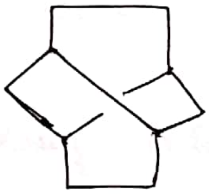
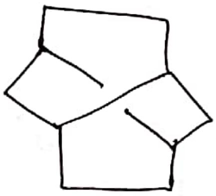
pseudorotation in twist boat form then we do expect enantiomerism. This is actually the case in twistane which can exist in two enantiomeric forms which are





## SUBSTITUTED CYCLOHEXANE

### 1. Monosubstituted cyclohexane.

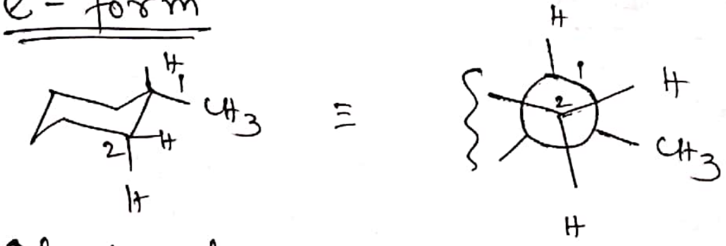
All the monosubstituted cyclohexane can exist in two diastereoisomeric forms which are

and

e-form a-form

Now the difference in energy of methyl cyclohexane between the a-form and e-form can be estimated from an inspection of the models.

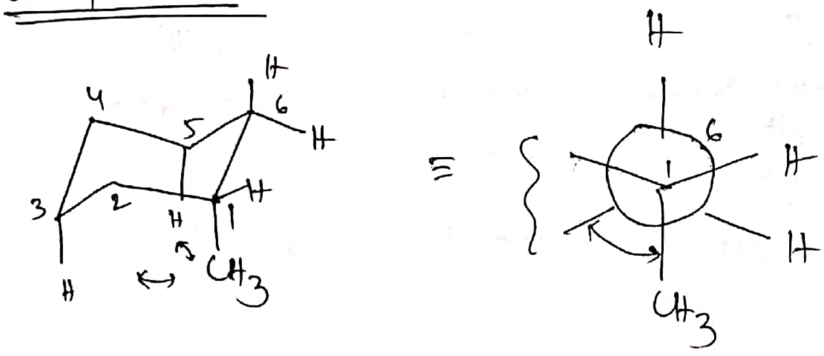
e-form



Obviously there is no extra gauche

butane interaction.

a-form



Looking along $C_1-C_6$ we have above newman projection, which shows an extra gauch butane interaction. Similarly looking along $C_1-C_2$ we will be able to detect another gauch butane interaction. Thus there are two extra gauch butane interaction as shown. There are also 1,3-diaxial intereaction between $C_3-H$ & $C_1-CH_3$ and $C_5-H$ & $C_1-(CH_3)$.

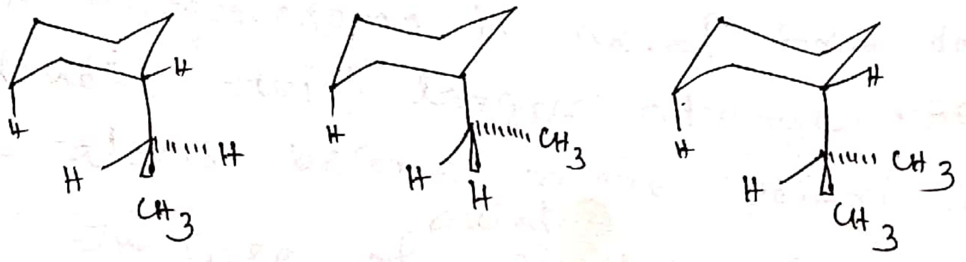
Thus e-form is more stable than a-form by an energy 1·73 (0·9×2=1·8) K·Cal/mole.

## Energy Difference Between the Axial and Equatorial Conformations of Mono sub. Cyclohexane

| Group | K·Cal/mole |
|---|---|
| —F | 0·2 |
| —Cl | 0·53 |
| —Br | 0·48 |
| —I | 0·51 |

| Group | K.Cal/mole | Group | K.Cal/mole |
|---|---|---|---|
| $-OH$ | 1.0 | $-CH<^{CH_3}_{CH_3}$ | 2.21 |
| $-COOH$ | 1.4 | | |
| $-CH=CH_2$ | 1.68 | $-C(CH_3)_3$ | 4.7 |
| $-CH_3$ | 1.73 | | |
| $-CH_2CH_3$ | 1.79 | $-Ph$ | 2.8 |

A larger group usually has a larger energy difference between the axial and equatorial positions, because the 1,3-diaxial interaction is stronger for larger groups. In case of ethyl and isopropyl group the syndiaxial interaction may be minimised turning α-hydrogen which is commonly known as rotamers. In ethyl cyclohexane the axial conformer has two rotamer where as isopropyl cyclohexane exists the single rotamer.



So these two compound relatively more stable than t-butyl cyclohexane.

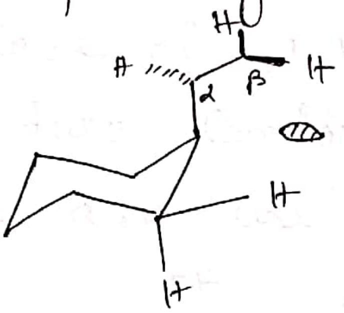
There is no rotamer in case of t-butyl cyclohexane in which the axial conformer is approximately 1 in 10000 at ambient temp$^r$. Such system is called <u>conformationally biased</u> or <u>anancomeric system</u>.

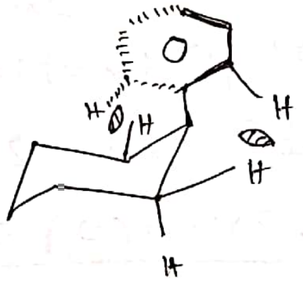
Let us consider the conformational free energies for halogens:

| | | |
|---|---|---|
| $-F$ | 0.25 | KCal/mole |
| $-Cl$ | 0.53 | 〃 |
| $-Br$ | 0.48 | 〃 |
| $-I$ | 0.51 | 〃 |

As size of F is relatively small, so it's free energy also low. However the conformational free energies of Cl, Br and I are almost equal which is due to the fact that as the size of the halogen increases the bond length also increases and as a result the synaxial interaction with halogen atoms in axial form decreases. Secondly, with larger atomic volumes, the atoms become more polarisable.

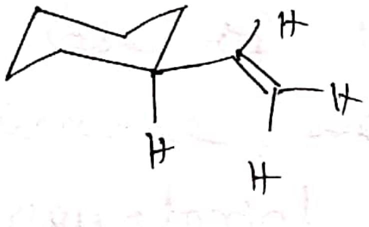
In case of $\overset{\text{axial}}{\wedge}$ vinyl cyclohexane, the sp$^2$ hybridised groups orient themselves so as to confront the ring with their flat sides. In this rotational Conformation imposes a Steric crowding between the β hydrogen of vinyl group and an equatorial hydrogen of ring.

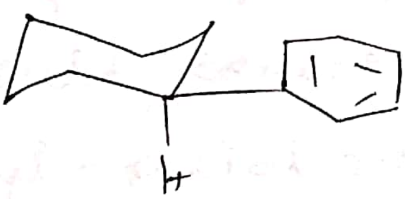




Similarly in the case of axial phenyl, this rotational Conformation imposes a Steric Crowding between the ortho - hydrogens and both equatorial hydrogens of Cyclohexane ring.

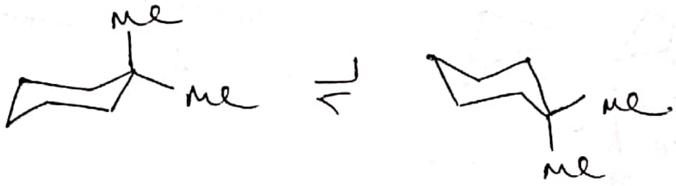
On the other hand equatorial Phenyl or vinyl is most Stable as it is in the bisector plane of cyclohexane ring where Steric repulsion is avoided.



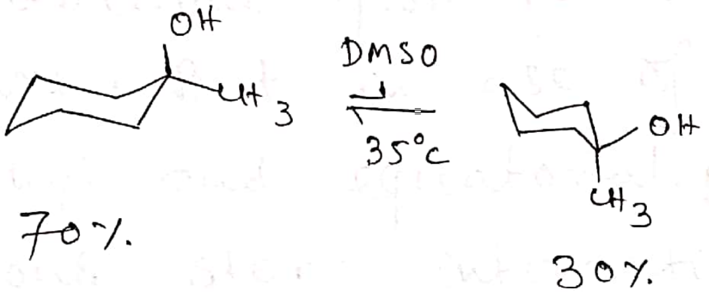


# 2. DISUBSTITUTED

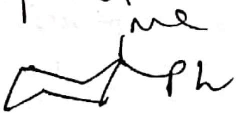
## ⓐ 1,1 - Disubstituted



In Case of 1,1 - dimethyl cyclohexane the two Conformers are identical. These are called topomers.

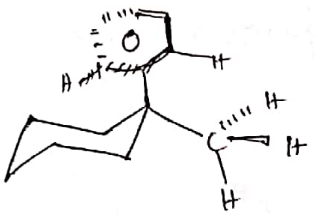


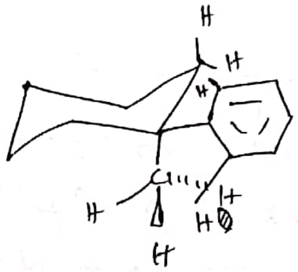
In 1 - methyl cyclohexanol, the two Conformers are diastereoisomeric and present in unequal amounts. Now the Conformational free energy of methyl group is higher than that of hydroxy group. So equatorial methyl cyclohexanol is more stable.

The Conformational free energies of phenyl is greater than methyl gr. So in case of 1- methyl - 1 - phenyl cyclohexane, we would expect the equatorial phenyl - axial methyl i.e.  to be preferred.

In fact, however axial phenyl -

equatorial methyl is preferred.

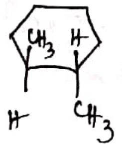




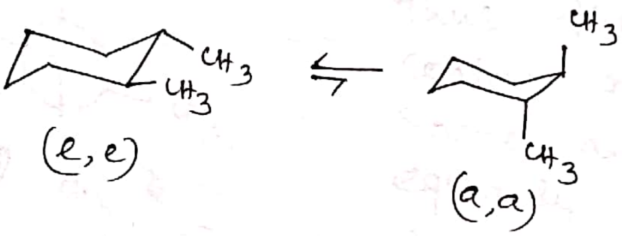
Introduction of equatorial methyl and axial phenyl causes no complication as obvious from the above figure. But in case of axial methyl and equatorial phenyl, a serious steric interaction arises between the methyl group and one of the ortho hydrogens of phenyl group.

## ⓑ 1,2 - Disubstituted cyclohexanes

⊛



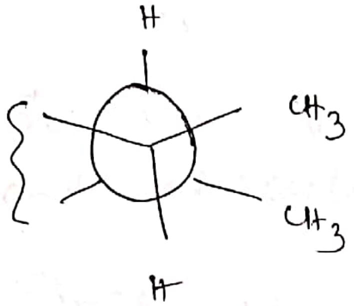
Trans - 1,2- dimethyl cyclohexane



Trans form can exist in two interconvertible chair conformations diequatorial and diaxial form.

In (e, e) form, there is one extra

gauch butane interaction between the methyl groups. But in (a,a)-form there are four gauch-butane interaction between the methyl gr. and ring Carbons. Thus (e,e)-form is more stable than (a,a) form by an energy difference 3 × 0.9 = 2.7 Kcal/mole. There is no σ plane in this compound, therefore it is resolvable.



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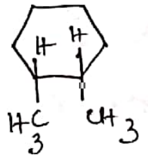
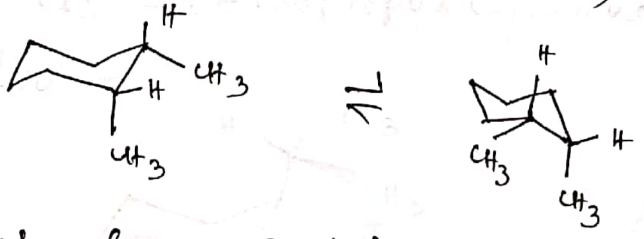
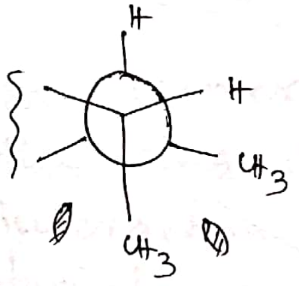


Cis-1,2-dimethyl cyclohexane

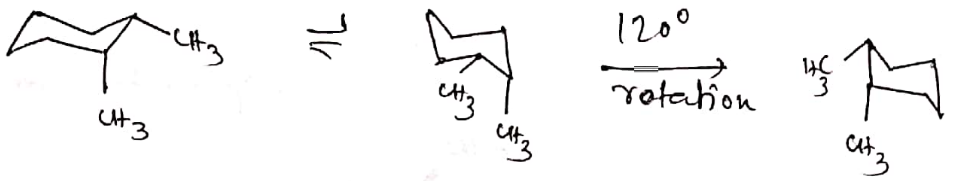
Cis form can exist in two interconvertible chair conformations - (e, a) and (a, e) form.



Each form contains three extra gauch butane interactions.



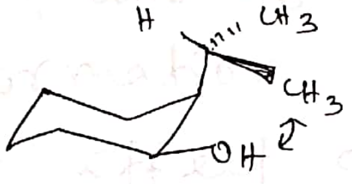
Thus the energy ~~contain~~ content of two forms are same and both forms are equally populated. Now either forms has no element of symmetry. So both the form are optically active. But one form is the mirror image of the other form.



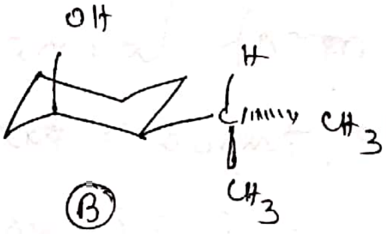
So they form enantiomeric mixture and optically inactive.

Since cis-1,2-dimethyl cyclohexane has three gauch butane interaction and the more stable, diequatorial form of the trans isomer has only one, the two configurational isomer differ in potential energy by 2×0.9 = 1.8 K.Cal/mole. Thus trans form is more stable than cis-form.

✲ The two diastreoisomeric conformation of cis-2-isopropylcyclohexanol are shown below –



Ⓐ

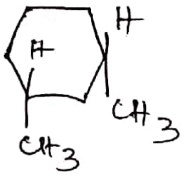


Ⓑ

In isomer Ⓐ methine hydrogen confornt the ring due avoiding (1,3) diaxial interaction. Under this situation, equatorial $-OH$ and $-CH_3$ of $-CH(CH_3)_2$ generates a severe steric interaction. In the conformation Ⓑ, no such interaction occurs. There fore Ⓑ

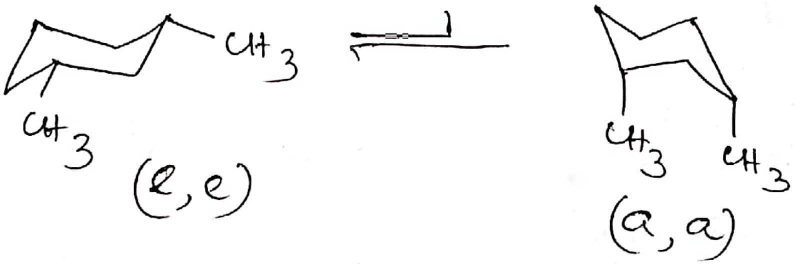
Again in the Conformation -IV the o- hydrogen are in interaction with one equatorial hydrogen and One equatorial amino group of the ring. Thus for trans- isomer III is more stable.

## 1, 3 -DISUBSTITUTED CYCLOHEXANES

⊛ 

Cis -1,3- dimethyl Cyclohexane

It Can exist in two interConvertible chair Conformations diequatorial and diaxial.

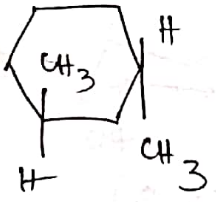


In (e,e) form there are no extra gauch butane interaction whereas in (a,a) there are extra 4 gauch butane interaction. Thus (e,e) form is more stable than (a,a) form.

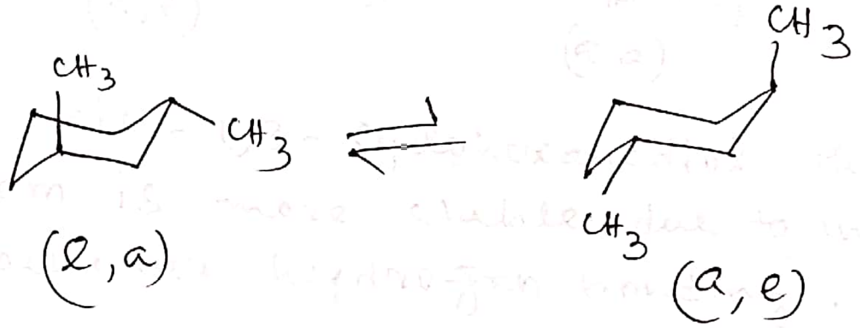
Both form Contain σ passing

vertically through the $C_2$ & $C_5$. Thus molecule is optically inactive or non resolvable.

⊛

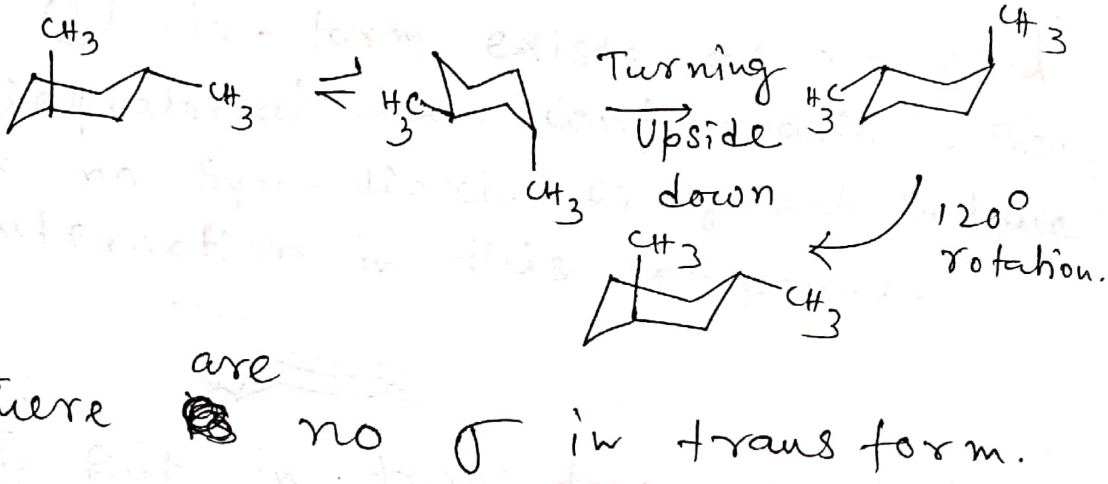


Trans -(1,3)- dimethyl Cyclohexane



It Can exist in two inter Convertible chair Conformations (e,a) and (a,e).

Now the two forms are equivalent.



There are no σ in trans form. So it is optically active.

Now trans form Contain two extra gauch - butane interaction where cis form has no extra