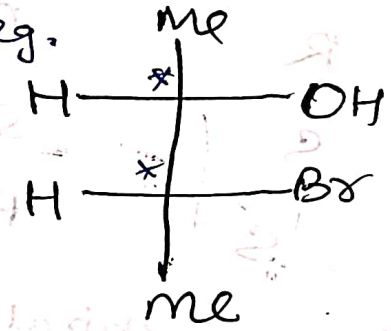
Total OI = 2^n n = chiral carbon

OA = 2^n

OIA = 0

RM = 2^{n-1}

eg.



n = 2

Total OI = $2^2 = 4$

OA = 4

OIA = 0

RM = 2

② If symmetry is present

n = even

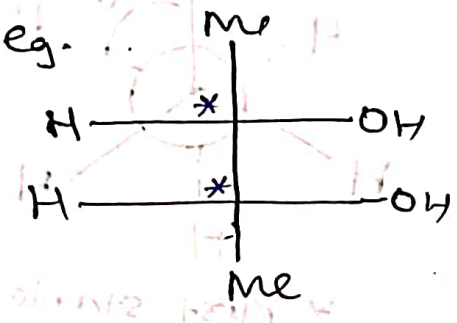
Total OI $= 2^{n-1} + 2^{\frac{n}{2}-1}$ n : chiral carbon

$OA = 2^{n-1}$

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

$RM = \frac{OA}{2}$

eg.



n = 2

Total OI $= 2^{2-1} + 2^{\frac{2}{2}-1}$

OI = 3

OA = 2

Meso = 1

RM = 1

n = odd

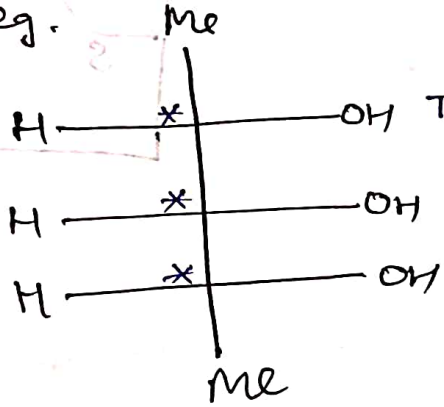
Total OI $= 2^{n-1}$ n = chiral carbon

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

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

$RM = \frac{OA}{2}$

eg.



n = 3

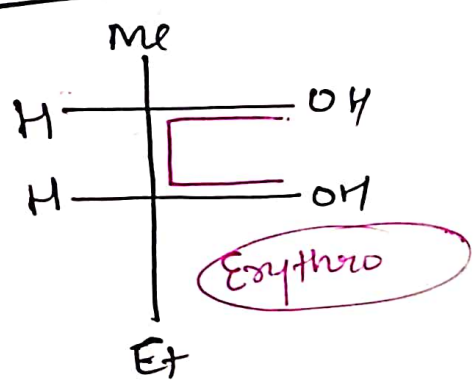
Total OI $= 2^{3-1} = 4$

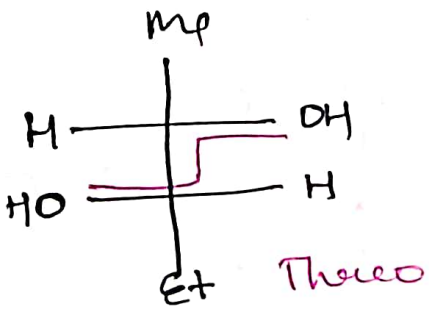
OA = 2

$Meso = \frac{2^{3-1}}{2} = 2$

RM = 1

Erythro & Threo





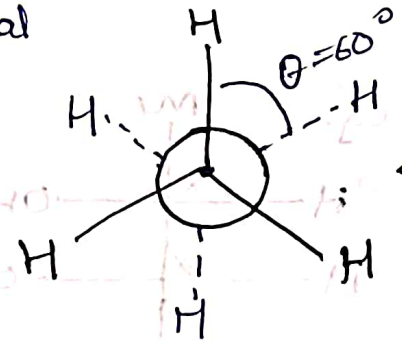
Conformers → Arises due to free rotation around C-C.

Total conformers = ∞

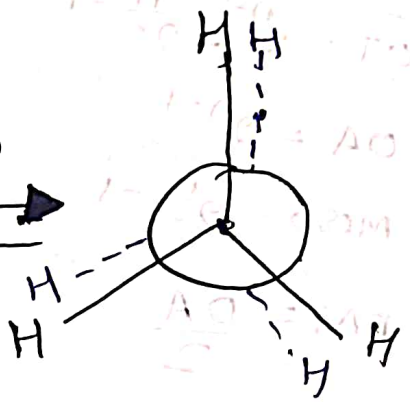
Ethane $\overset{1}{CH_3}-\overset{2}{CH_3}$

θ = dihedral angle

$\theta = 60°$



60°

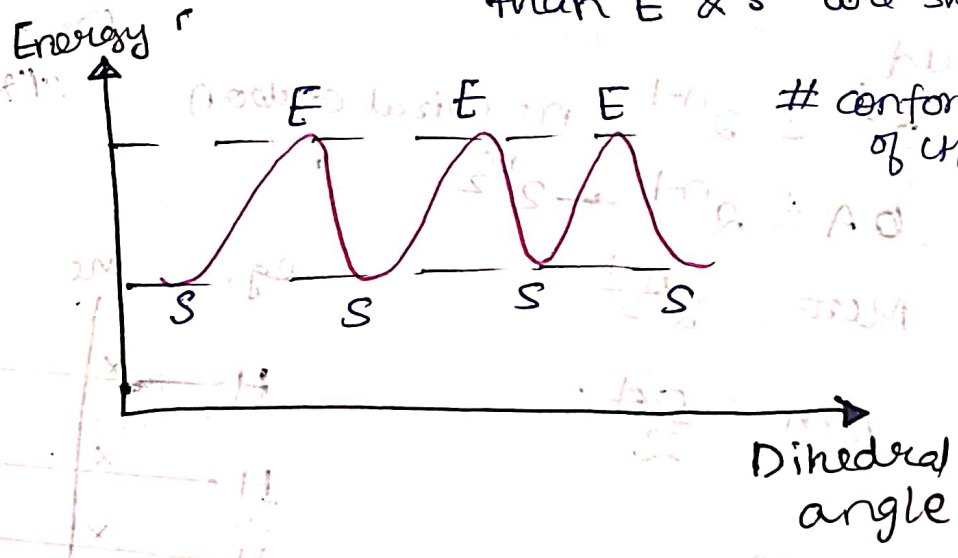


* Most stable staggered

* least stable Eclipsed

All conformers other than E & S are skew form.

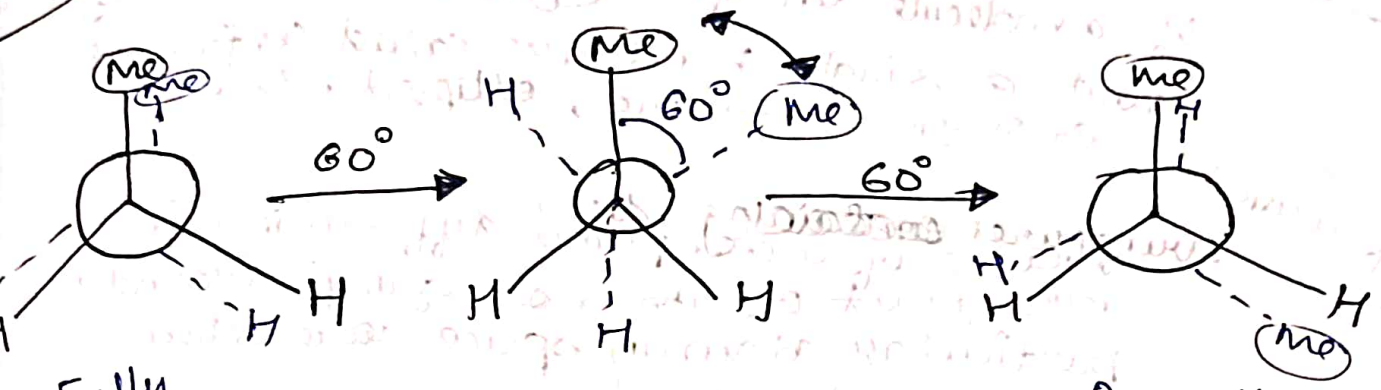
Energy Profile



conformers of CH_4 = 0

ane

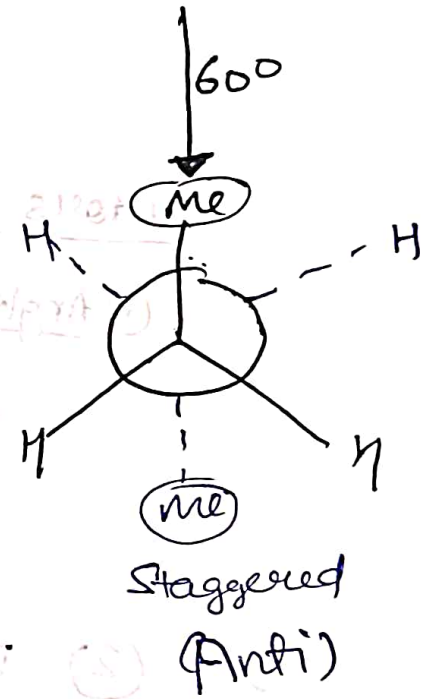
$CH_3 - \overset{1}{CH_2} - \overset{2}{CH_2} - CH_3$



Fully eclipsed

Staggered (Gauche)

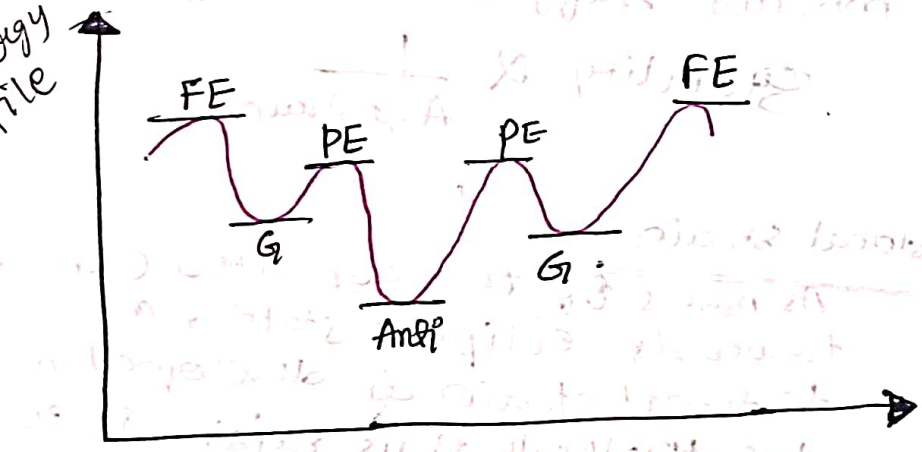
Partially eclipsed



Staggered (Anti)

Stability

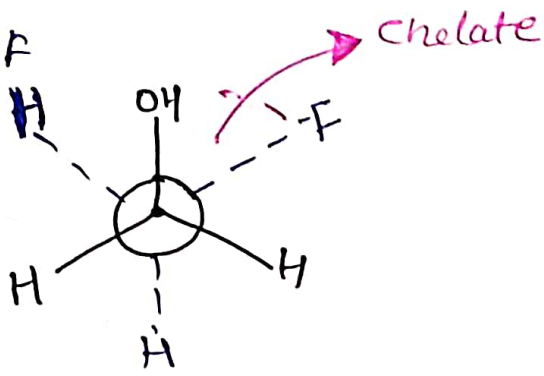
Anti > Gauche > PE > FE



*Gauche Effect

When Hydrogen bonding is present at Gauche Stage then Gauche is more stable than anti.

Stability G > A > PE > F



2-fluoro Ethanol

$\overset{2}{CH_2} - \overset{3}{CH_2}$

| |

F OH

Conformation Structures containing different arrangement of atoms of a molecule in space which can arise by rotation about a single bond are called conformers
eg staggered, gauche, eclipsed, skew

Configuration Stiructures of a compound differencing in the arrangement of atoms or groups around a particular atom in space are called configurations
eg. Enantiomers, diastereomers and G I.
d & l – lactic acids.
cis & trans butenes

Factors affecting relative stability of Conformations

① Angle strain : If there is any deviation from this normal bond angle, the molecule suffers from angle strain

$$\text{Stability} \propto \frac{1}{\text{Angle strain}}$$

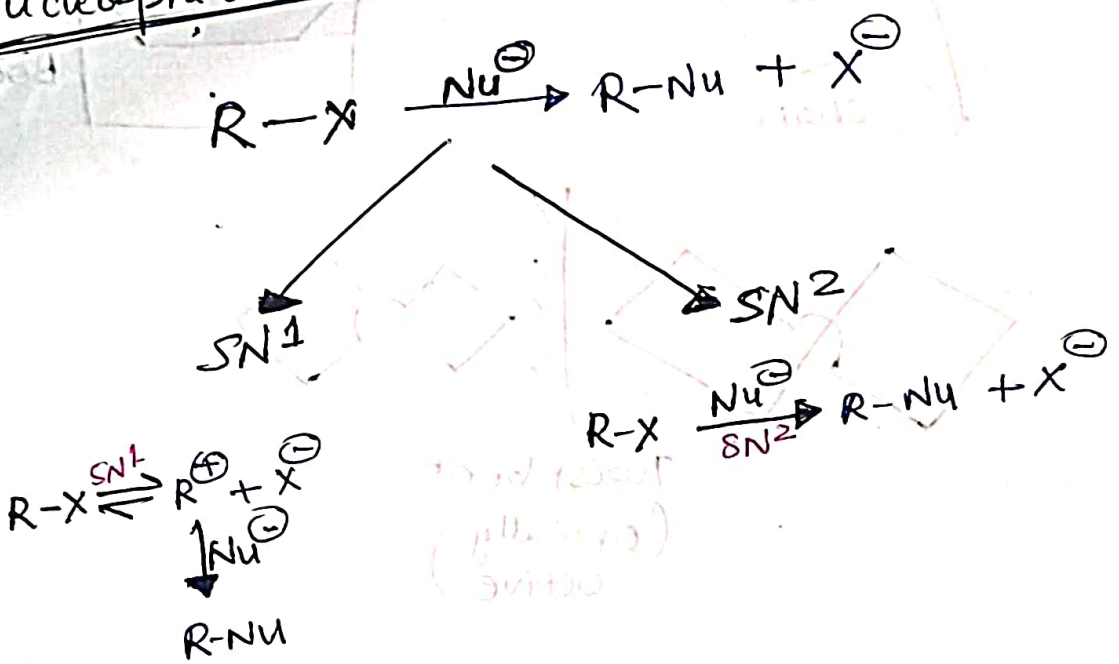
② Torsional strain
As bonds of two connected C move towards eclipsed state, a torsional strain is developed in the molecule thus raising its energy

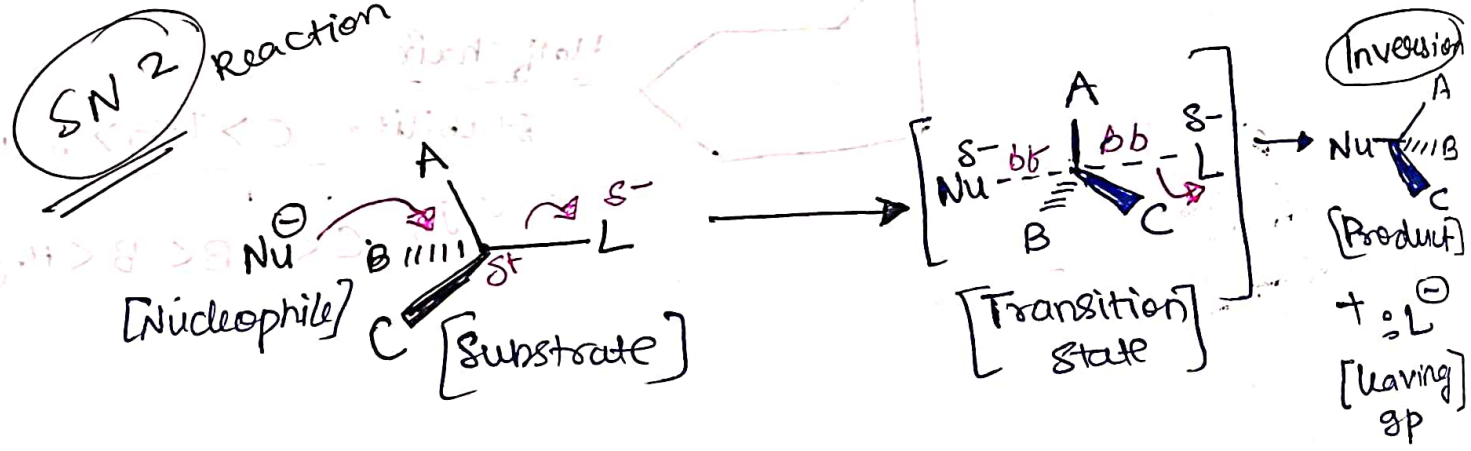
③ Steric Hinderance [Van der Waal's strain)

④ Dipole - Dipole Interactions

Reactions

Nucleophilic substitution reactions (NSR)





* Reaction is
  - stereospecific (Walden inversion of configuration)
  - concerted - all bonds form & break at same time
  - Bimolecular - rate depends on conc^n of both Nucleophile & substrate

$$r = k[\text{substrate } (R\text{-}X)][Nu^{\ominus}]$$

ROR α $\frac{1}{\text{Steric Hinderance}}$

  - No intermediate [only Transition state is formed]
  - No rearrangement
  - 1 step rxn (RDS)

* **substrate**
  - Best if Primary (one substituent on carbon bearing leaving group)
  - works if secondary, fails if tertiary

* **Nucleophile :**
  - Best if more reactive (i.e. more anionic or more basic).

* **Leaving Group :-**
  Best if more stable (i.e. can support negative charge well)
  - TsO^- (very Good) $> I^- > Br^- > Cl^- > F^-$ (Poor)
  - RF, ROH, ROR, RNH_2 are Never substrates for SN2 reactions
  - Leaving groups on double bonded carbons are never replaced by SN2 reactions.

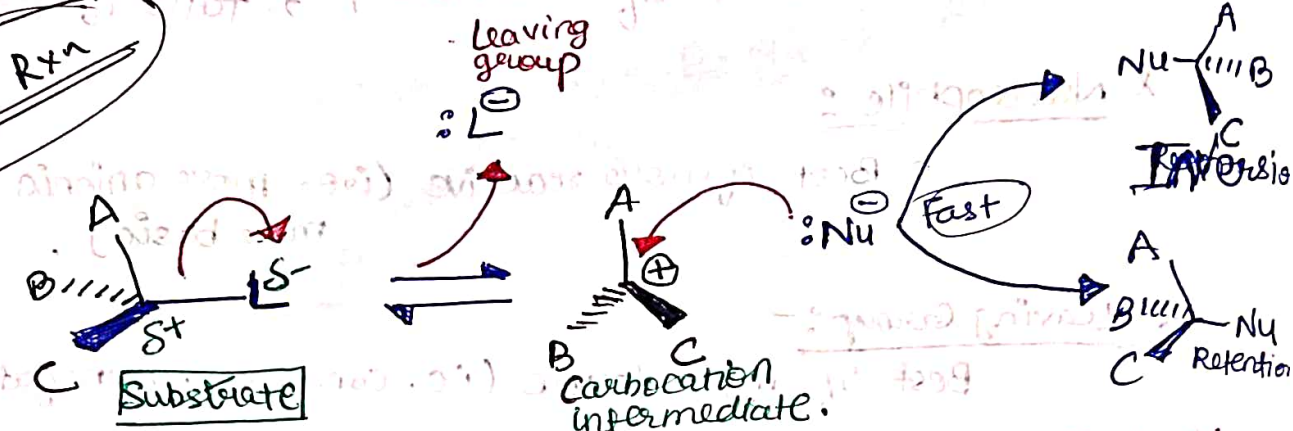
* **Solvent :-**
  Polar Aprotic (i.e. No OH) is best
  - for example dimethylsulfoxide (CH_3SOCH_3)
    dimethyl formamide ($HCON(CH_3)_2$
    acetonitrile (CH_3CN)
  - Protic solvents (eg. H_2O or ROH) deactivate nucleophile by hydrogen bonding but can be used in some case.

$$ROR \propto \frac{1}{\text{Steric Hendrence}}$$

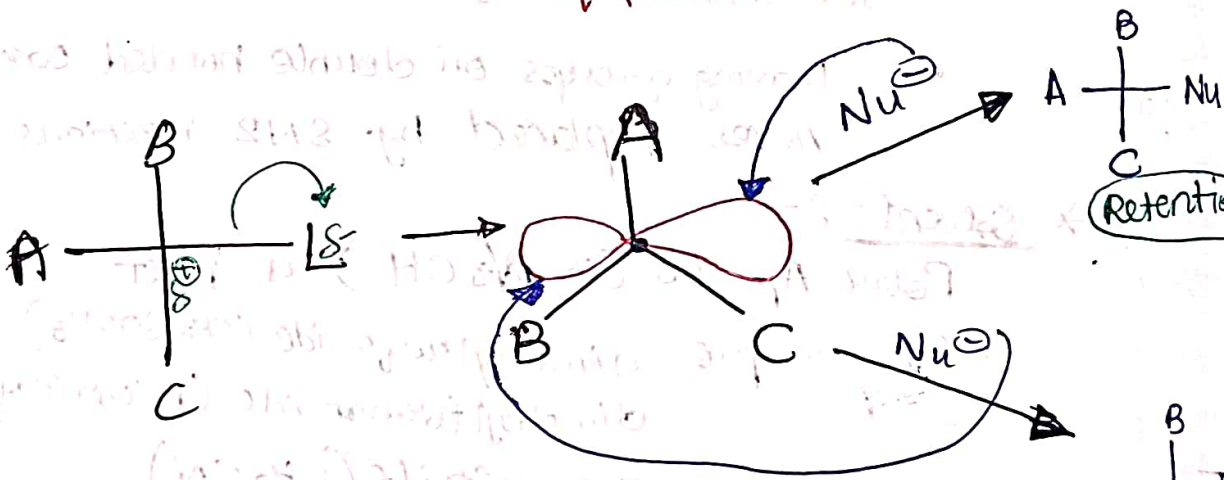
$1^\circ > 2^\circ > 3^\circ$

Nucleophilic Substitution Reactions - SN1 Rxn

SN1 Rxn



* Rearrange if possible



① & ② are Enantiomers
Racemisation occurs.

Reaction is:

- Non-stereospecific (attack by nucleophile occu on both sides):
- Non-concerted - has carbocation intermedia
- Unimolecular - rate depends on conc of only
  - Rate = K [substrate]
  - 1st step is RDS.
  - 2 step Rxn
  - Possibility of rearrangement
- ROR ∝ stabili of C⊕

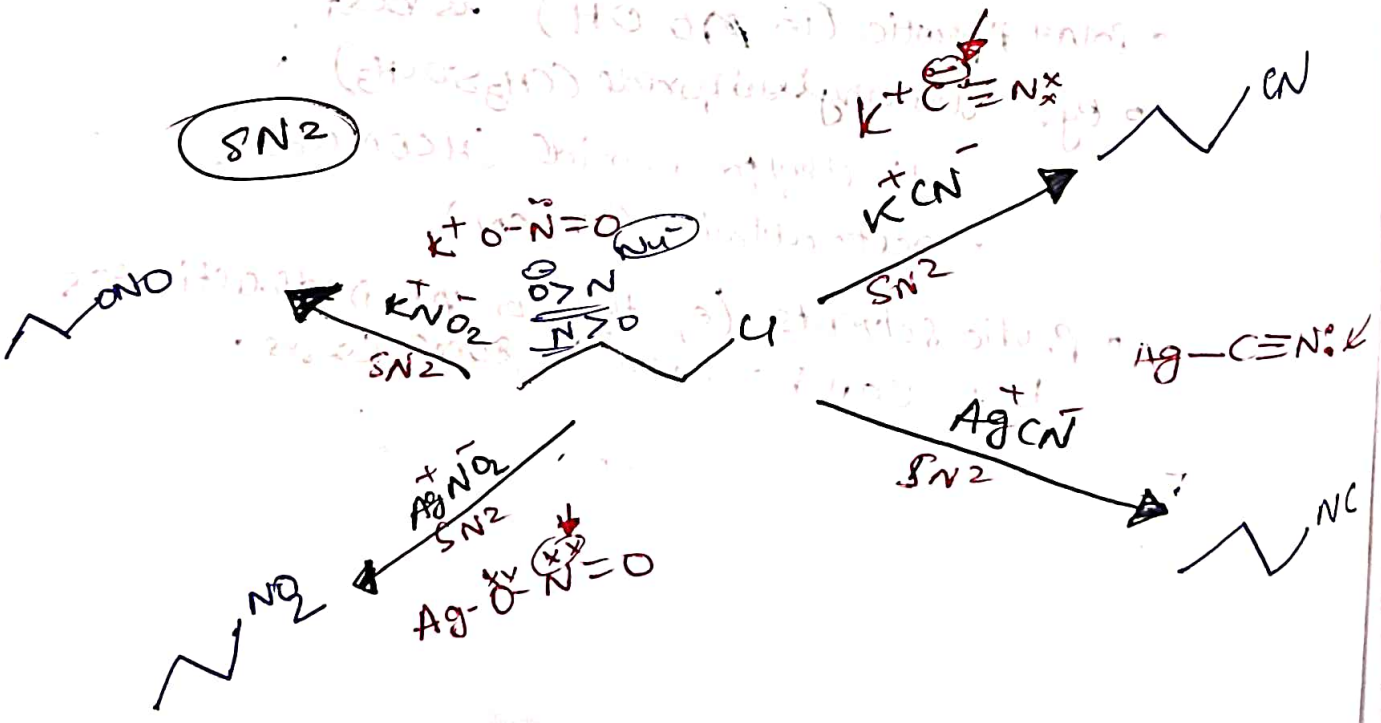
* Substrate
  - Best if tertiary or conjugated (benzylic or allylic) carbocation can be formed as leaving group departs.
  - never Primary.

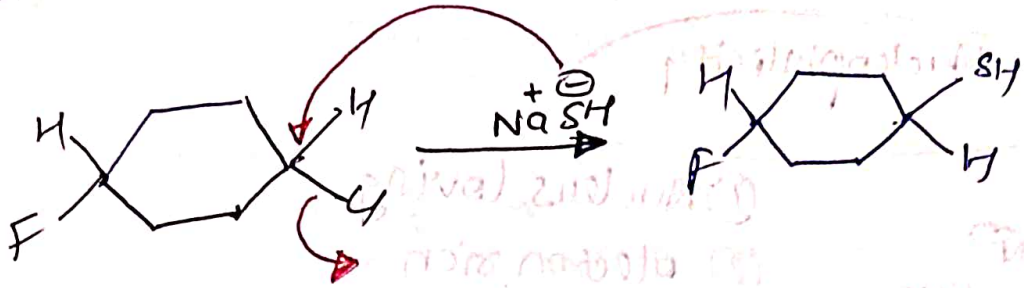
* Nucleophile
  - Best if more reactive (i.e. more anionic or more basic)

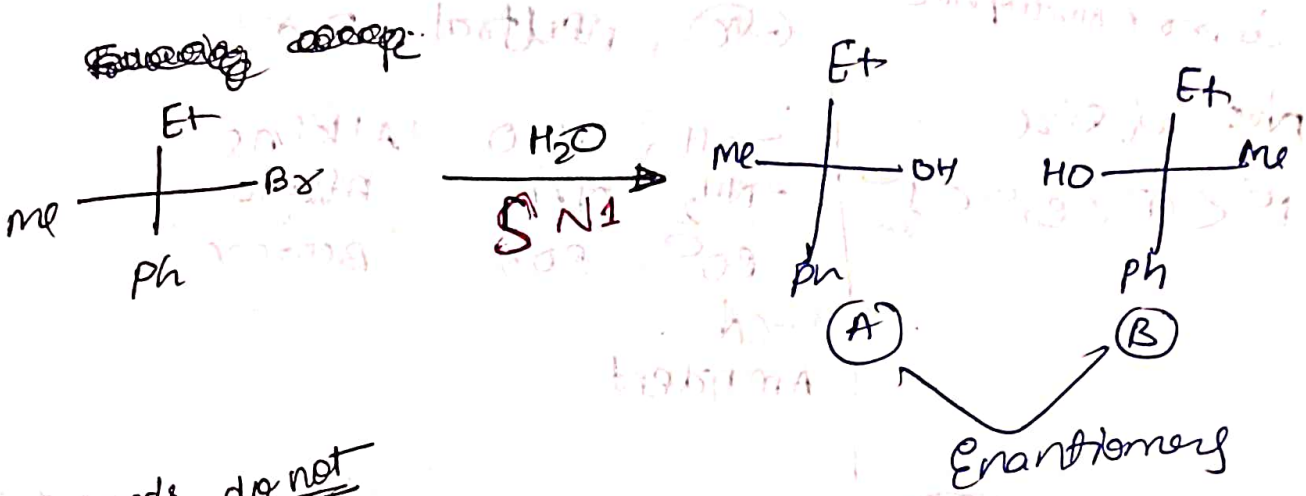
* Leaving Group
  - same as SN2
  - best if more stable (ie. can support negative charge well.)
  - eg. TsO^- (very good) $> I^- > Br^- > Cl^- > F^-$ (Poor)
  - However tertiary or allylic ROH or ROR' can be reactive under strongly acidic conditions to replace OH or OR.

* Solvent
  - same as SN2
  - Polar Aprotic (ie. no OH) is best.
  - eg. dimethylsulfoxide (CH_3SOCH_3), dimethylformamide ($HCON(CH_3)_2$), acetonitrile (CH_3CN)
  - Protic solvents (eg H_2O or ROH) deactivates but can be used in some cases.

Reagent		Nu⊖
NaOH (KOH)	SN2	HO^-
H_2O	SN1	H_2O
NaOR'	SN2	$R'O^-$
NaI	SN2	I^-
NH_3	S SN1	NH_3
$R'NH_2$		RNH_2
R'R"NH		R"NH
* KCN		$^{\ominus}C{\equiv}N:$
* AgCN		$Ag{-}C{\equiv}N:$
* KNO_2		$O{=}N{-}O^{\ominus}$
* $AgNO_2$	SN2	$Ag{-}O{-}N{=}O$
* R'COOAg		$R{-}COO^-$
$LiAlH_4$		$H^{\ominus}$
R^-M^+		$R^{\ominus}$







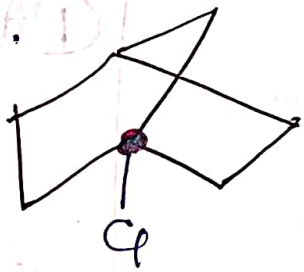
Following compds do not give S_N1 or S_N2

Reason

1) $Ph-\ddot{\underset{\cdot\cdot}{Cl}}:$ due to Partial double bond characteristics

$CH_2=CH-\ddot{\underset{\cdot\cdot}{Cl}}:$

2) $R-F$ $F^{\ominus}$ is a poor leaving group.

3) 

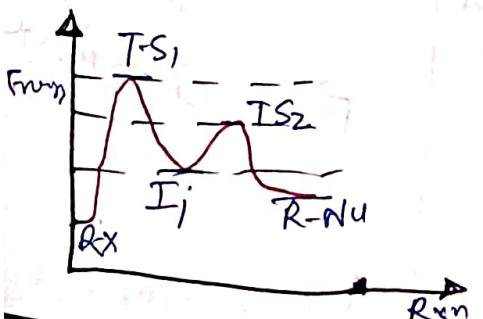
Bredt's Rule.

Energy Profile

① S_N1

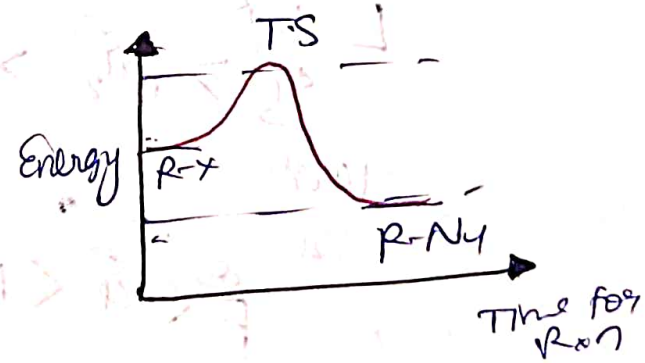
$R-X \underset{\text{step-1}}{\overset{\text{slow}}{\rightleftharpoons}} R^{\oplus} + X^{-}$

$R^{\oplus} \xrightarrow{Nu^{\ominus}\ \text{step-2}} R-Nu$



② S_N2

$R-X \xrightarrow[1\text{ step}]{Nu^{\ominus}} Nu^{\delta-}\cdots R^{\delta+}\cdots X^{\delta-} \longrightarrow Nu-R+X^{\ominus}$



Nucleophilicity

① Nucleus loving
② electron rich
(-ve), neutral, $\pi e^{\ominus}$

⊖ ve charge Nu$^{\ominus}$ is more Nucleophilic

Nu$^{\ominus}$ α Size
$F^{\ominus} < Cl^{\ominus} < Br^{\ominus} < I^{\ominus}$

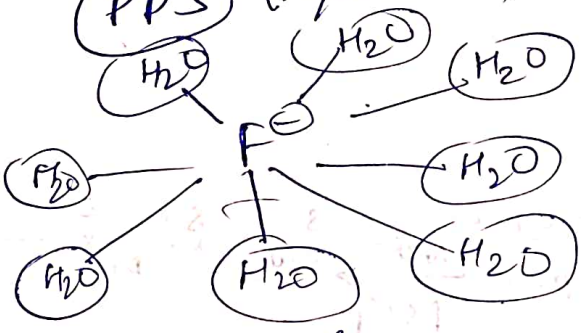
$-OH$, $RO^{\ominus}$	H_2O, ROH	Alkene
$-NH_2$	NH_3	Alkyne
$-CN$		Benzene
Ambident		

Nu$^{\ominus}$ order may vary in diff solvent

• Polar Protic ($\mu \neq 0$) H_2O, ROH etc {H is connected with more EN element

• Polar Aprotic ($\mu \neq 0$) DMSO, Acetone, DMF (H is not connected with more EN.

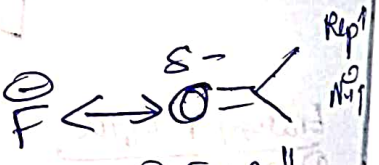
PPS (Hydration)



L to R
$CH_3^{\ominus} > NH_2^{\ominus} > OH^{\ominus} > F^{\ominus}$ small size

large size
$F^{\ominus} < Cl^{\ominus} < Br^{\ominus} < I^{\ominus}$

PAS (Repulsion)



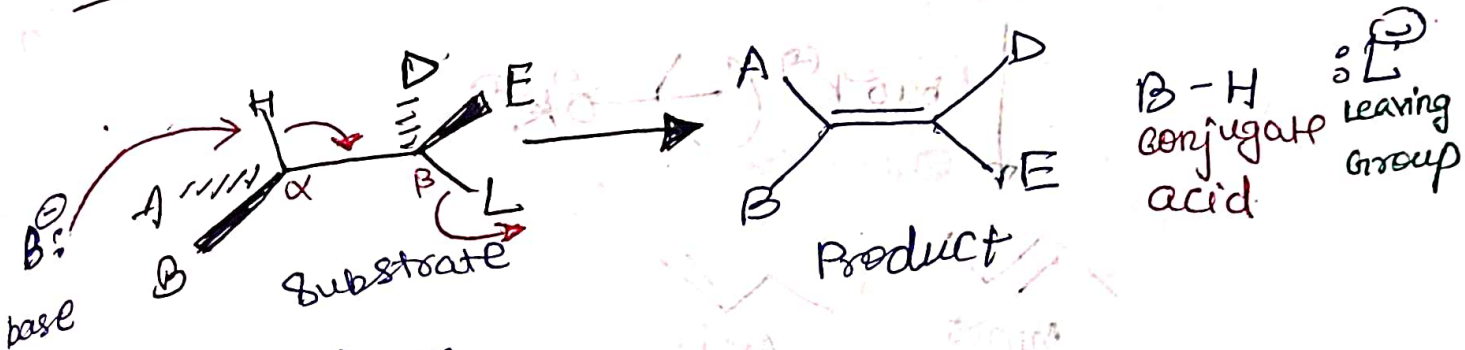
$F^{\ominus}$ Size ↓
Charge density ↑

$CH_3^{\ominus} < NH_2^{\ominus} < OH^{\ominus} < F^{\ominus}$

$F^{\ominus} > Cl^{\ominus} > Br^{\ominus} > I^{\ominus}$

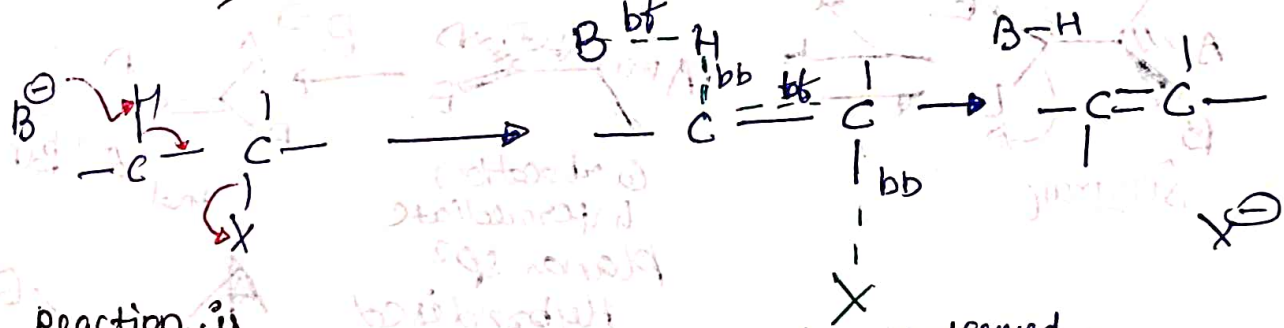
Elimination Rxns

E2 Rxn (β-elimination or α,β-elimination)



H & L are anti-Periplanar

E2 mechm



Reaction is

- stereospecific (Anti-periplanar geometry preferred, Syn-periplanar geometry possible)
- Concerted - all bonds form and break at same time.
- Bimolecular - rate depends on concn of both base & substrate.
- favoured by strong bases.

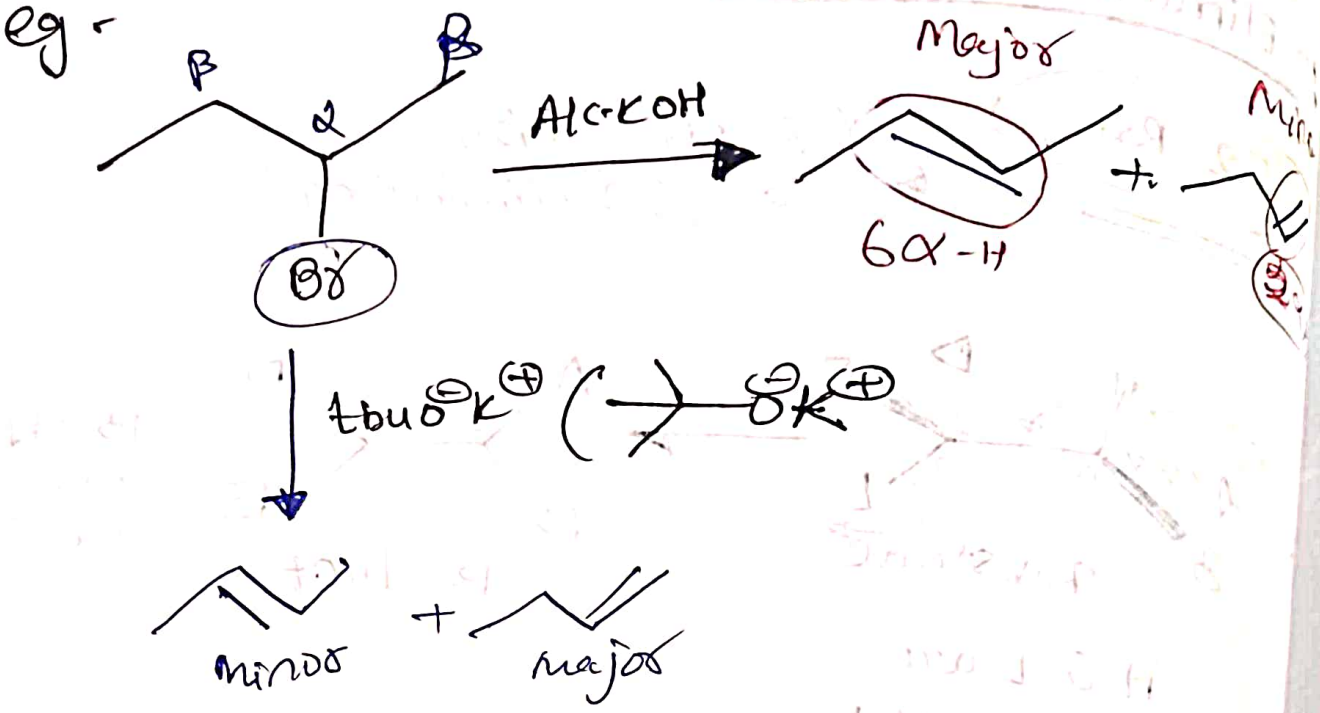
Important Point

1) T-S formed
2) No intermediate formation
3) all 5 atoms involve in T-S are in one-plane.
4) Carbon is pentavalent in T-S.
5) ROR : 3° R-X > 2° R-X > 1° R-X

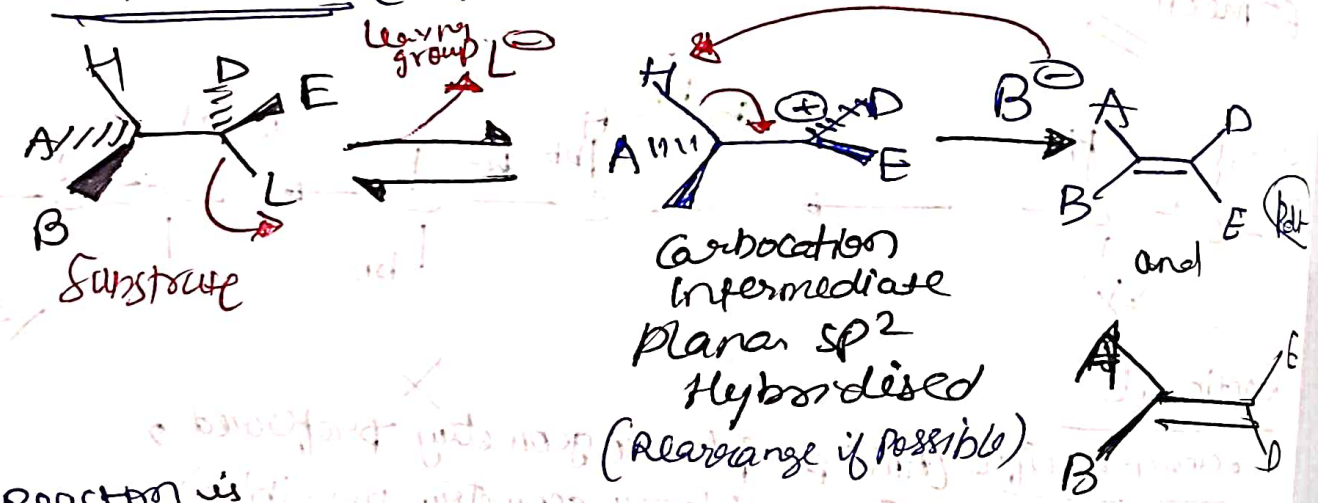
R-I > R-Br > R-Cl.

6) Anti-Elimination
7) More stable alkene is major pdt (less bulky base is used)
8) In case of more bulky base less hindered alkene is the major pdt.

eg -

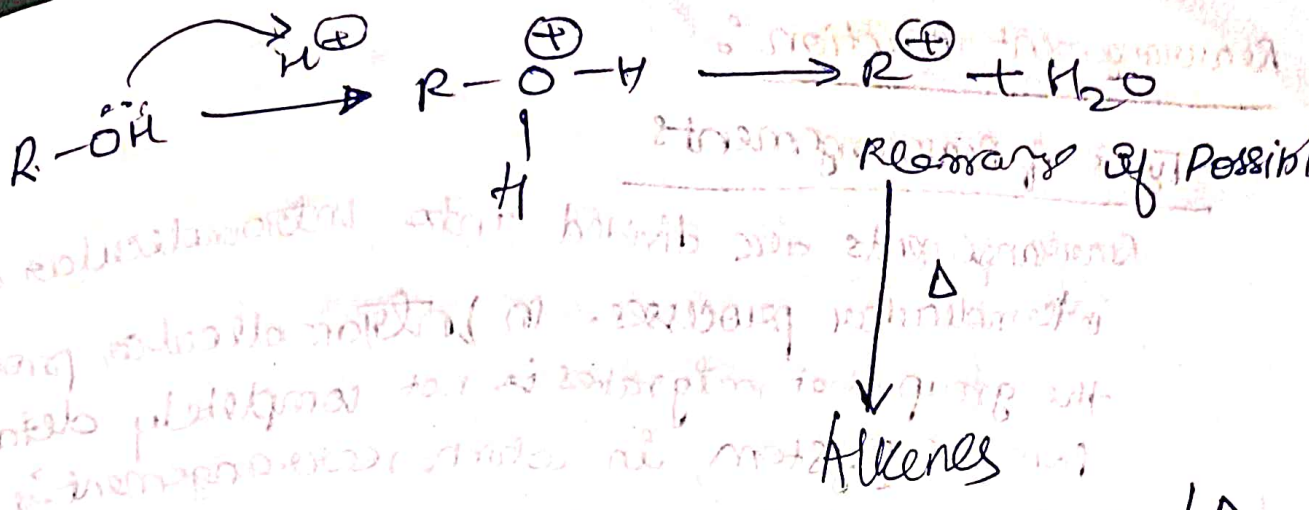


Elimination: (E1 Rxn)



Reaction is →

- Non-stereospecific - follows Zaitsev (Saytzeff) Rule
- Non-concerted - has carbocation intermediate
  - favoured for tertiary leaving groups,
- Unimolecular rate depends on concn of only substrate
- Does not occur with primary alkyl halides (leaving gp)
- Strong acid can promote loss of OH as H_2O or OR as HOR if tertiary or conjugated carbocation can be formed.



Reagent :- H^+/Δ or conc. H_2SO_4, H_2SO_4/Δ, H_3PO_4

Step

① Carbocation intermediate is formed

② formation of 1st carbocation is RDS

③ ROR α stabilize the $C^{\oplus}$

④ More stable Alkene is major Pdt

—— o ——

Rearrangement Reaction :

Types of Rearrangements

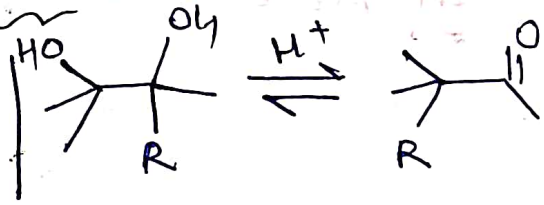
Rearrangements are divided into intramolecular & intermolecular processes. In intramolecular process the group that migrates is not completely detached from the system in which rearrangement is taking place. In contrast intermolecular process, the migrating group is first detached & later re-attached

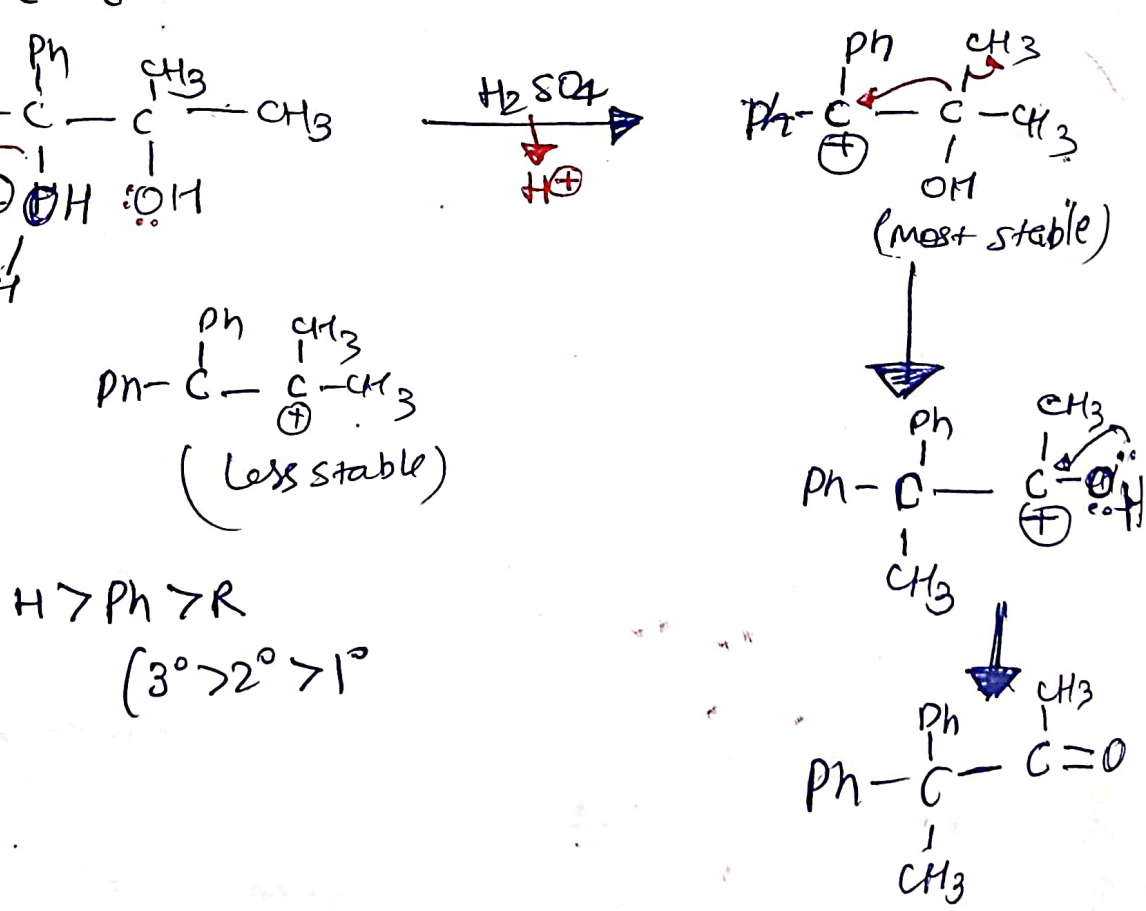
Rearrangement into Electron deficient Carbon

These rxn are classified according to the nature of group that migrates.

Pinacol / Pinacolone Rearrangement

Pinacol = 1,2-diol system

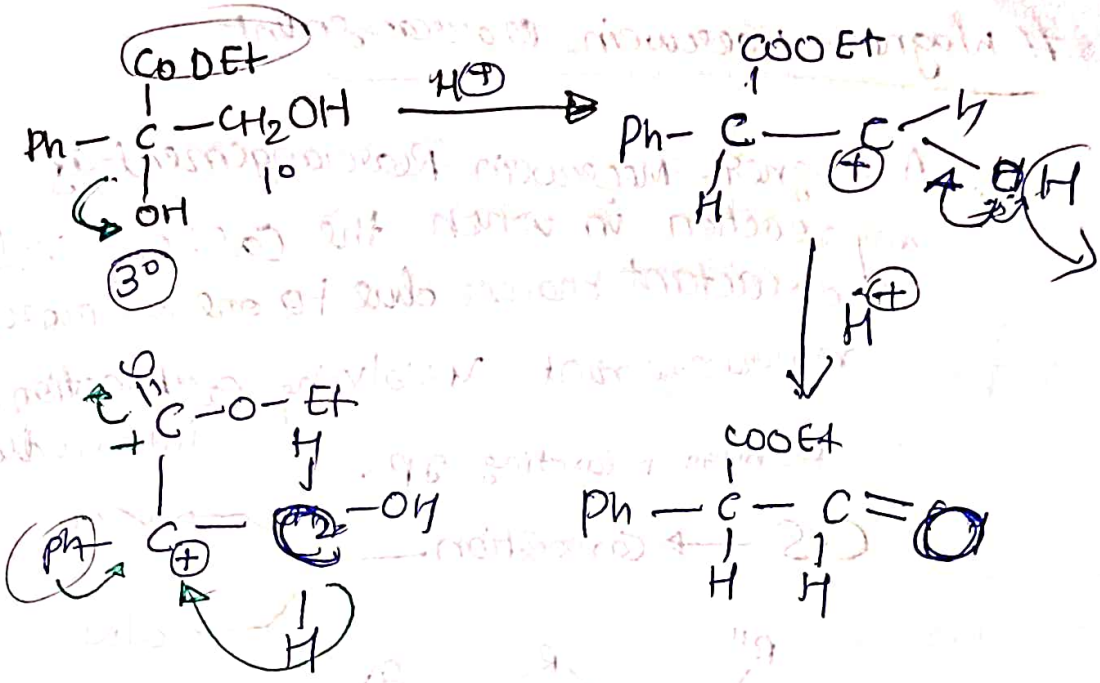


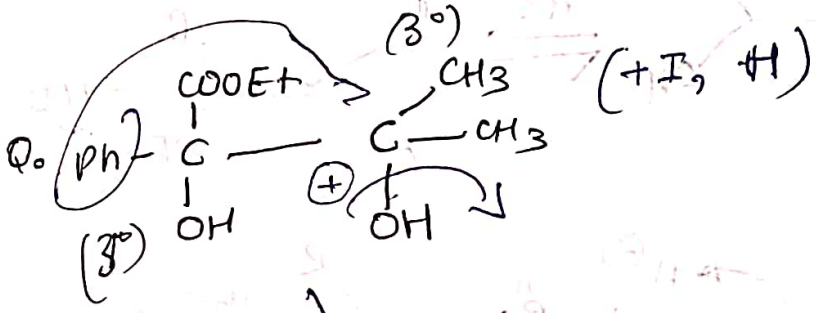


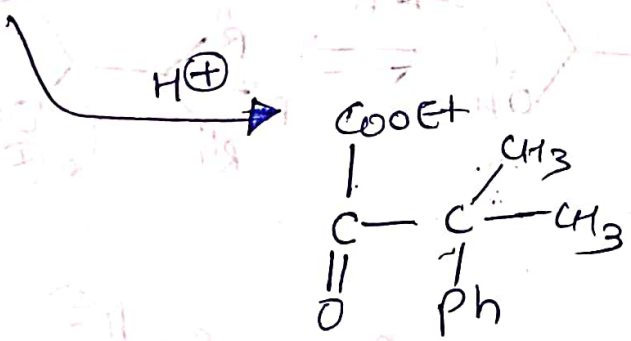
Migration H > Ph > R

(3° > 2° > 1°

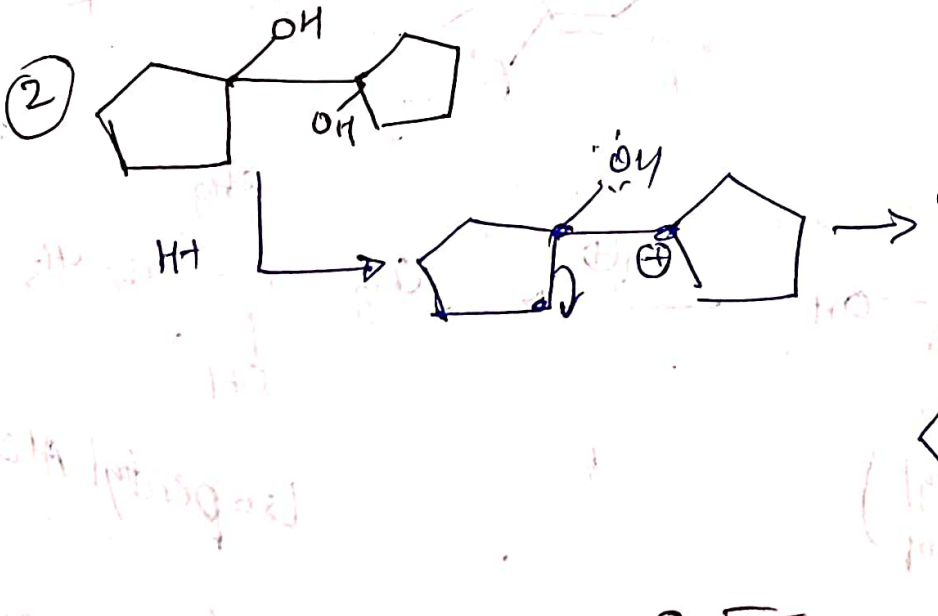
Q.1.







Q.



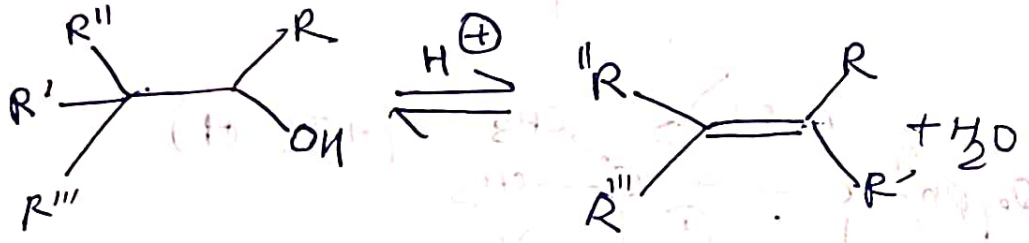
(2)

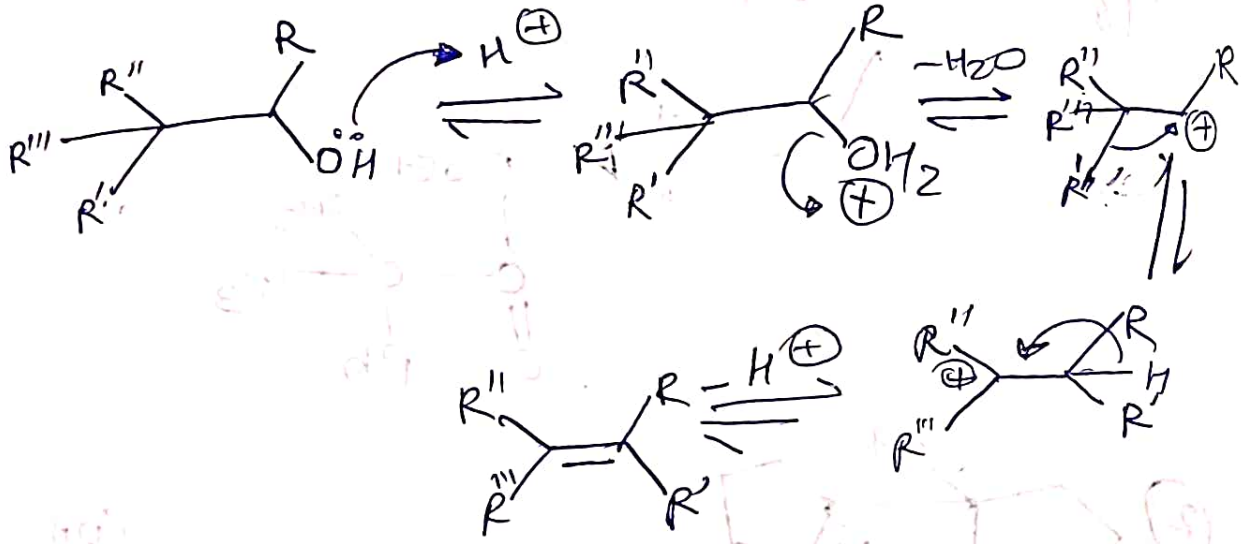
Wagner- Meerwein Rearrangement

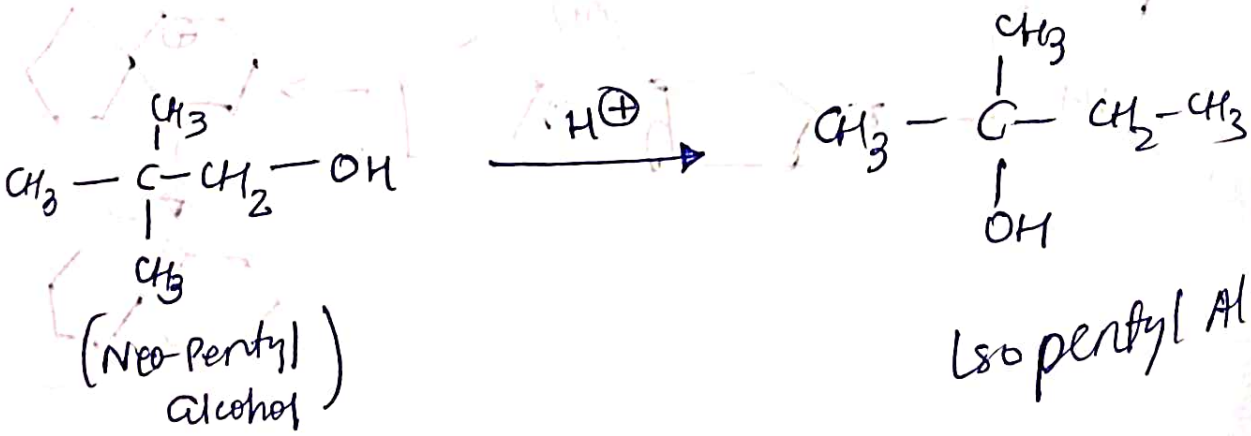
A wagner- Meerwein Rearrangement is any reaction in which the carbon skeleton of a reactant changes due to one or more rearrangement involving carbocation. Intermediate.

through migrating gp.

C.S → Carbocation → ✓ OH
→ alkene





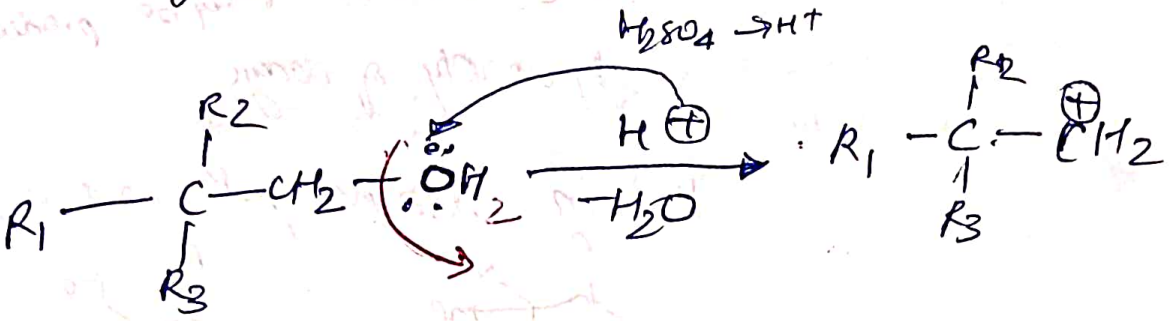


(Neo-Pentyl Alcohol)

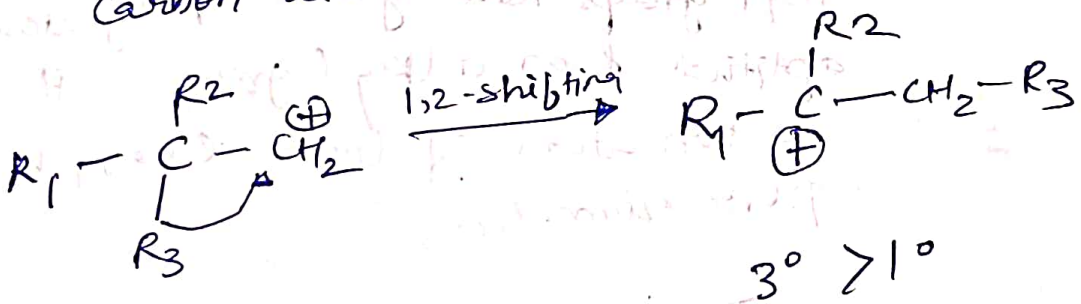
Isopentyl Alcohol

OH = X (leaving gp)

Step-1 In 1st step in presence of H^+ ion the X group take two bonding pair of e^- & leave HX forming carbonium ion.



Step-2 In 2nd step this carbonium ion rearrange to produce more stable tertiary carbonium ion by the transfer of 1R group to neighbouring carbon atom called 1-2 shift.

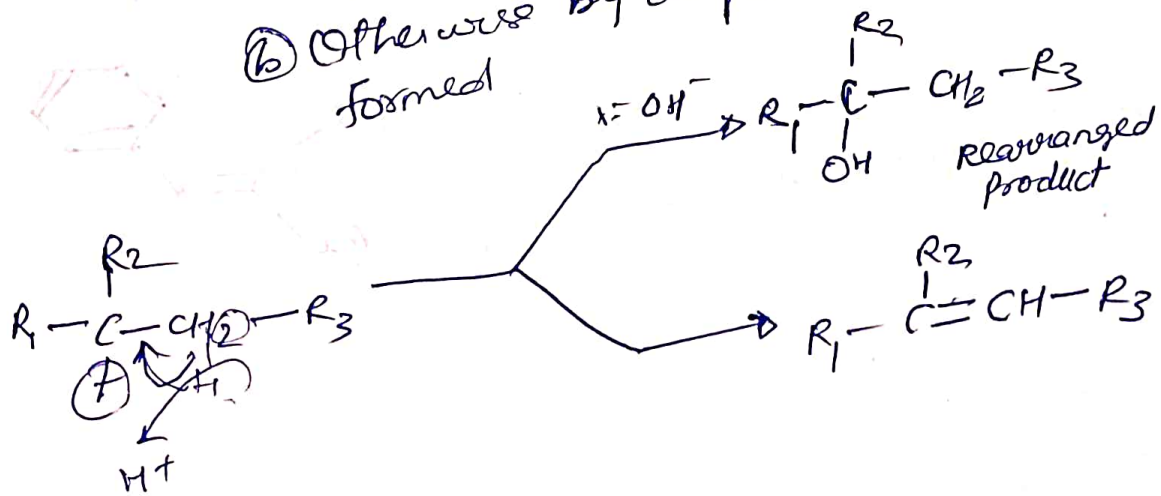


$3^\circ > 1^\circ$

Step-3 In 3rd step there occur a nucleophilic attack on carbonium ion & there are two possibility

(a) If attacking $Nu^\ominus$ is same (which is detached in 1st step) then rearranged product is same.

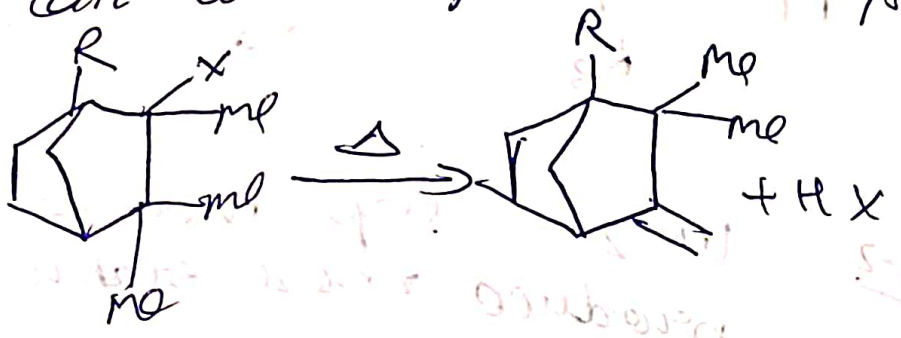
(b) Otherwise by de protonation alkenes is formed



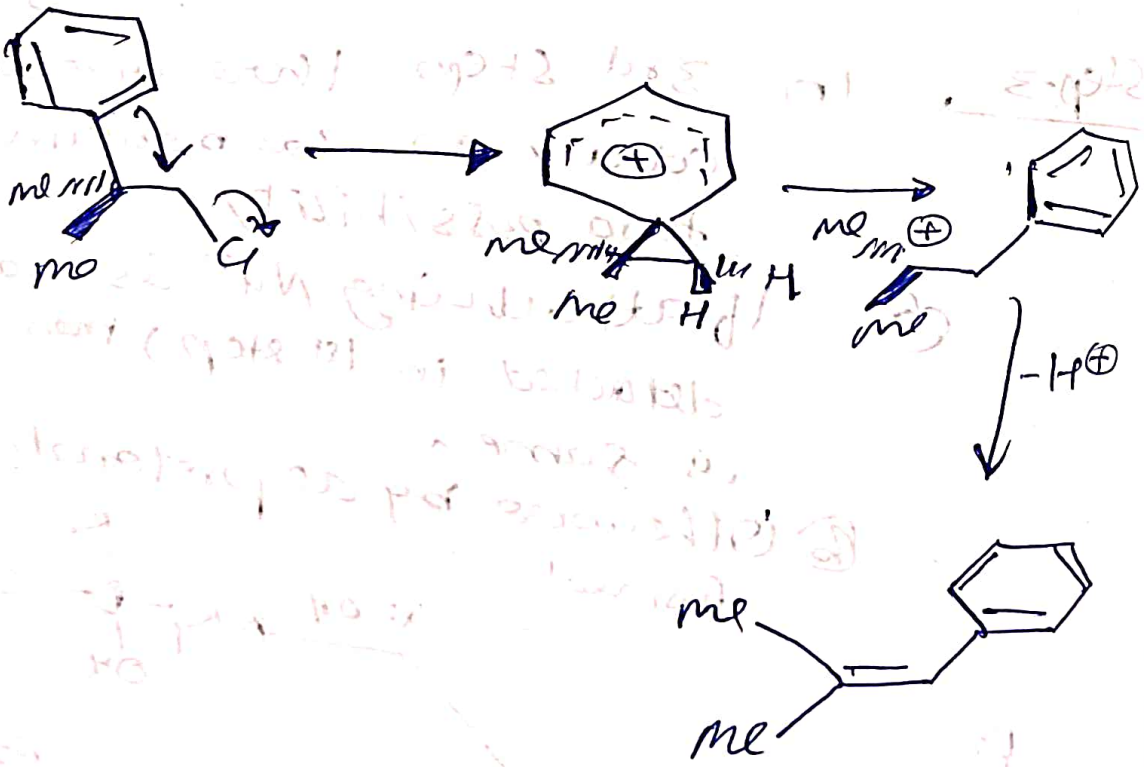
Features of migration

The carbocation may be produced by variety of ways

H can also migrate in this system



Aryl groups have greater migratory aptitude than alkyl groups or H due to formation of lower energy bridged benzenium ion.



Hoffmann Rearrangement

Hoffmann Bromamide degradation.

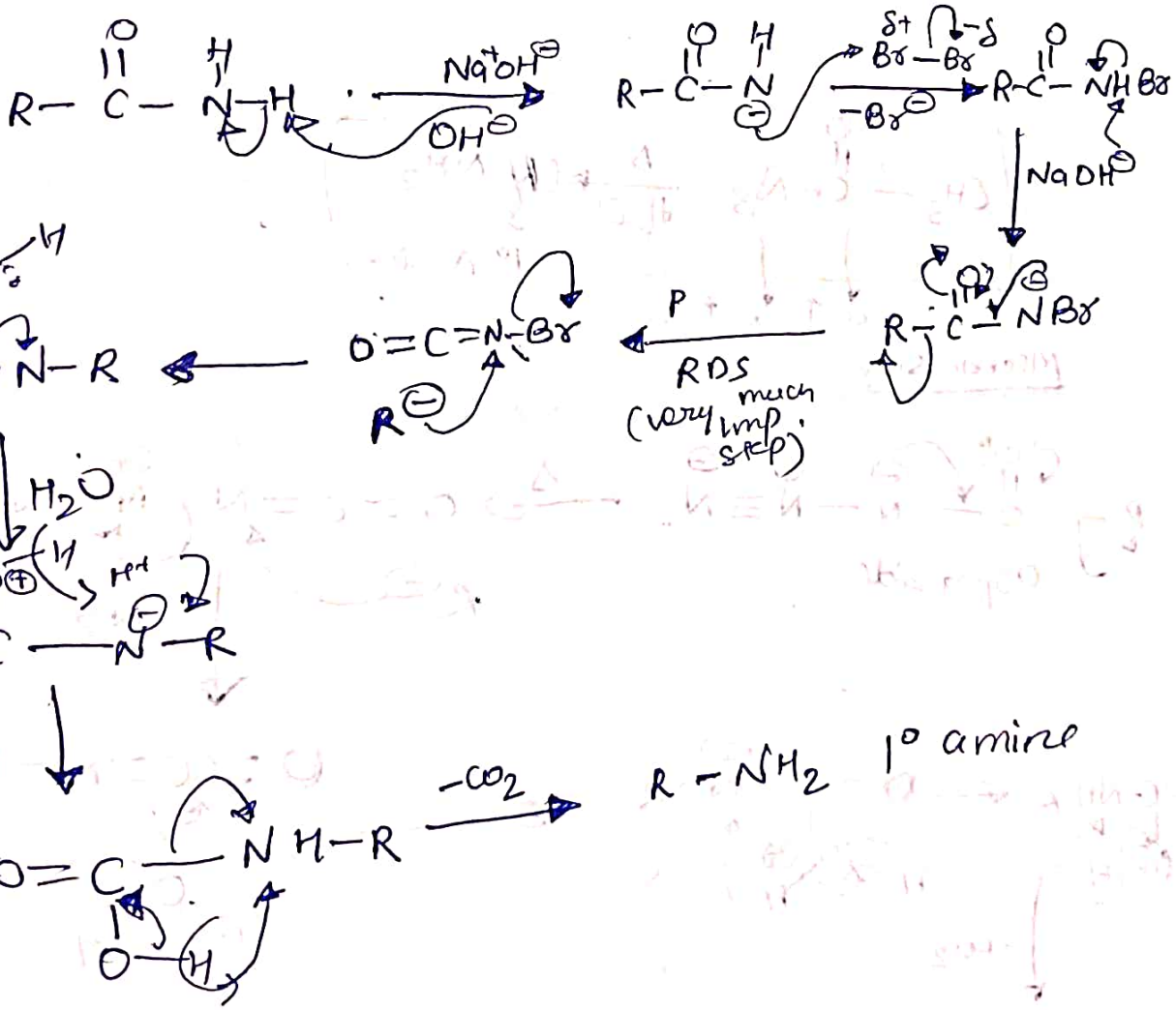
$$R-\underset{\underset{O}{\|}}{C}-NH_2 + Br_2 + NaOH \longrightarrow \underset{\text{amine } (1^\circ)}{R-NH_2} + Na_2CO_3 + NaBr + H_2O$$

(Br_2 only 1 unit)

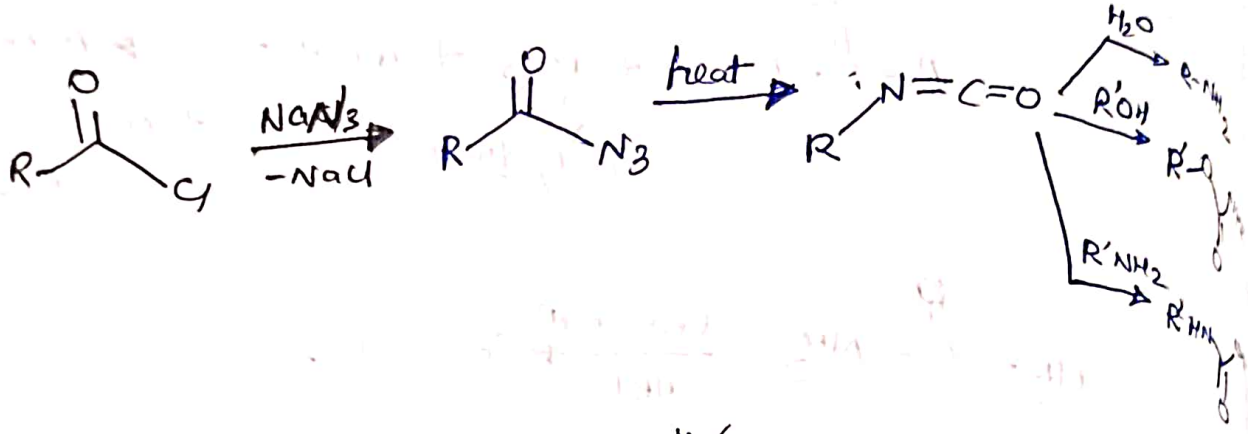
$$CH_3-\underset{\underset{O}{\|}}{C}-NH_2 \xrightarrow[HBD]{(Br_2+KOH)} CH_3-NH_2.$$

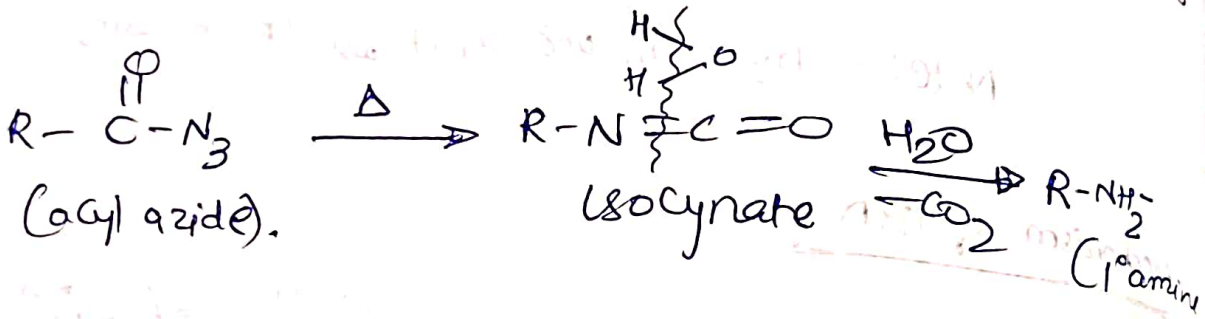
Note:- Br_2 only one unit use (mechanism)

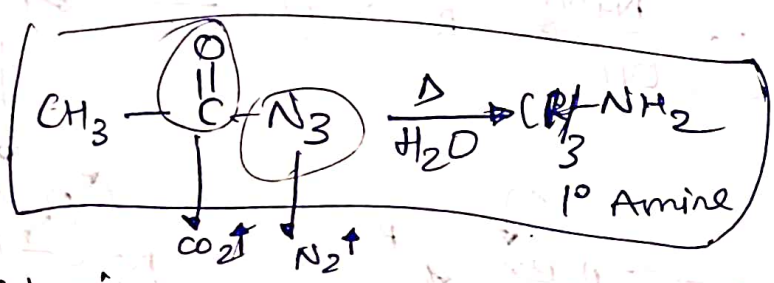
Mechanism of HBD :-



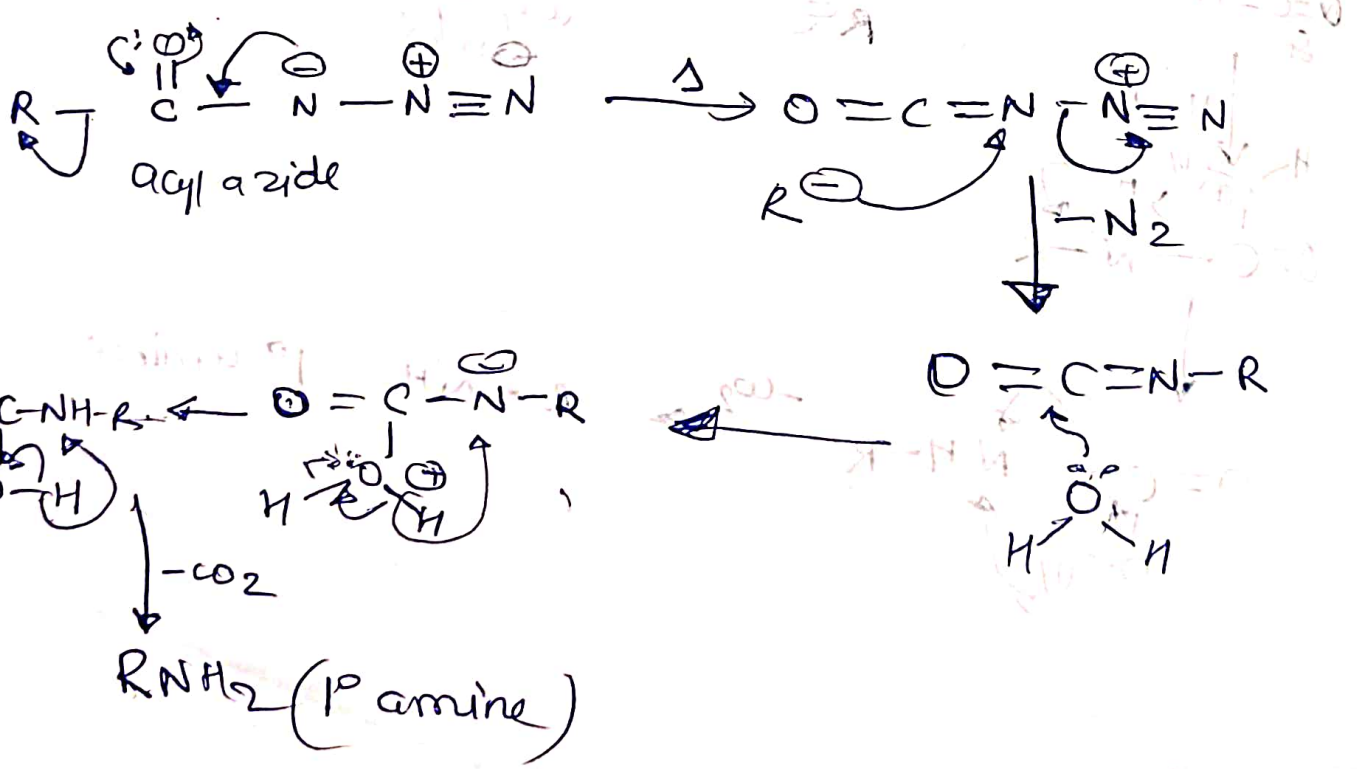
Curtius Reaction







Mechanism



Lossen Rearrangement

Ester of hydroxamic acid reacts with base to give isocyanate that could be converted into amine as shown in Hoffmann rearrangement