

Compounds of identical molecular formula

1

Isomeric

Identical

constitutional  
or structural

conformational  
Isomers.

- rotation about single bonds.
- Cyclohexane / ring flipping
- Amine Inversion

Stereoisomers

configurational  
Isomers.

Stereoisomers which are not mirror images of each other.

Geometrical Isomers are related as diastereomers.

Meso-tartaric acid & + tartaric acids are related as diastereomers.

S-2-brom and R-2-brom are related as enantiomers.

Tautomers : Isomers of different energies which are interconvertible via a low energy barrier, the isomerisation involves atom or group migration.



Valence Isomers : These Isomers are interconvertible by recognition of some of bonding electrons.



They are not tautomers.

## object / molecule

2

### Achiral Molecule

Generally it has either  
Plane of symmetry or  
Centre of symmetry  
or both. These  
molecules are optically  
inactive. The mirror  
image of the molecule is  
superimposable on  
the original molecule.

### Chiral Molecule

Di Sby  
metric  
It has  
no POS,  
no COS,  
but  
In  
axis is  
present.

(C<sub>2</sub>, C<sub>3</sub>, ...).

Asymmetric.  
It has no POS,  
no COS, no  
In axis of  
symmetry.  
only C axis  
of symmetry  
is present

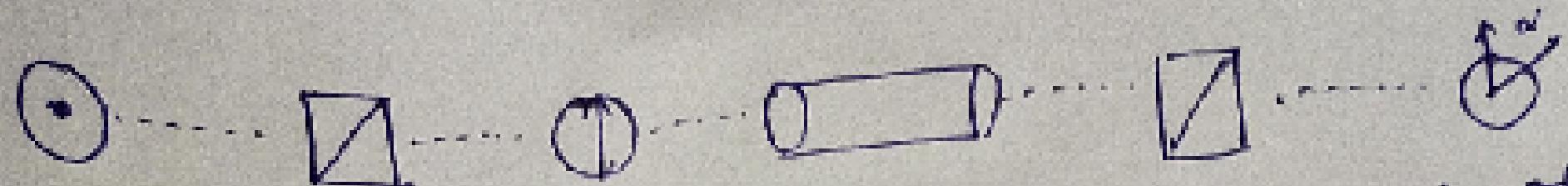
=> chiral molecule & its mirror image form  
two distinct species which are nonsuperimposable  
=> They are called enantiomers. Chiral molecules  
exhibit a type of stereoisomerism known as  
enantiomerism. They are found to be optically active.

### Optical activity:

Optically active stereoisomers can rotate the plane of  
plane polarised light monochromatic light, i.e  
the light having a single wavelength ( $\lambda$ ) & whose  
electric vector is oscillating in a single plane &  
to the plane of direction of propagation.

The optical activity is measured in Polarimeter  
in which the angle ( $\alpha$ ) by which the polarisation  
plane rotates as PPL passes through a sample of  
optically active compound is measured.

3



Source of  
mono  
chromatic  
light.

Polar  
meter

PPL  
through which PPL  
is passed.

$\alpha$  = observed  
angle of rotation

The optically active liquid/gas or solution rotates PPL to an angle  $\alpha$ . If the angle of rotation is found to be clockwise w.r.t initial plane of polarisation then the rotation is said to be (+) or Dextro/ d. If it is anti-clockwise, then it is Laevo/ l. Said to be (-) or Laevo/ latory.

The observed optical rotation is proportional to the concentration of the optically active molecule & path length of the solution through which PPL is passed. It is called Biot's law. So  $\alpha = [\alpha] \times (c \cdot l)$ .

$c$  = conc<sup>n</sup> of compound in g/m<sup>3</sup>.

$l$  = length of polarimeter tube in dm.

$[\alpha]$  = specific rotation. So  $[\alpha] = \frac{\alpha}{c \cdot l}$

$\lambda$  = wavelength of polarised light.

$t^{\circ}C$  = experimental temperature.

Calculate  $[\alpha]$  of a 1(M) solution of 2-chloropentane in a 10 cm cell when the observed value is +3.64°.

Q.  $\alpha$  in a 10 cm cell when the observed value is +3.64°.  
 $c = \frac{106.5}{1000}$ ,  $l = 1\text{dm}$ .  $[\alpha] = \frac{3.64}{1 \times 0.1065} = (+)34.2$

\* Specific rotation is independent on conc<sup>n</sup> of solution. It depends on the nature of solvent, experimental temperature & wavelength of PPL. So on dilute it does not change.

Q. The specific rotation of D-D-Glucose is (+) 112°. Assuming that 3 table spoons weighs 36g & a small glass tube 5 cm in diameter holds 100 ml of solution. Calculate how much  $\alpha$  should have been observed.

$$[\alpha] = \frac{\alpha}{l \times c} \quad V = \pi r^2 l \quad l = \frac{V}{\pi r^2} = \frac{400 \text{ cm}^3}{3.14 \times 6.25 \text{ cm}^2}$$

$$[\alpha] = \frac{+112^\circ}{2.038 \text{ dm}} = +20.38 \text{ cm} = 2.038 \text{ dm}.$$

$$c = \frac{36}{400} = 0.09 \text{ gm ml}^{-1}$$

$$\alpha = [\alpha] \times l \times c = (+) 112^\circ \times 2.038 \times 0.09 = + 20.54^\circ$$

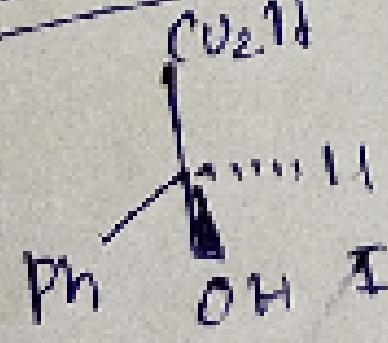
Definition of some terms associated with chiral/achiral system:  
Classification of stereoisomers based on symmetry.

### Stereoisomers

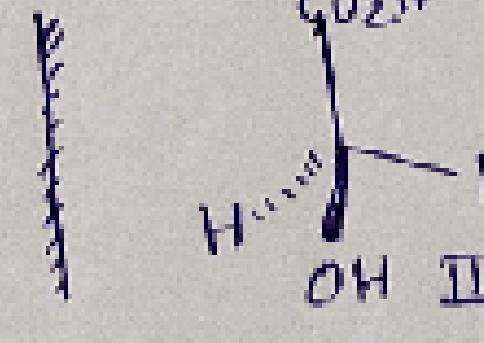
Enantiomers.  
Nonsuperimposable mirror images.  
| energy barrier

High configuration and enantiomers

Enantiomers:

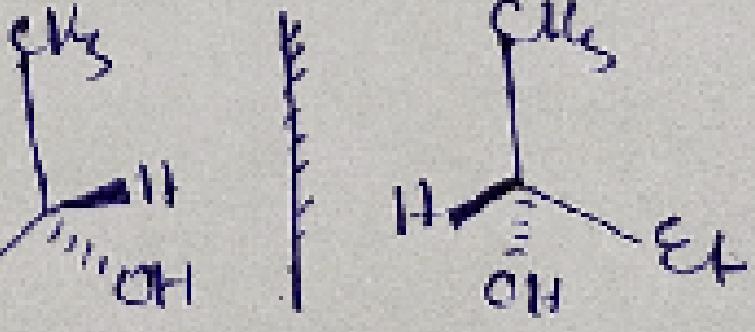


Conformational enantiomers



Diaxialenes.  
Not mirror image relationship.

| energy barrier  
High configuration diaxialenes      Low conformational diaxialenes



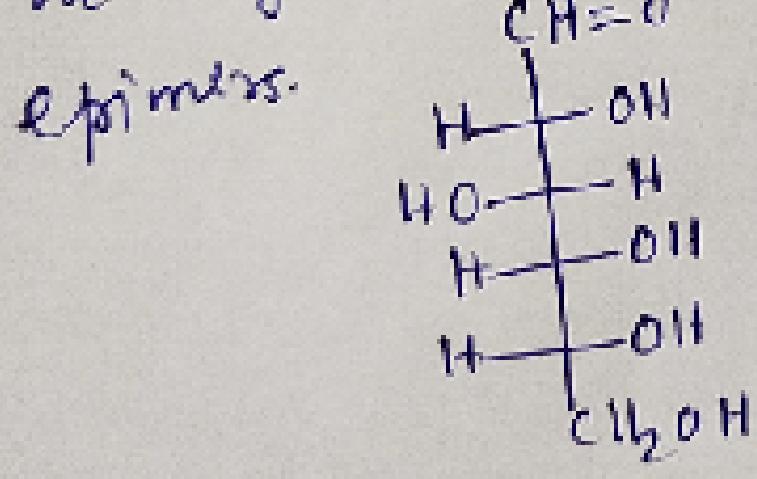
Two enantiomers of Mandelic Acid & 2-butanol.

They have same physical properties like m.pt., b.pt, solubility & pKa. The magnitude of

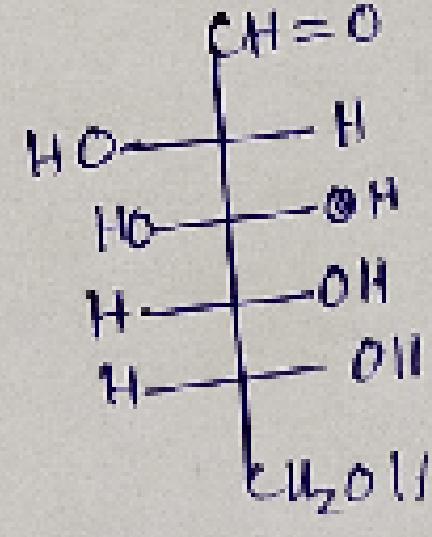
Optical rotation of enantiomers are same but they <sup>5</sup>  
 have different signs of optical rotation. With achiral  
 reagents e.g. OH, the rate of reaction of enantiomers  
 e.g. R (+) 2-bromobutane & (-) 2-bromo butane is same.  
 But the enantiomers will react at different rates  
 with chiral reagent. Enantiomers are chiral & op. active.

### Diastereomers:

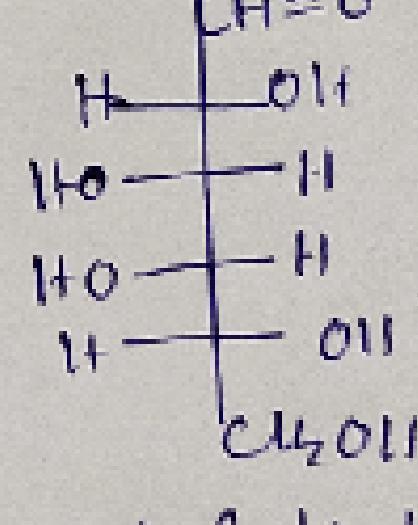
- ⇒ They are not mirror image w.r.t each other.
- ⇒ They have different physical properties like m.pt, b.pt & solubility. They can be separated by fractional distillation; E, Z isomers & cis & trans isomers are related as diastereomers.
- ⇒ They can be individually optically active / chiral molecule or they can be optically inactive / achiral molecules. They can be PPL, or can not.
- ⇒ When two diastereomers differ in the stereochemistry at only one stereocentre then they are called epimers.



D-glucose.



D-Mannose.



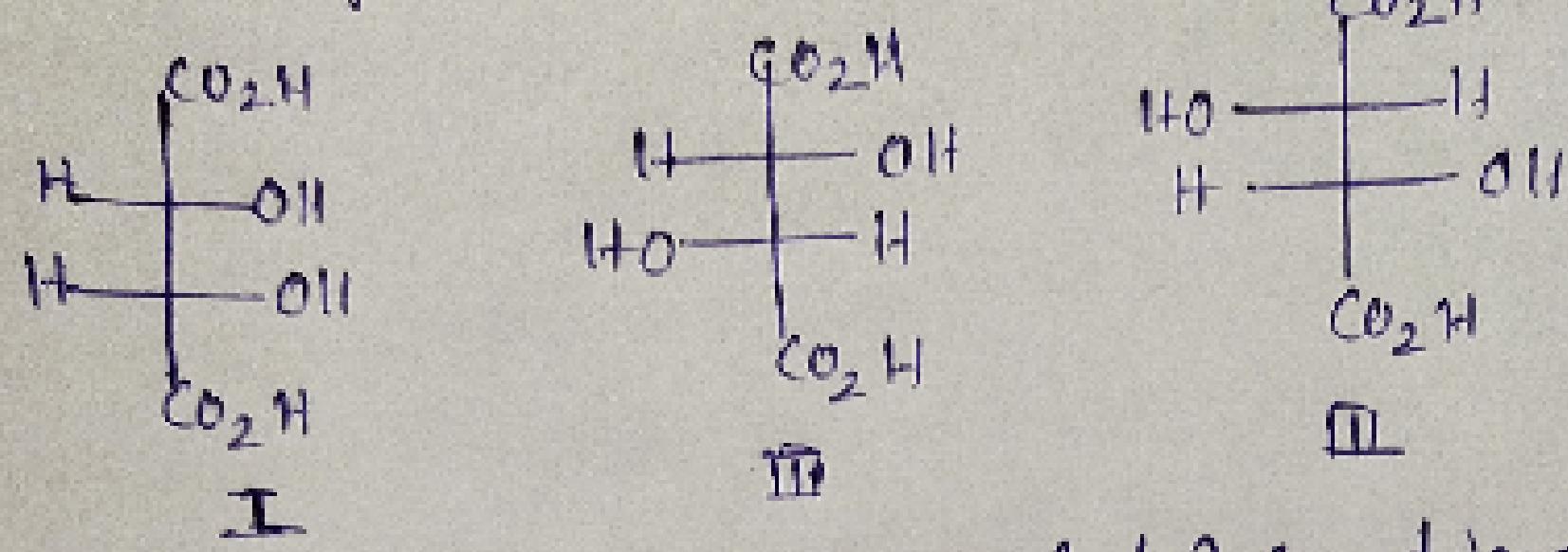
D-Galactose.

D-glucose, D-Mannose are related as epimers.

D-glucose, D-Galactose are related as epimers.

⇒ Enantiomers can exist only in pair whereas more than one a particular molecule can have more than one diastereomers. e.g. meso tartaric acid

has two diastereomers (diastereomeric relationship with either of the enantiomers). 6



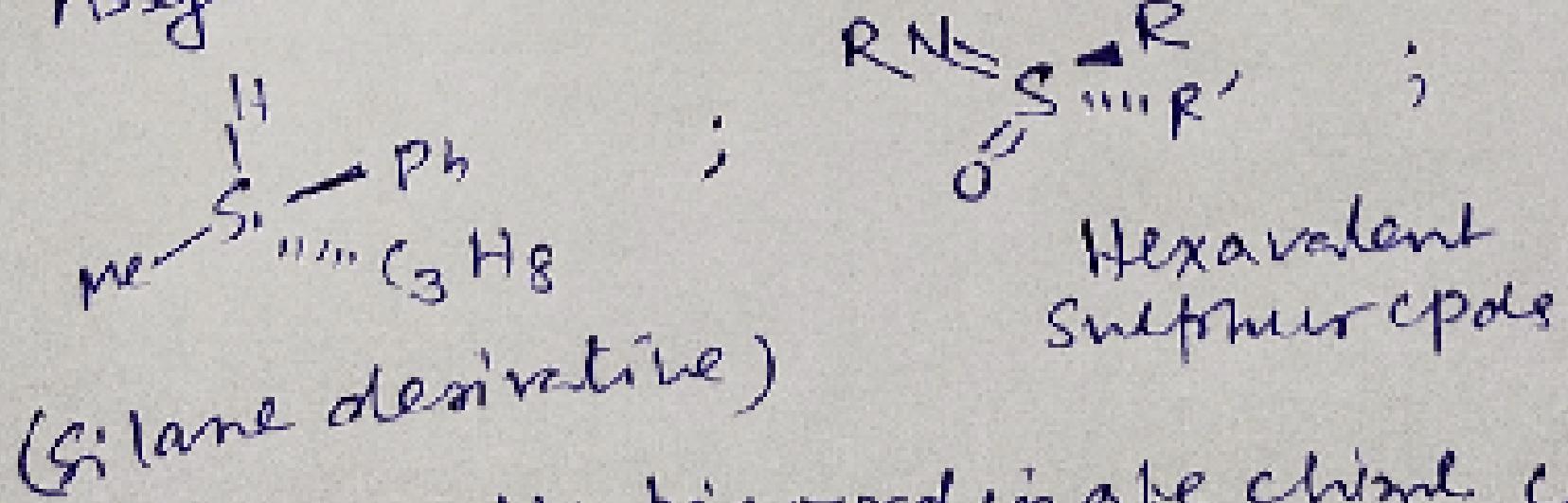
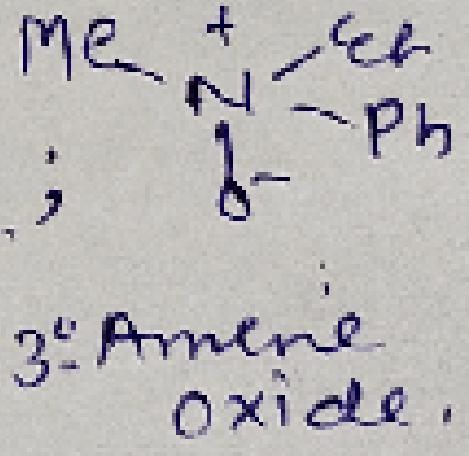
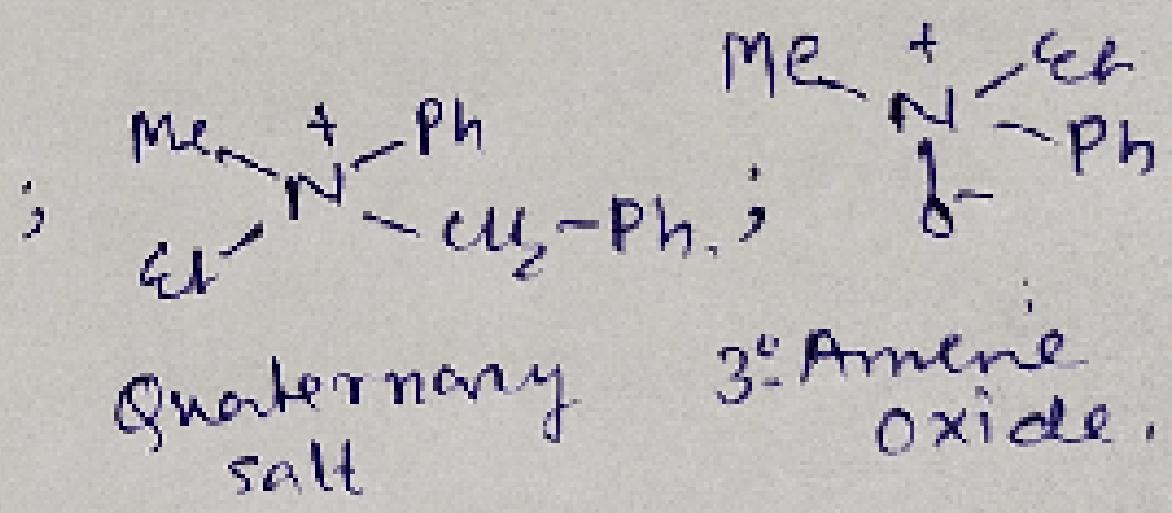
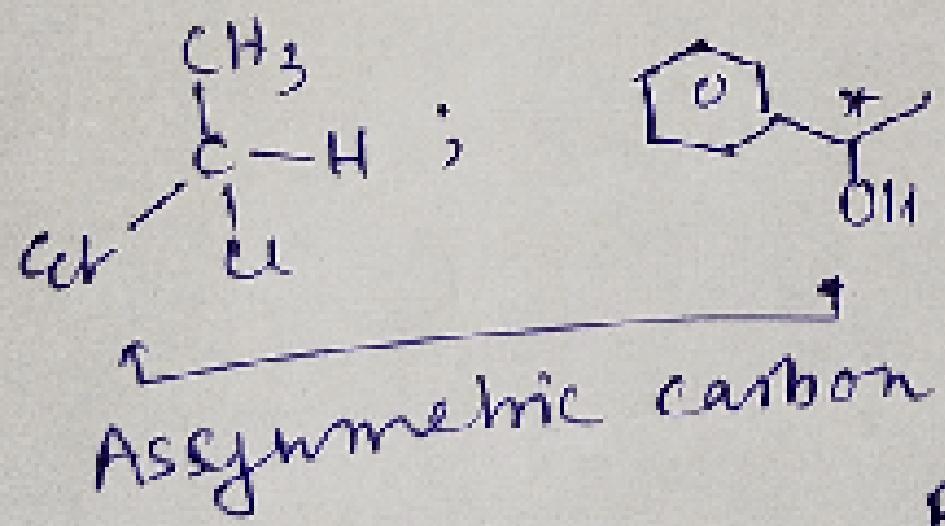
I, II & I, III are related as diastereomers.

but II, III are related as enantiomers.

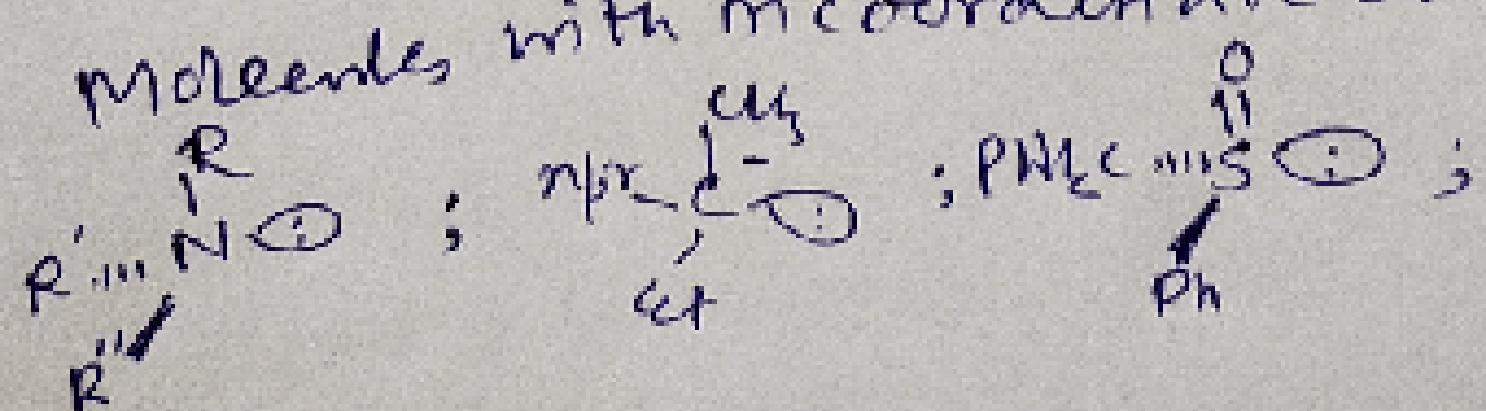
⇒ Enantiomers cannot be separated by fractional distillation.

: Stereo / Chiral centre:

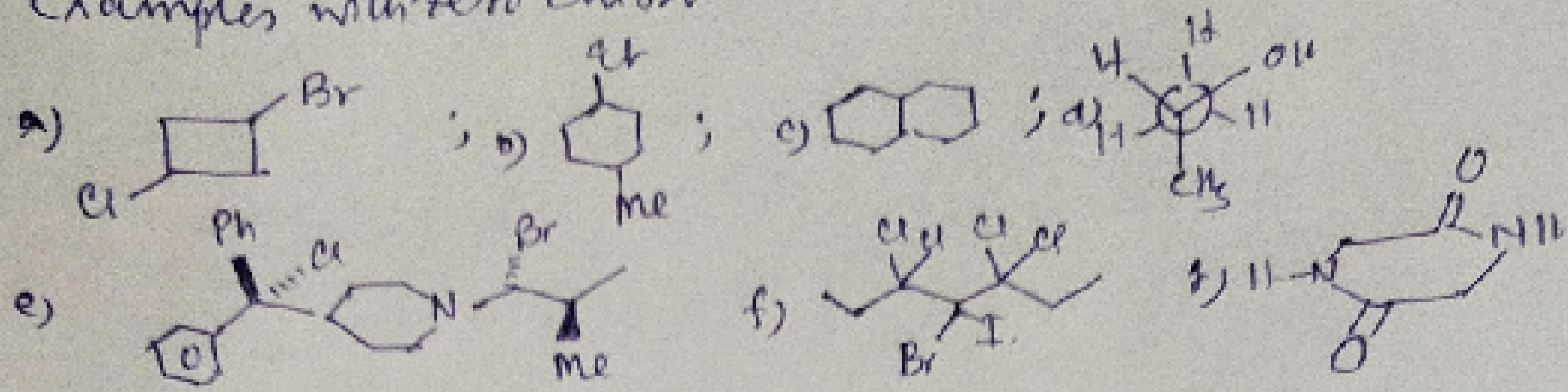
If  $sp^3$  hybridized carbon has four different groups attached then such carbon is called asymmetric carbon. Also there are molecules containing N/P/S/Si with a tetra coordinate chiral centre.



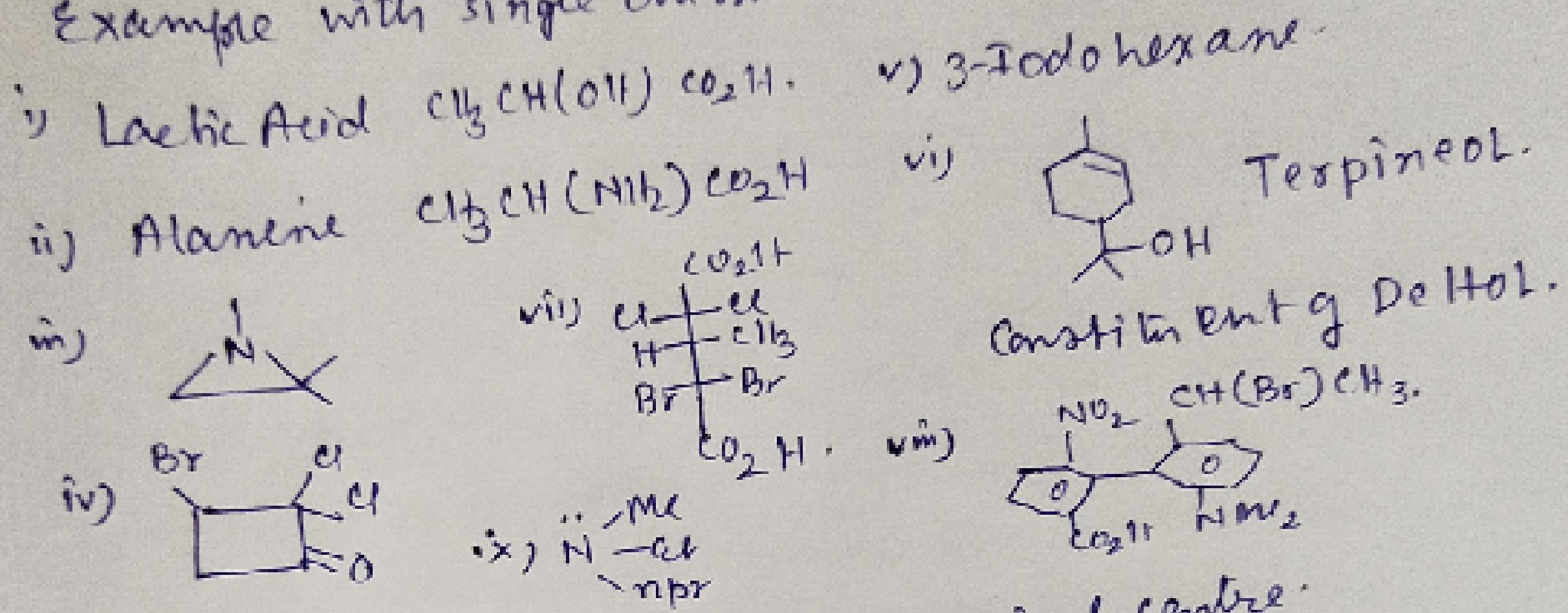
Molecules with tricoordinate chiral centre:



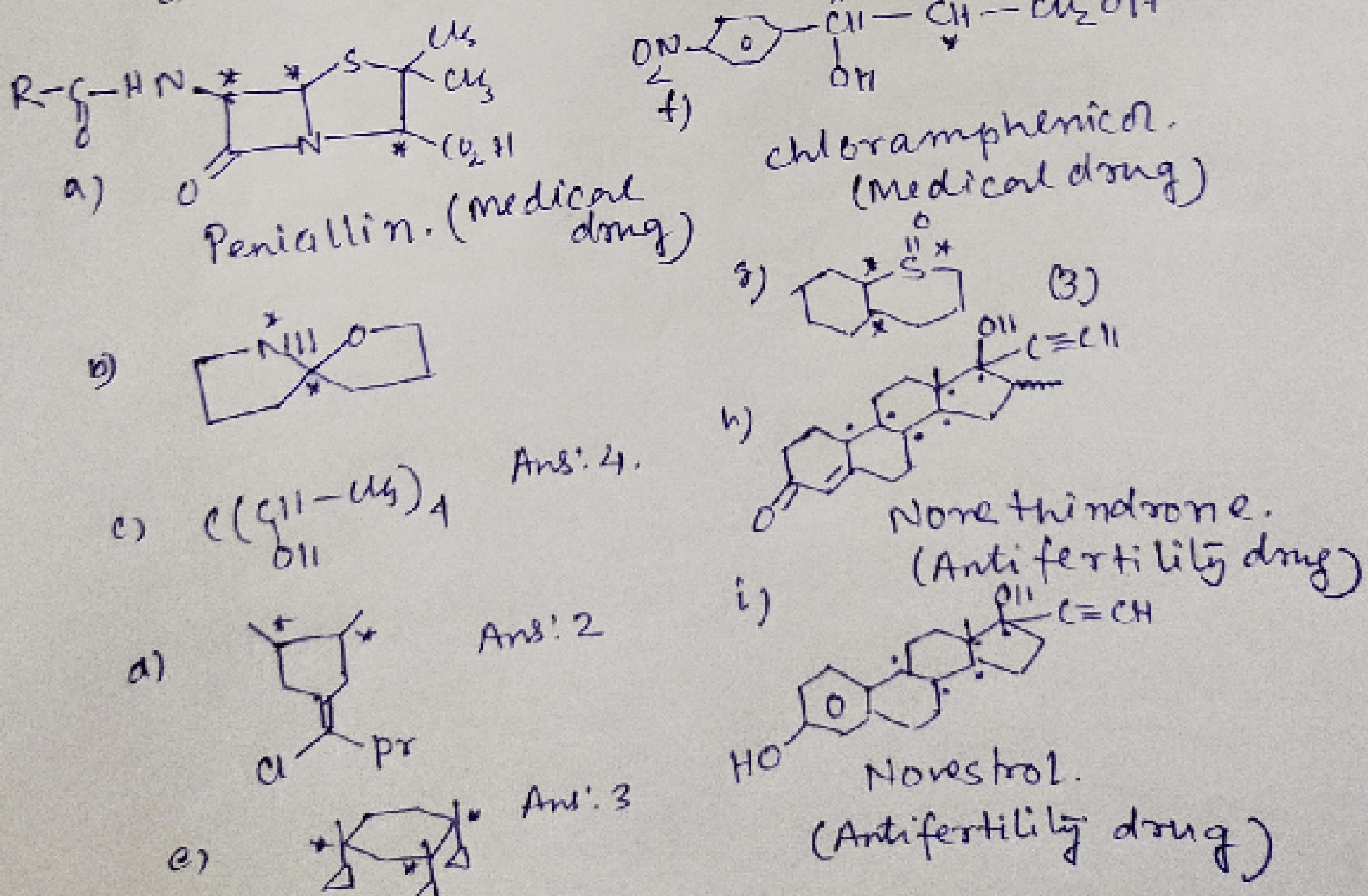
Examples with zero chiral centre:



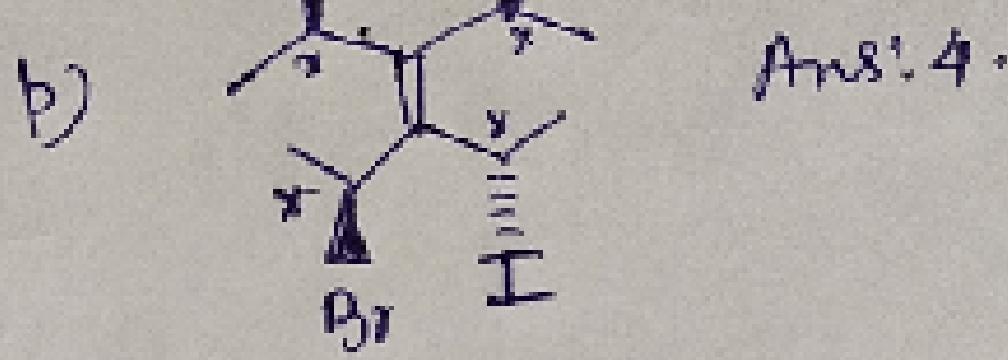
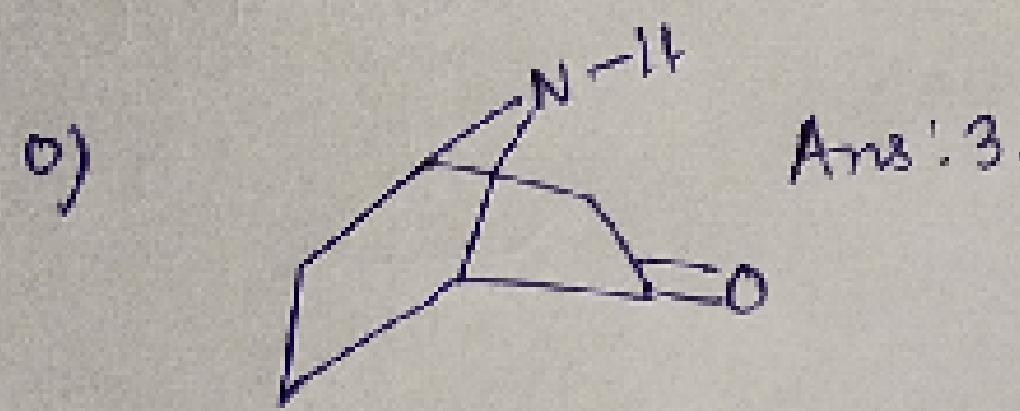
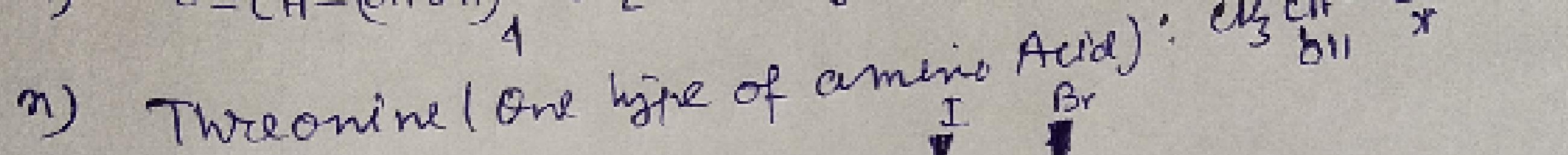
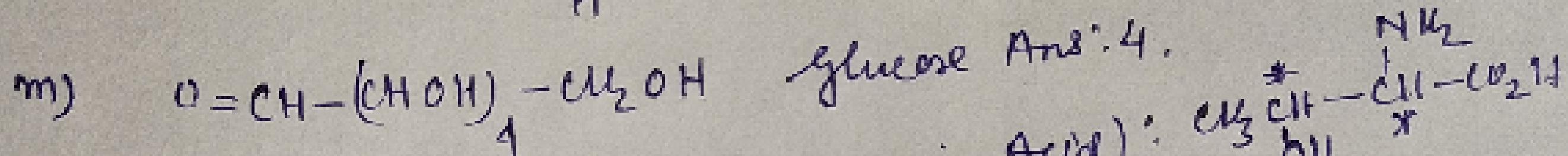
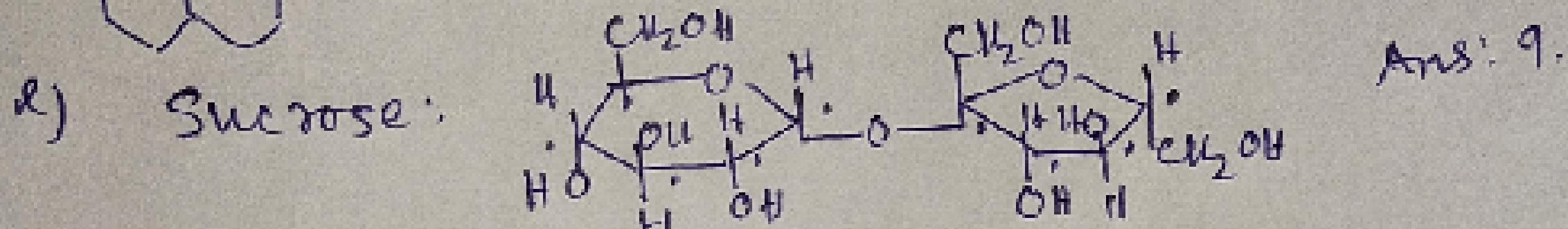
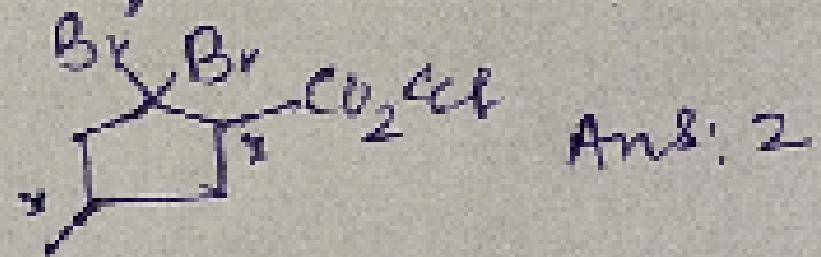
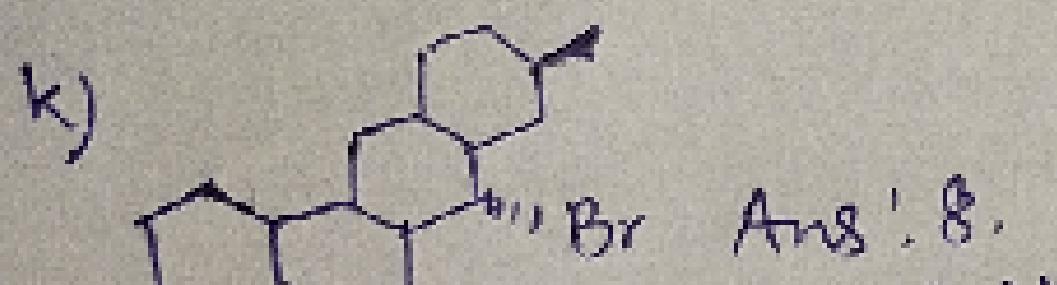
Example with single chiral centre:



Example with more than one chiral centre:

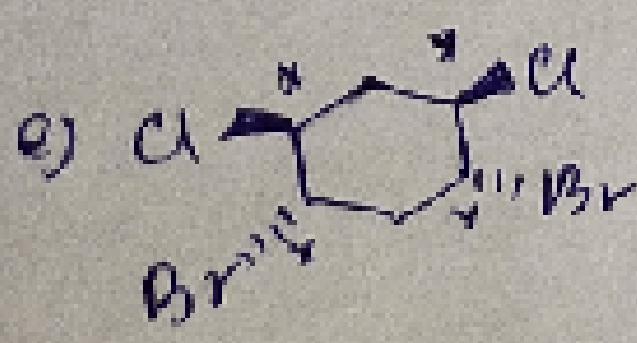
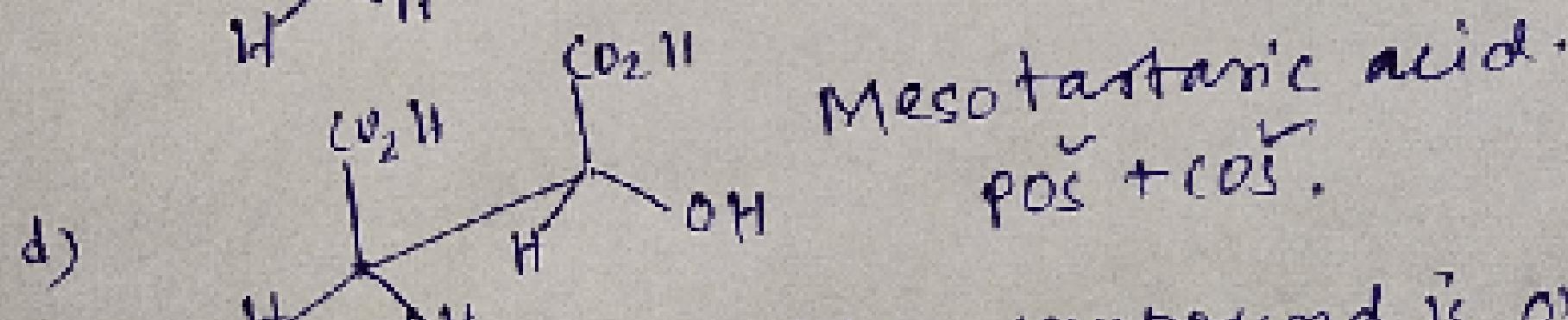
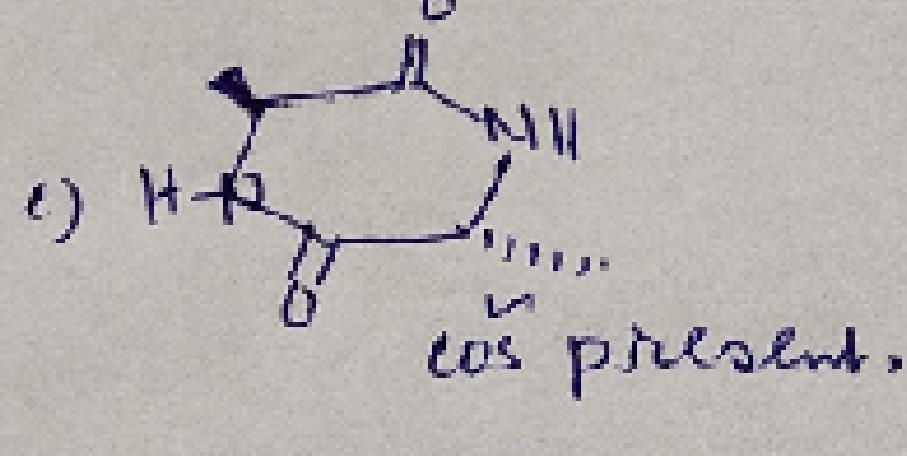
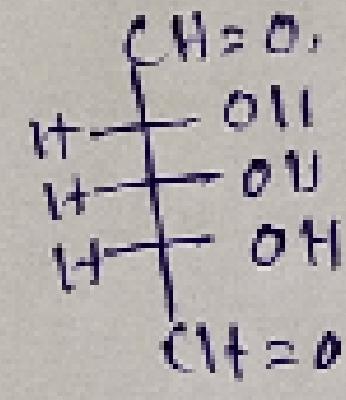
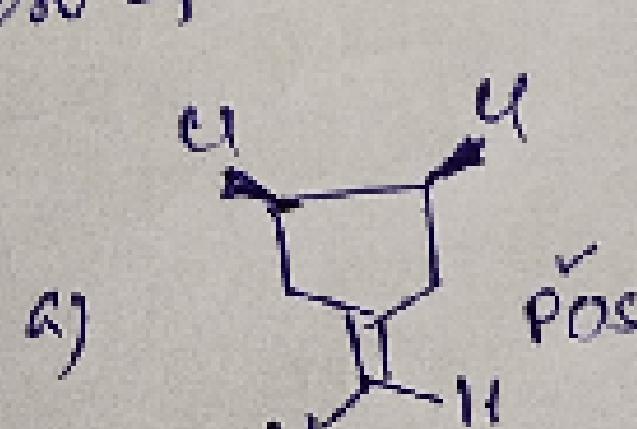


j) Ethyl-2,2 dibromo-4-methyl cyclopentane carboxylate Ans: 2



:Meso compounds:

Optically inactive compounds with multiple (more than one) chiral centres are called meso compounds. Meso compound is optically inactive either by POS or COS or both. Meso cpd cannot rotate PPL. Enantiomers are not applicable for meso cpds.

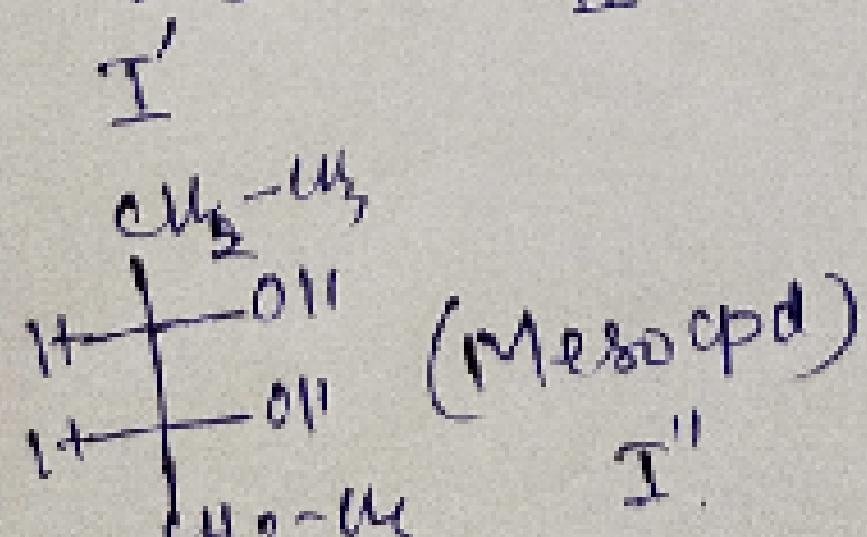
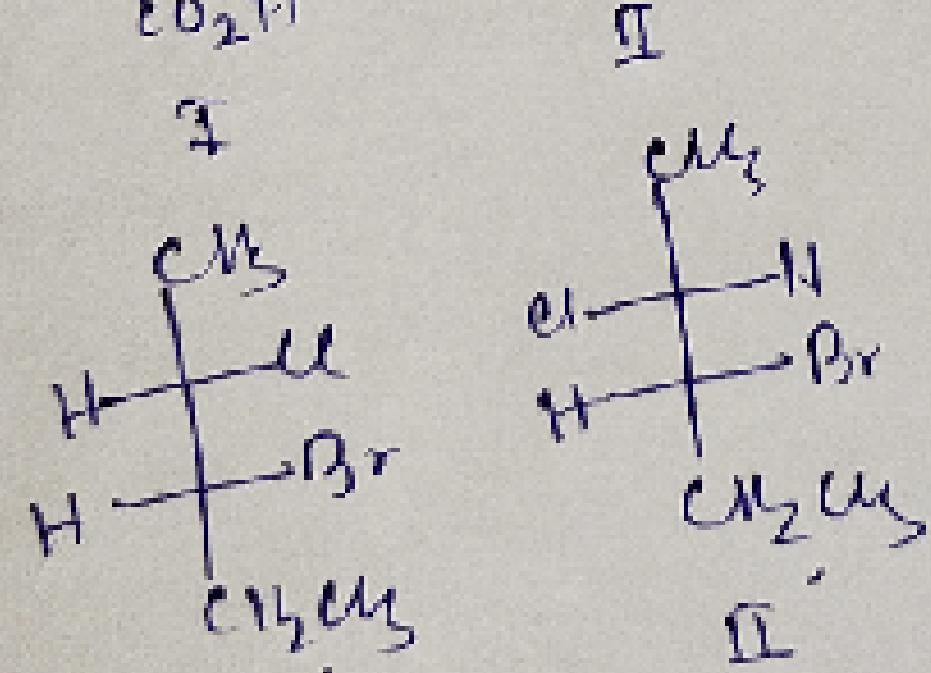
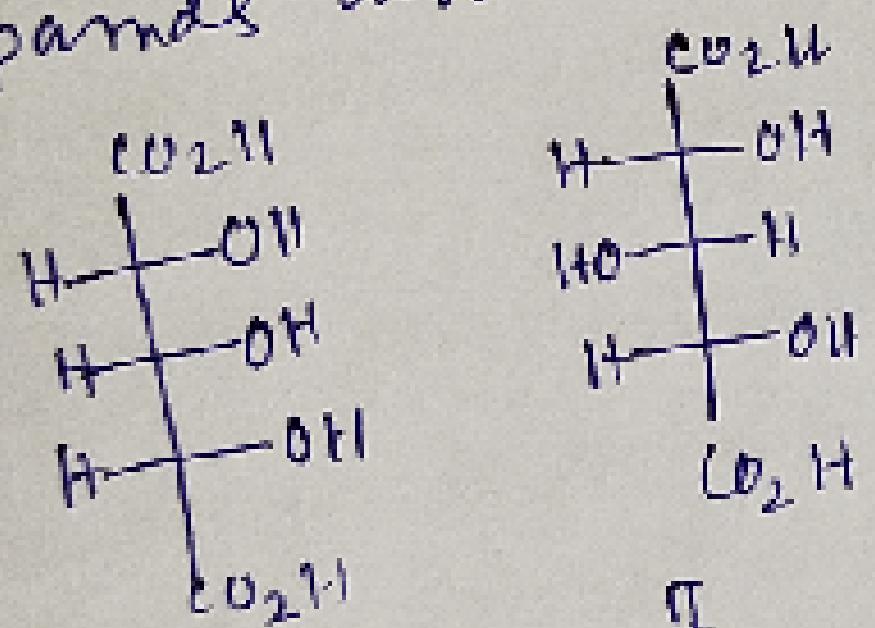


⇒ Meso compound is optically inactive due to internal compensation.

Points to be noted:

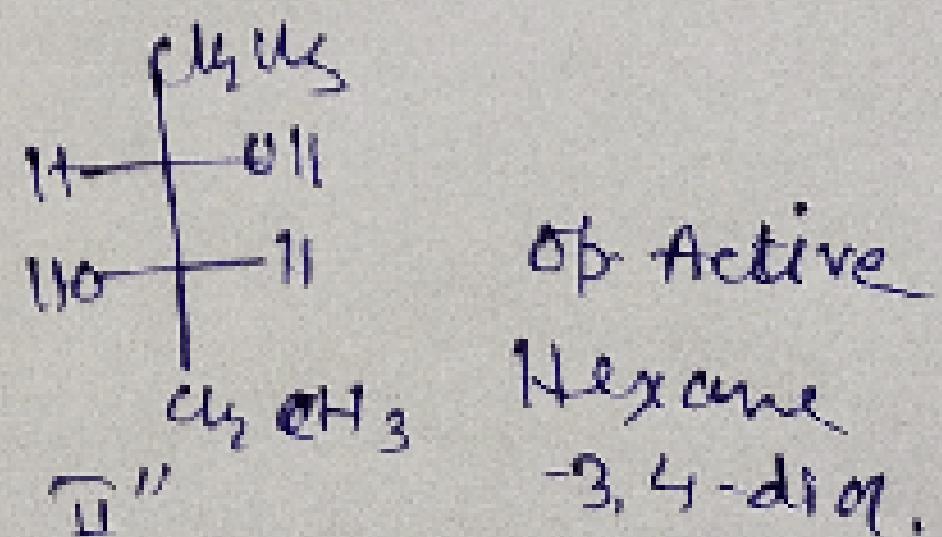
Qa

- ⇒ Achiral centre molecule can be optically active / chiral molecule.
- ⇒ Compounds with multichiral centre can be optically inactive / active molecule [Meso].
- ⇒ Chiral molecules do not have any relation with chiral centre.
- ⇒ Chiral molecule always has enantiomeric relationship with another chiral molecule.
- ⇒ Chiral molecule can have diastereometric relationship with either chi another chiral compound or achiral compound. Two achiral compounds also can be related as diastereomers.



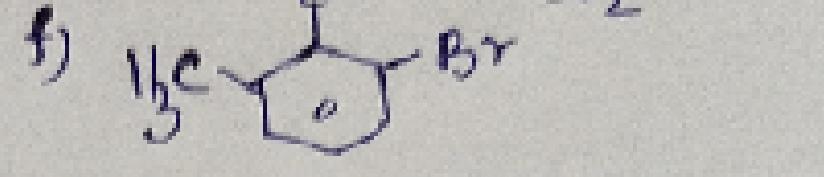
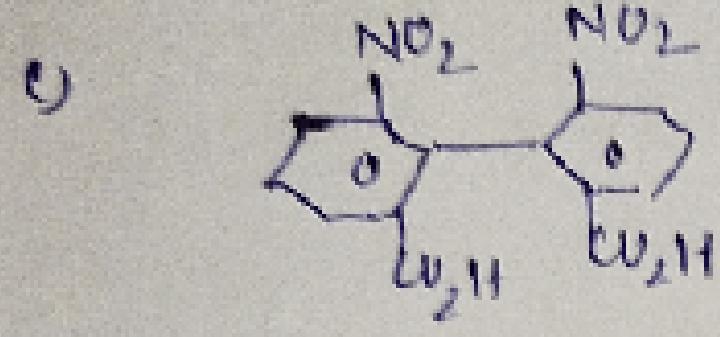
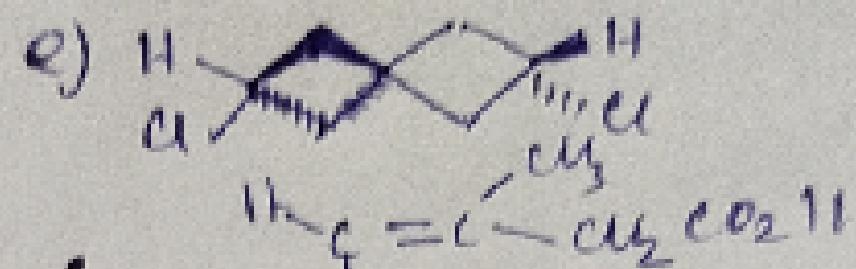
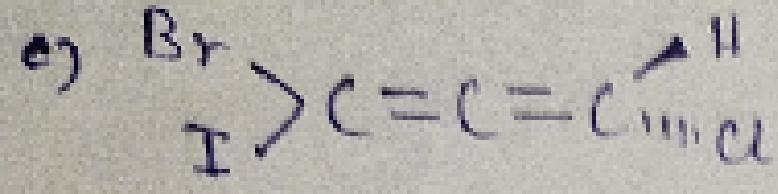
I, II both are meso Cpd.  
(achiral) & they are  
related as diastereomers.

I', II' both are chiral  
compound & they are  
related as diastereomers.



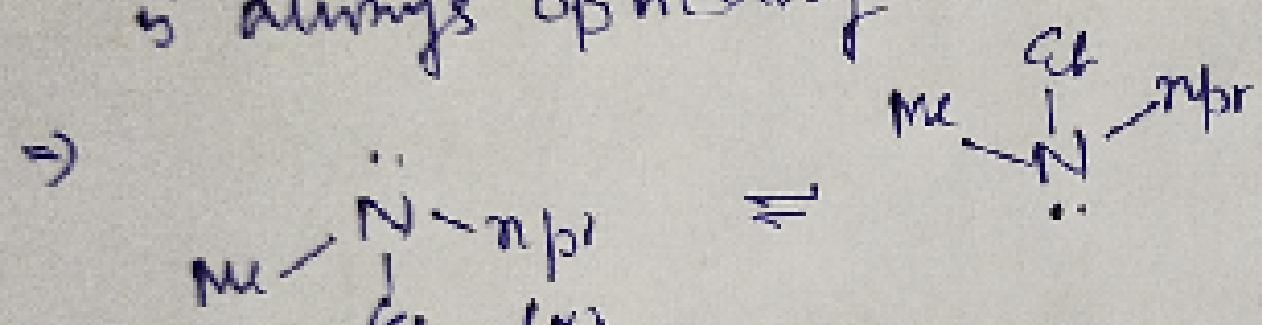
hexane 3,4 diol. are related as diastereomers.

Examples of zero chiral centre which are optically active qb



⇒ single chiral centre molecule (asymmetric carbon)

is always optically active.



X is optically inactive though it has single chiral centre. Because here enantiomers separation is not possible due to flipping (umbrella inversion).

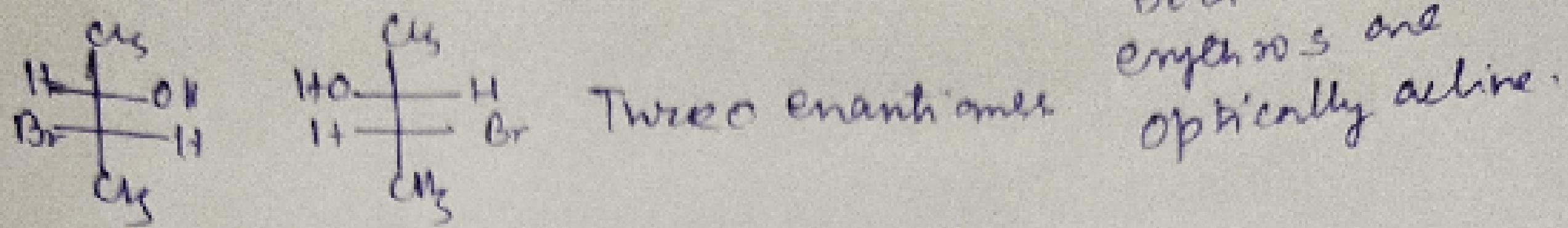
This is optically inactive though it has 2 chiral centre without symmetry because due to ring flipping (very fast inversion) enantiomers can not be isolated.

1. Erythro Cpd & Three Cpd:

A molecule with two adjacent stereocentres where there are two groups which are common to each carbon while the third is different, i.e.  $\text{CH}_3-\text{CH}_2$  give rise to erythro & three diastereomers.

If similar groups as one priority groups are in

the same side then they are called enantiomers. If similar groups / same priority groups are in the opposite side then they are called meso isomers. 10

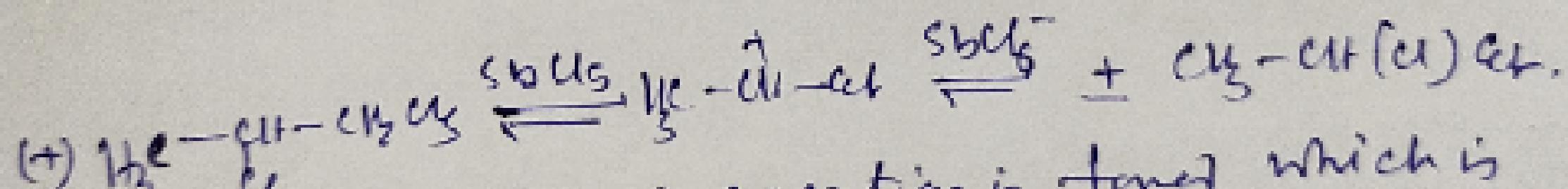


### Racemic Mixture: (Racemic modification)

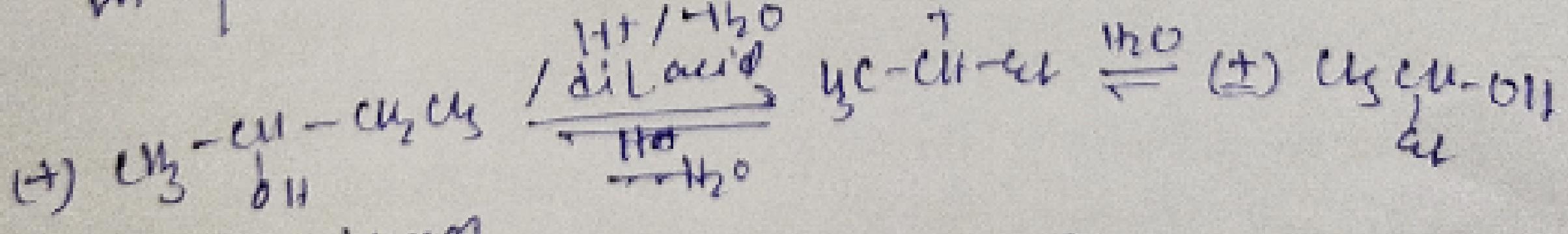
A mixture containing two enantiomers in equal proportion will have zero optical rotation, as the rotation of one isomer cancels rotation of other isomer.

So racemic mixture is optically inactive due to external compensation. The process of conversion of one enantiomer into racemic mixture is known as racemisation. Represented as dl or  $(\pm)$

Example: 2 chlorobutane  $\xrightarrow{\text{SbCl}_5}$  After sometime  
dl 2 chlorobutane  $\xrightarrow{\text{SbCl}_5}$  mixture contains  $(\pm)$  2 chlorobutane.



Here in 1st step carbocation is formed which is attacked by  $\text{SbCl}_5^-$  in both lobe of vacant p-orbital in equal proportion results in racemisation.

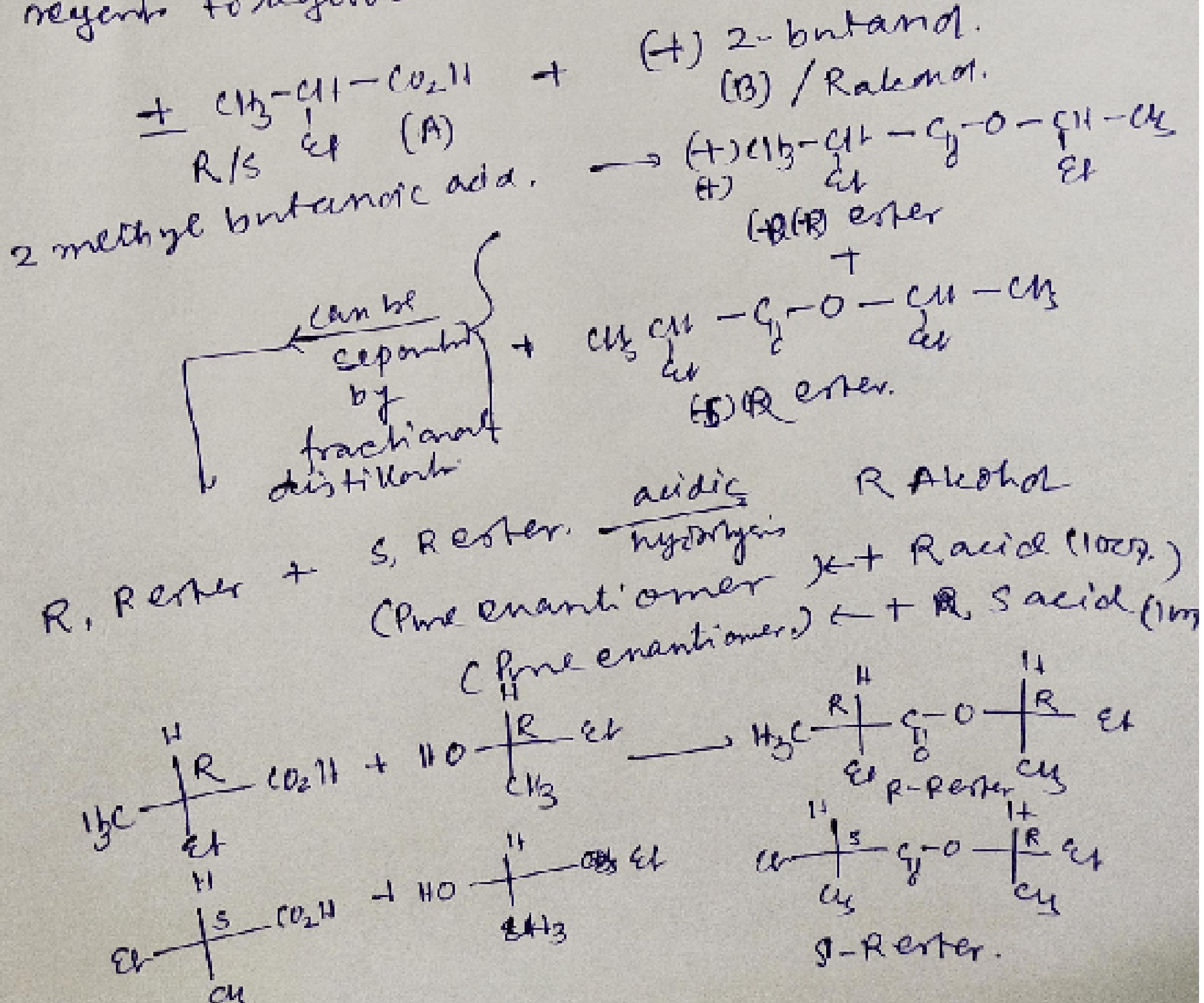


(+) 2 butanol similarly when (+) 2 butanol is allowed to react with dilute acid, carbocation is formed which is attacked by  $\text{H}_2\text{O}$  in the same manner results to give racemic mixture. Racemic mixture cannot be separated by physical process like fractional distillation.

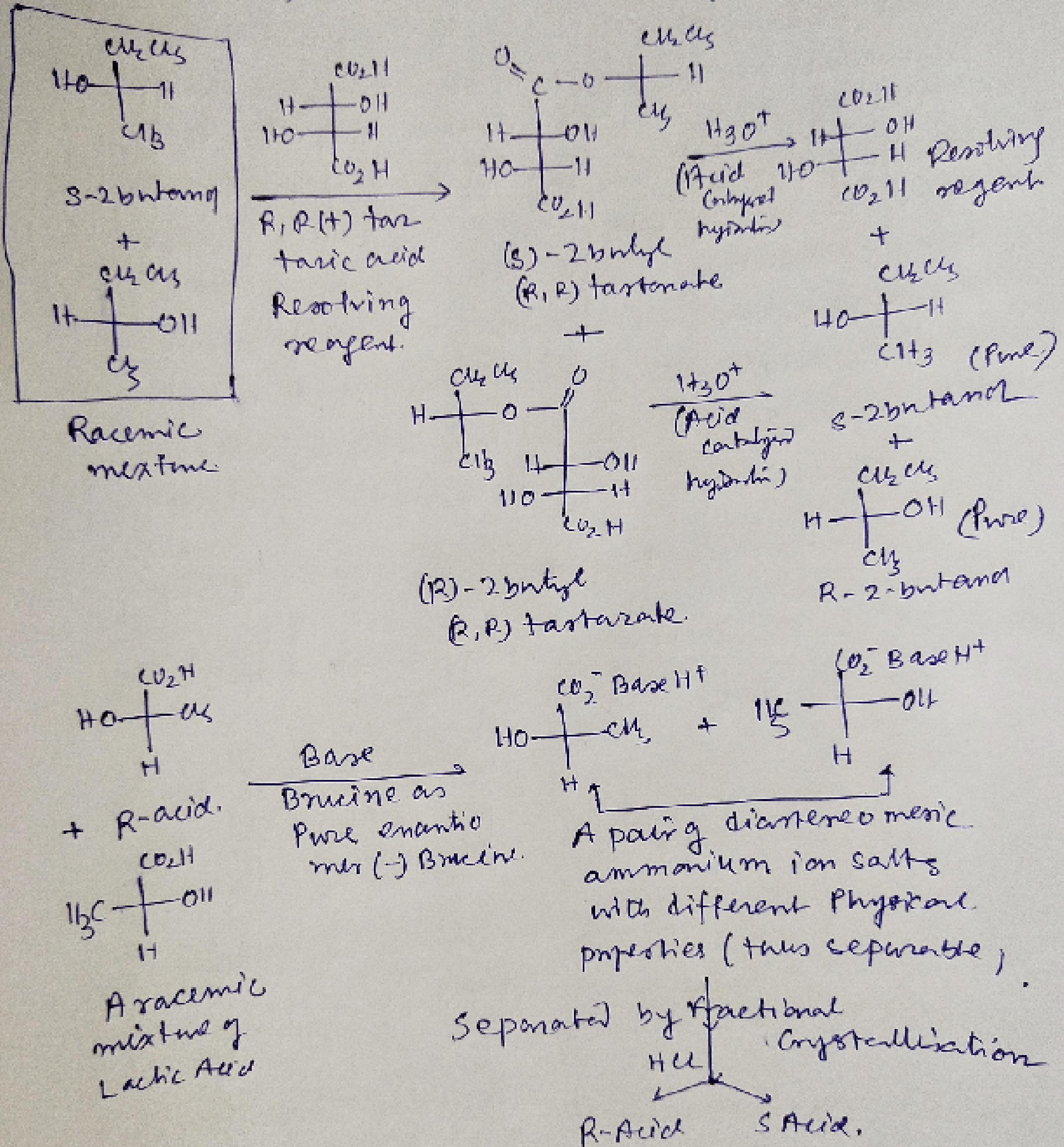
### Resolution:

Racemic modification is the method of separation of racemic modification into pure enantiomers.

The chemical method: Resolution changes the formality of diastereomers. The basis of chemical method of separation consists in converting the enantiomer of a racemic modification with a pair of diastereomers. The racemic modification is treated with an optically active substance & the diastereomers formed are separated by fractional crystallization or by chromatography. The separated diastereomers are then individually treated with suitable reagents to regenerate the pure enantiomer.



In the reverse way also we can separate the meso form of (racemic) R & S-2-butanone using R(R) (+) tartaric Acid



- ⇒ Meso compounds can not be resolved
- ⇒ for achiral compound, resolution is not possible
- ⇒ By the term "resolvable" means optically active / chiral system.

## Optical Purity:

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An optically pure compound is one which is 100% pure enantiomer. Optical purity of an enantiomeric mixture is the excess of one enantiomer over the d,l pair. It is called also as enantiomeric excess.

One compound is 30% optically pure w.r.t d form which means One compound is 30% optically pure w.r.t d form which means 30% d + 70% racemic mixture (35% d + 35% l)

$$30\% \text{ d} + 70\% \text{ l} = 35\%$$

$$\text{So total d} \Rightarrow 65\% \text{ d} + 35\% \text{ l}$$

$$\gamma_{\text{optical purity}} = \frac{\text{specific rotation of enantiomeric mixture}}{\text{specific rotation of pure enantiomer}} \times 100$$

$$\gamma_{\text{optical purity}} = 2(\% \text{ of major enantiomer}) \times 100$$

$$\gamma_{\text{optical purity}} = 100 - 2(\% \text{ of minor enantiomer})$$

Optical Purity w.r.t d.

d%      l%

100

2.5

100

95 + (2.5)

= 97.5

5%

95

90 + 5 = 95%

20

90

60 + 20 = 80

25

60

50 + 25 = 75

40

50

20 + 40 = 60

47.5

20

5 + 47.5 = 52.5

49.95

5

1 + 49.95 = 50.05

50.

0.1

50

0

Racemic mixture has zero optical purity.

Racemic mixture has zero optical purity.

⇒ Question based on Resolution / Optical Purity.

Q. When 2-methyl pentanoic acid (-) form is treated with

(+) 3-hexanol, find out no. of products (complete reaction)

(±) 3-hexanol, find out no. of products.

Tarles Marie & their relationships.

Ans: 2 Pdt (optically active diastereomers)

Q. Pure (+) enantiomer of an optically active cpd A has a specific rotation  $[\alpha]_D^{25^\circ} = -51.3^\circ$ . What is the optical purity of a sample A which shows specific rotation  $-35.9^\circ$ . How much of each enantiomer is present in E.N.T mixture?

$$\text{Optical purity} = \frac{35.9}{51.3} \times 100 = 70\% \quad 15\% (+) \text{ enantiomer.}$$

$$\text{So E.N.T mixture has } (70 + 15) = 85\% (-) \text{ enantiomer.}$$

Q. Predict the specific rotation of mixture of 30% (-) 2-bromo butane & 70% (+) enantiomer.  $[\alpha]_D$  of pure enantiomer is  $(-) 23.13^\circ$ . ( $D$  stands for D-light)

$$\text{Hence Optical purity} = \frac{2 \times (70)}{100} = 40$$

$$100 - 2 \times (30) = 40.$$

$$\text{So } 40 = \frac{[\alpha]_D}{23.13} \times 100 \text{ or, } [\alpha]_D = \frac{40 \times 23.13}{100} = (+) 9.25^\circ$$

Q. Which of the following compounds are optically active?

