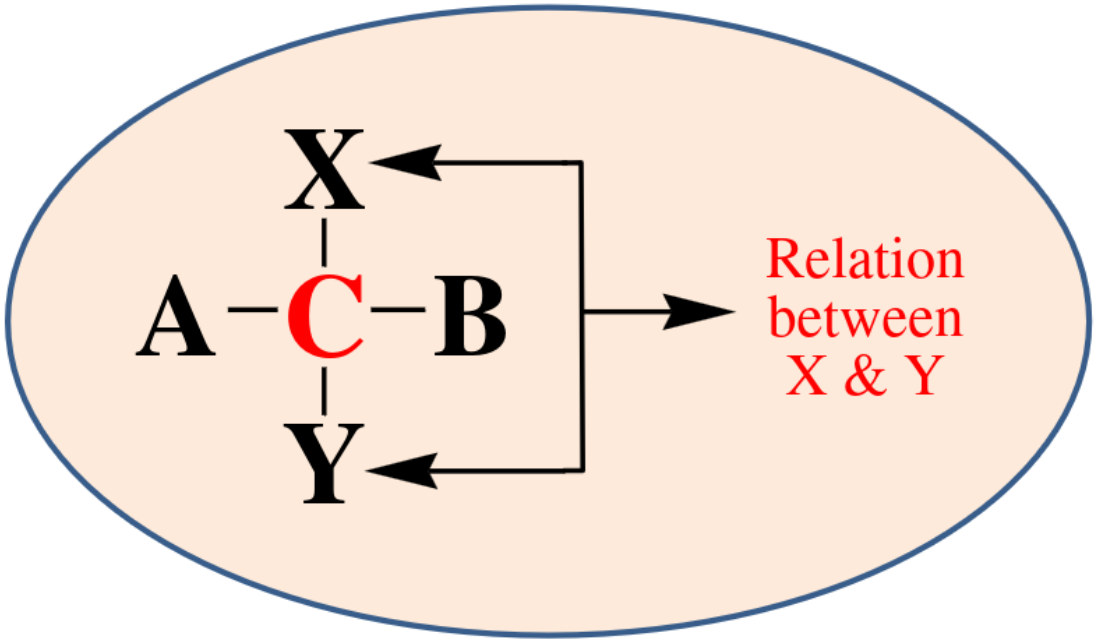
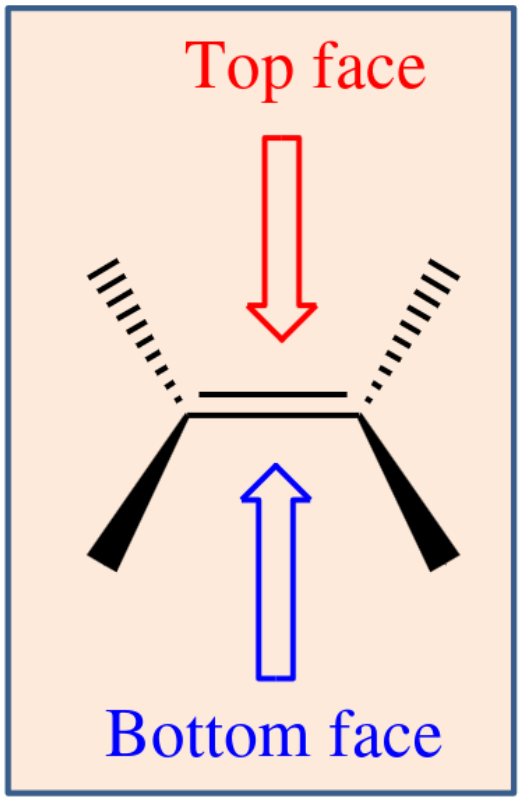
TOPICITY





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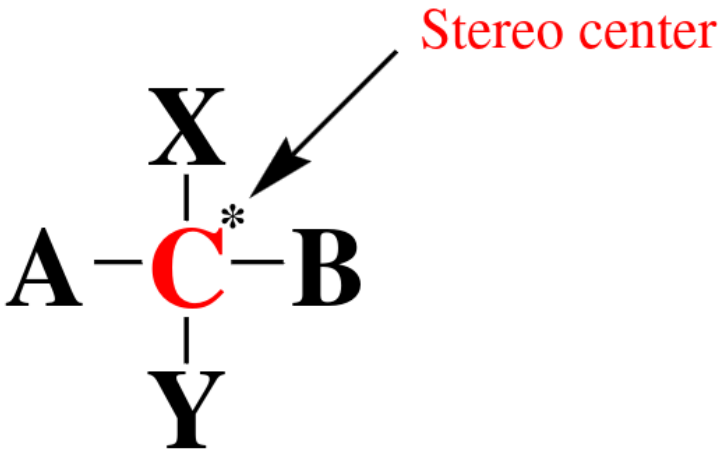
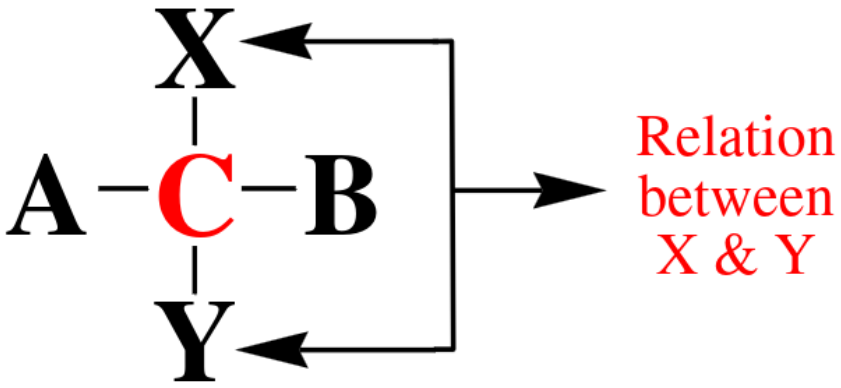
TOPICITY (TOPOs in Greek means place)

Earlier part of stereochemistry was concentrated on the stereo center.



Now we start to see the relationship between the ligands attached to stereo center if the attached ligands are homomorphic in nature.

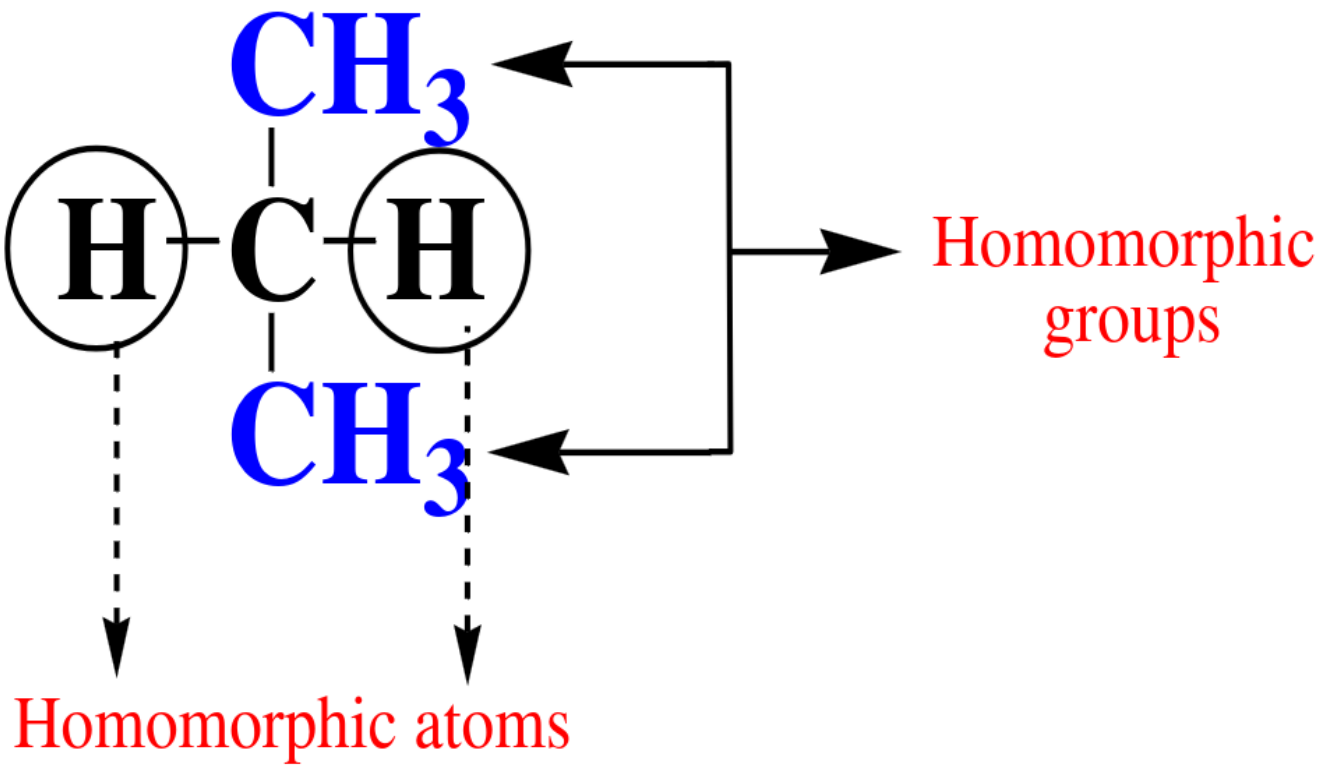


Homomorphic Groups / Ligands / Atoms

The Groups / ligands / atoms which are in isolation look the same or super imposable mirror images of each other are called homomorphic groups / ligands / atoms.

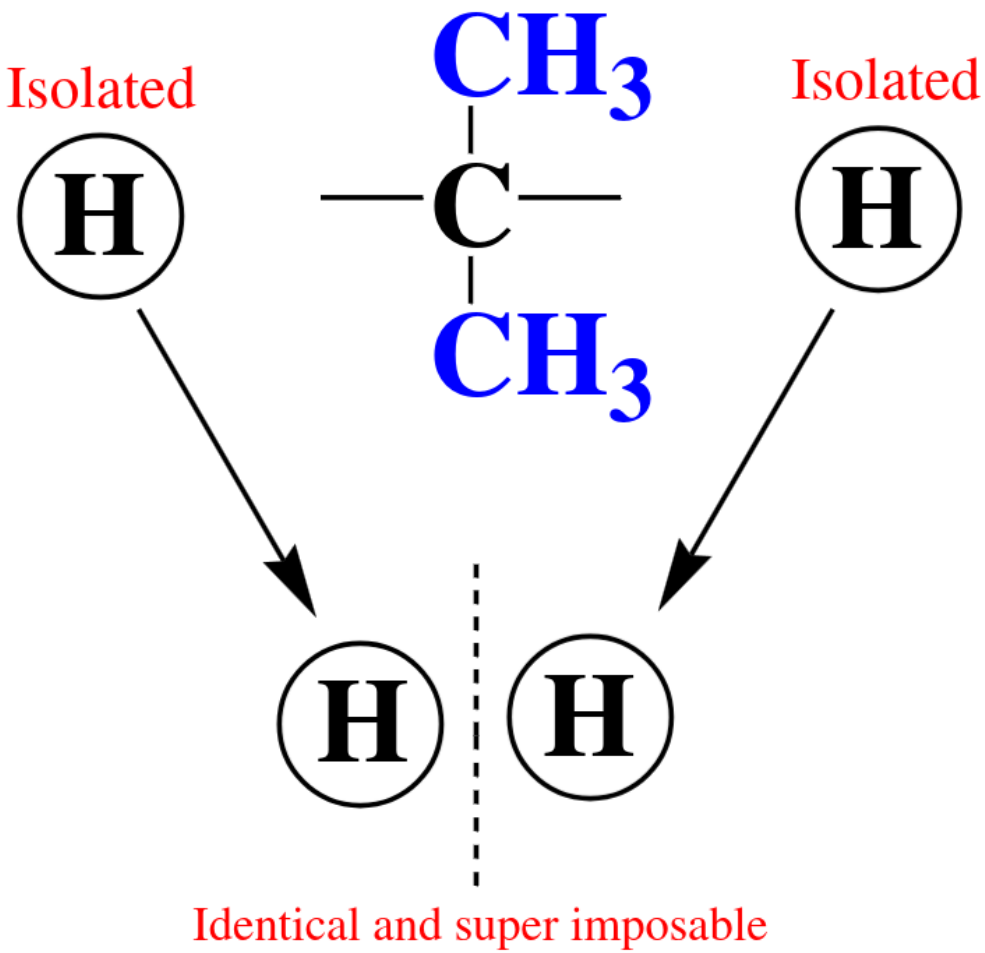
Homo in greek means same

Morph in greek means form



In case of atoms, they must be of same element example two H's or two Br atoms.

If we isolate the two H's, then they are same and super imposable to each other hence they are called homomorphic hydrogen's.



In case of groups, they must have same constitution and configuration. Example two methyl or two Ph groups of same chirality R or S.
They are called homomorphic groups / ligands / atoms.

TOPICITY can be defined as geometrical or sterochemical relationship between homorphic groups / ligands / atoms and structure of the molecule.

Different types of relationships are possible for homorphic ligands / groups / atoms.

1. **Homo topic (Homo-same; topo-place)**

2. **Hetero topic (Hetero-different; topo-place)**

Ligands can not by itself be called homotopic or heterotopic, in order to use this terminologies a comparison with other homomorphic ligand or ligands present either in the same molecule (internal comparison) or in a different molecule (external comparison) is necessary.

Two criteria are used to decide whether the ligands / groups are equivalent or not

1. **Substitution-addition criteria**

2. **Symmetry criteria**

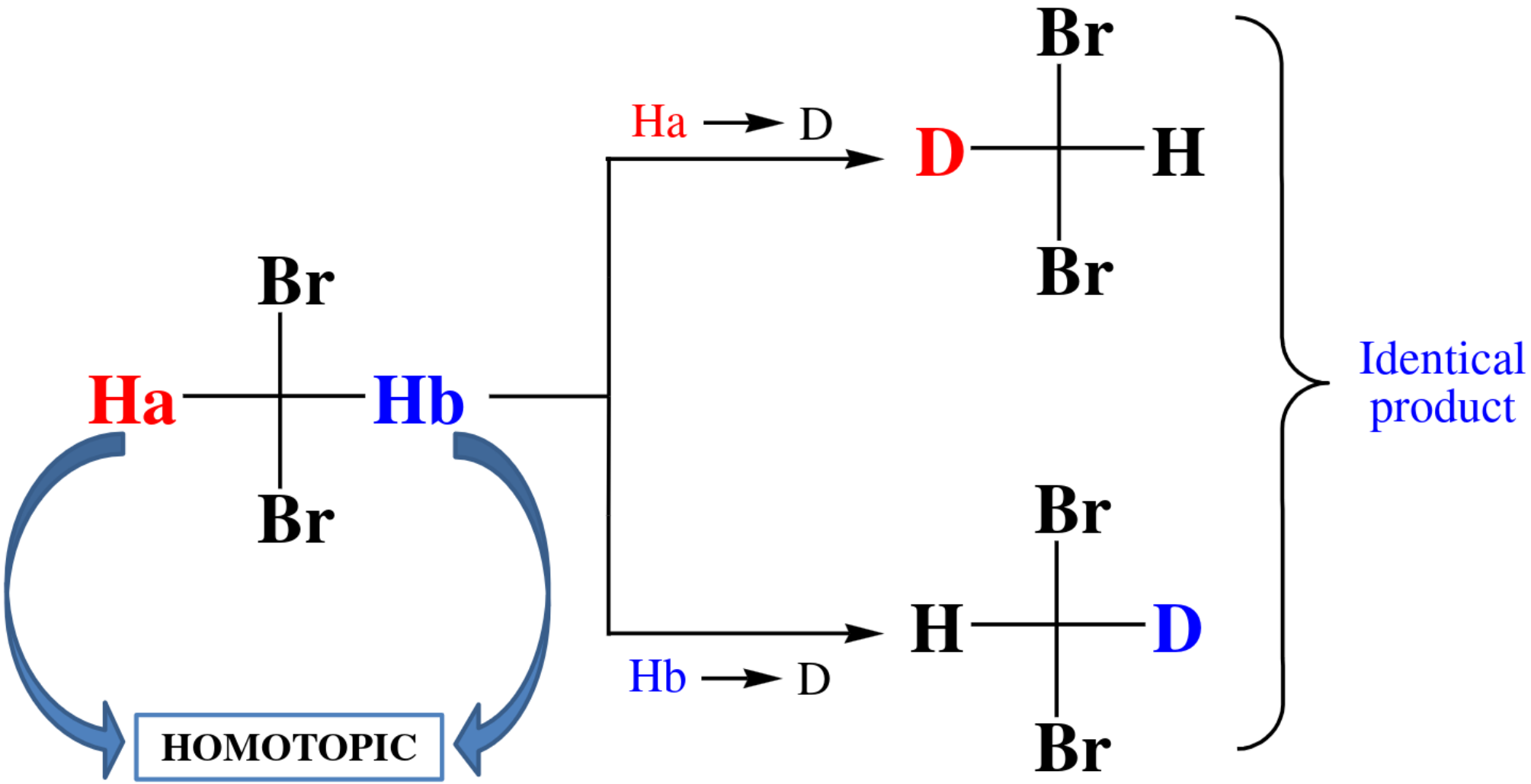
Are employed to determine the topic relationship of homomorphic ligands

1. (a) Homo topic ligands

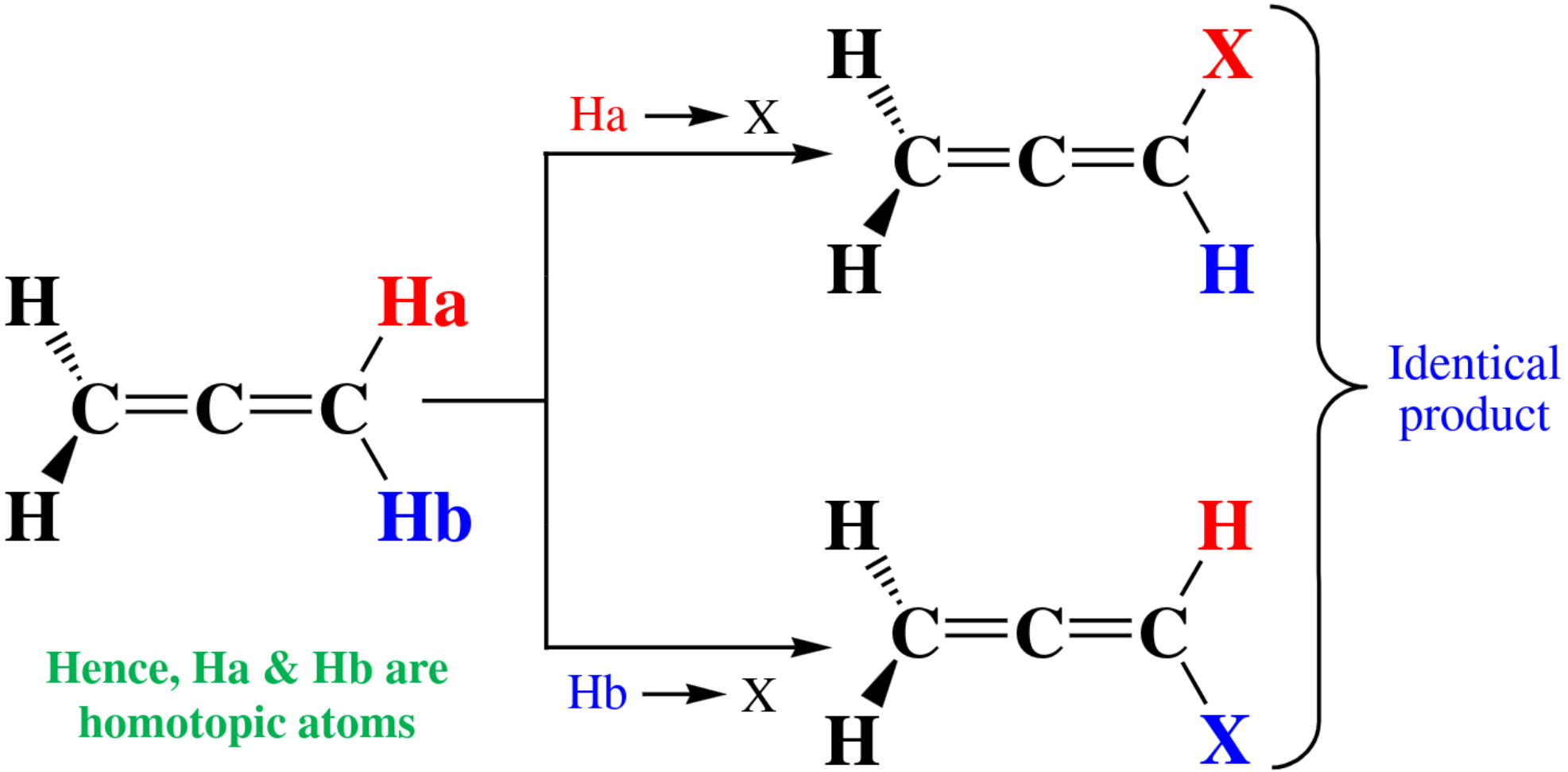
Two or more ligands that are identical when viewed in isolation but individual replacement of two identical ligands by another give rise to identical molecule, then they are called homotopic ligands.

1. Substitution-addition criteria

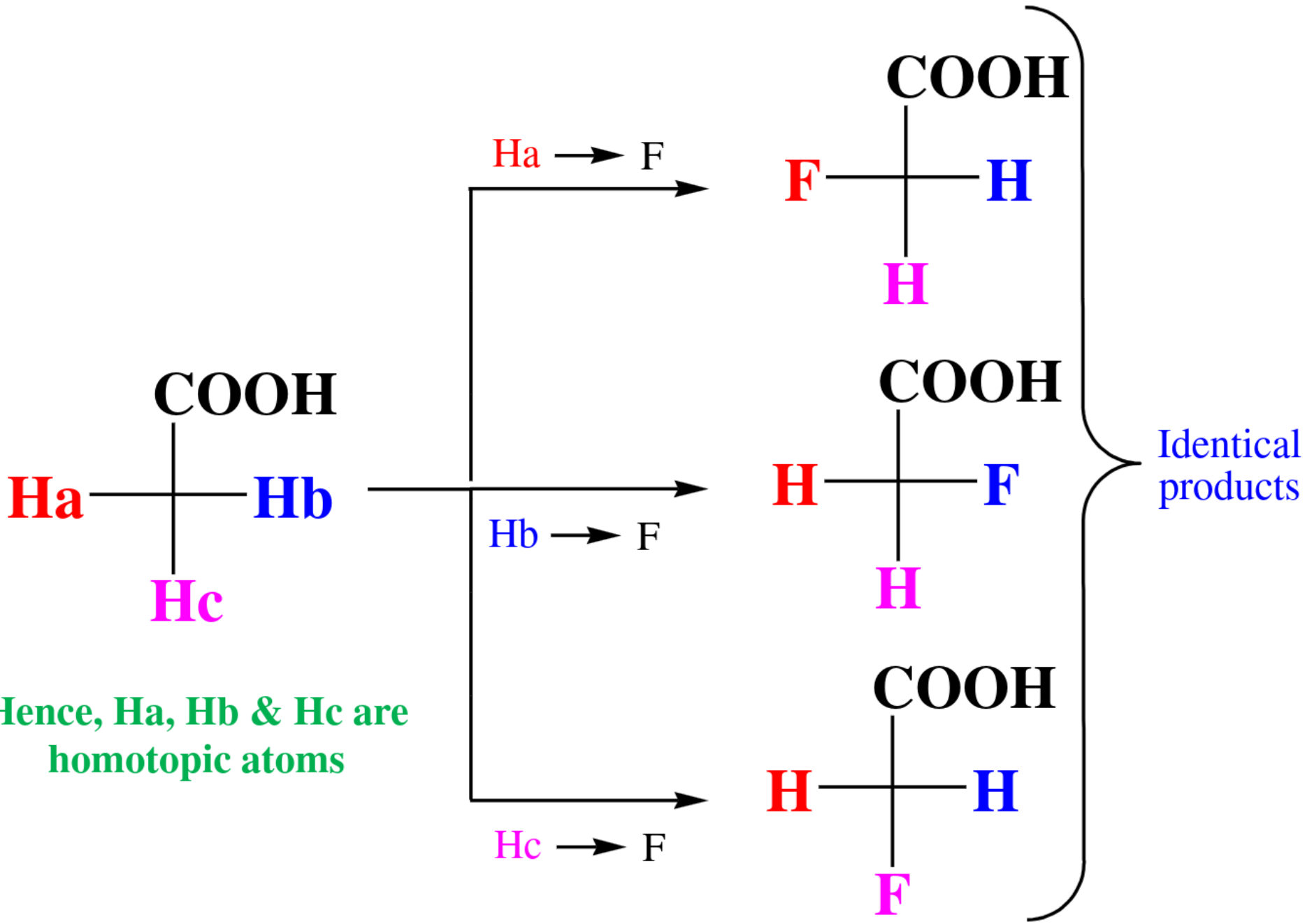
Two homomorphic ligands are homotopic if substitution (replacement) of first one and other by different test ligand leads to homomers or identical product.



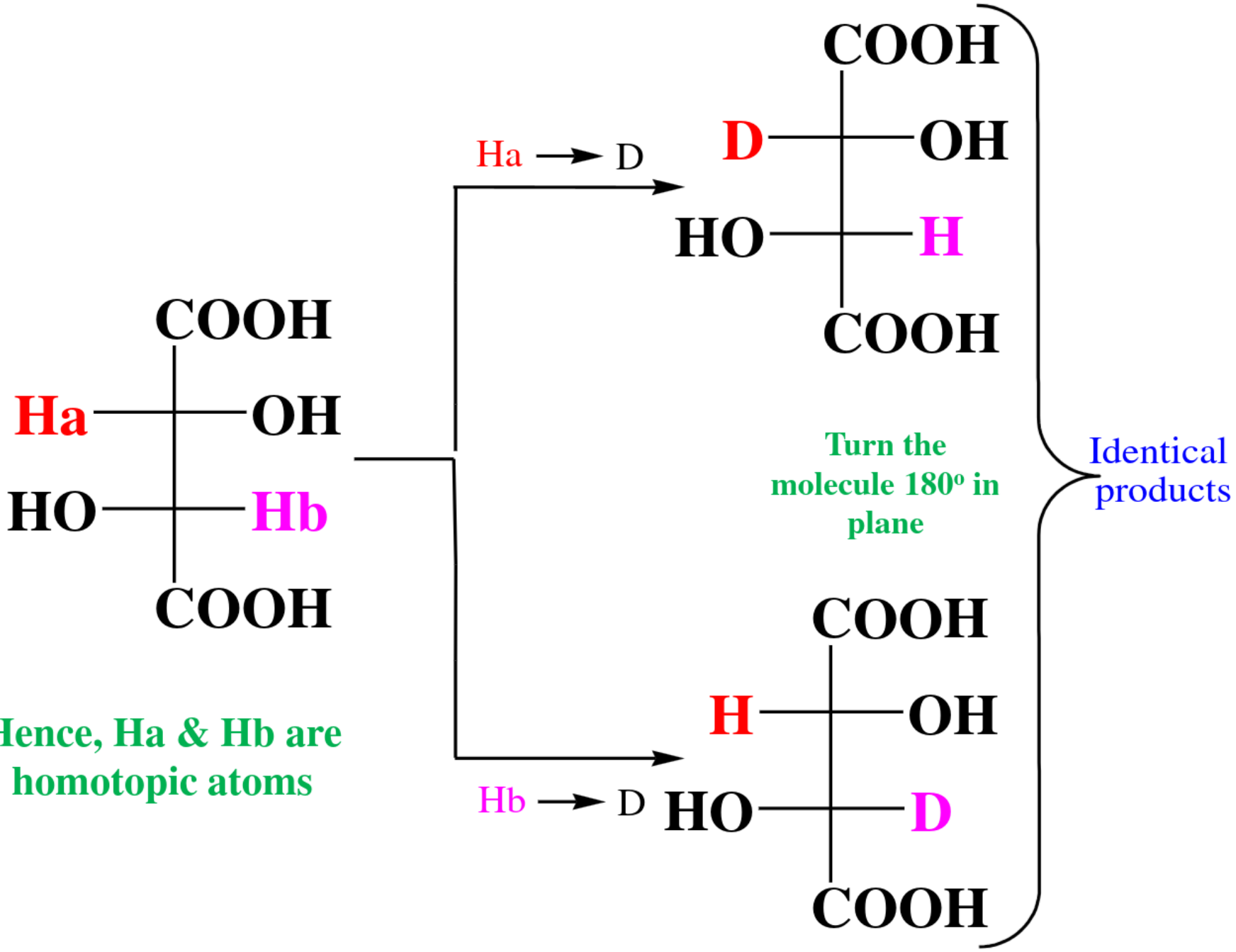
Hence, Ha & Hb are homotopic atoms



Hence, Ha & Hb are homotopic atoms

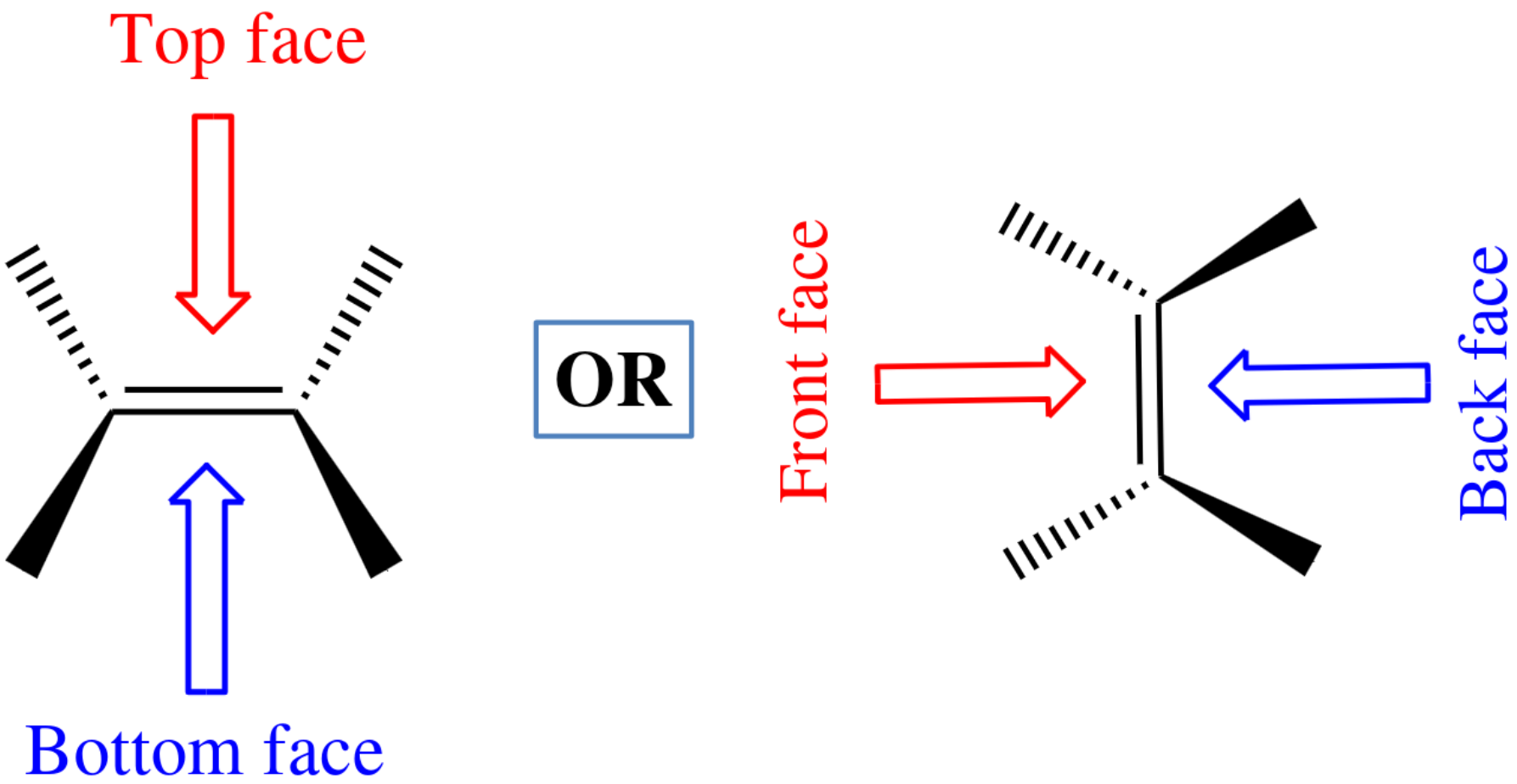


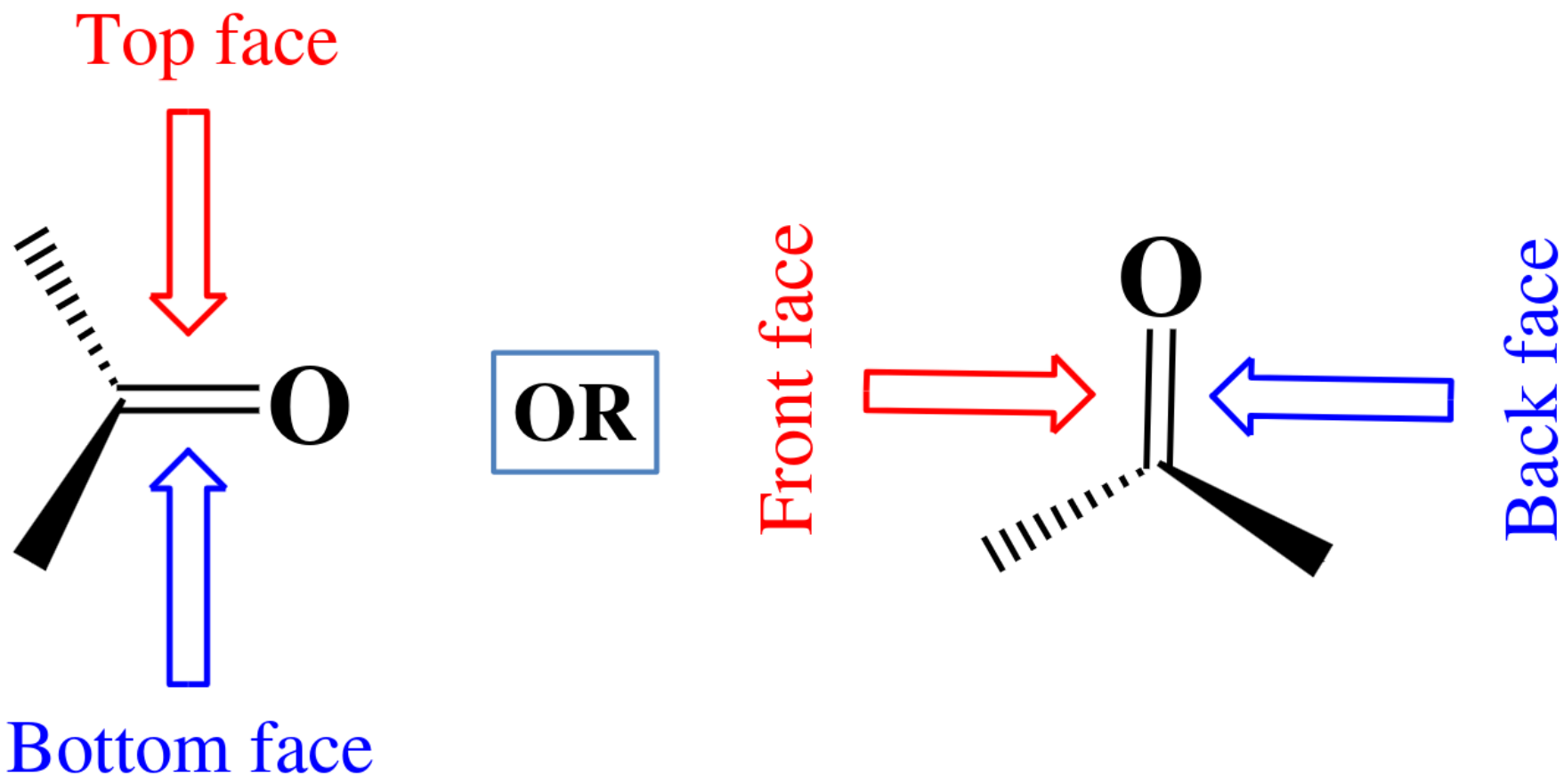
Hence, Ha, Hb & Hc are homotopic atoms

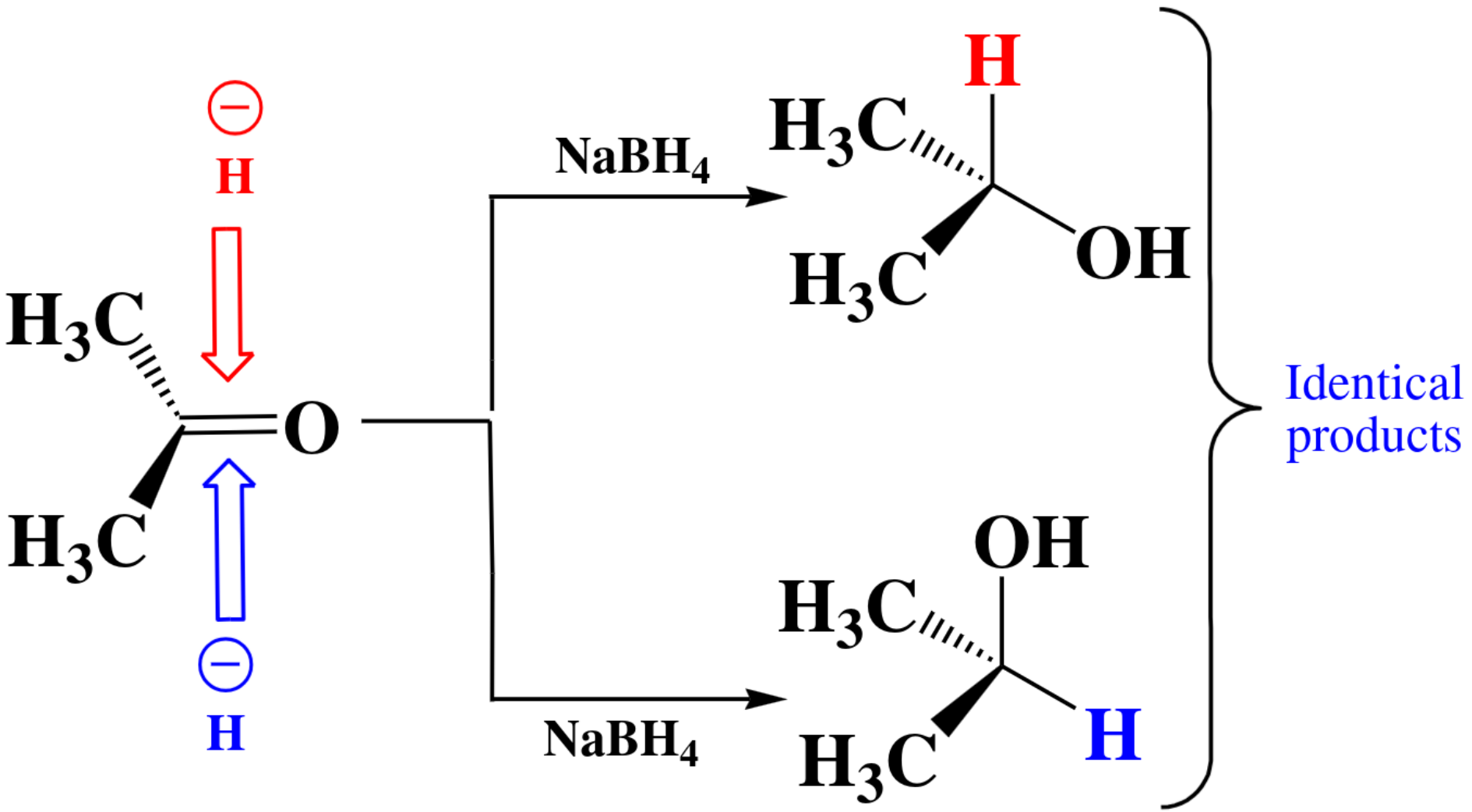

COOH
Ha
OH
HO
Hb
COOH
Ha → D
D
OH
HO
H
COOH
Hb → D
H
OH
HO
D
COOH
Turn the molecule 180° in plane
Identical products
Hence, Ha & Hb are homotopic atoms

1. (b) Homo topic faces

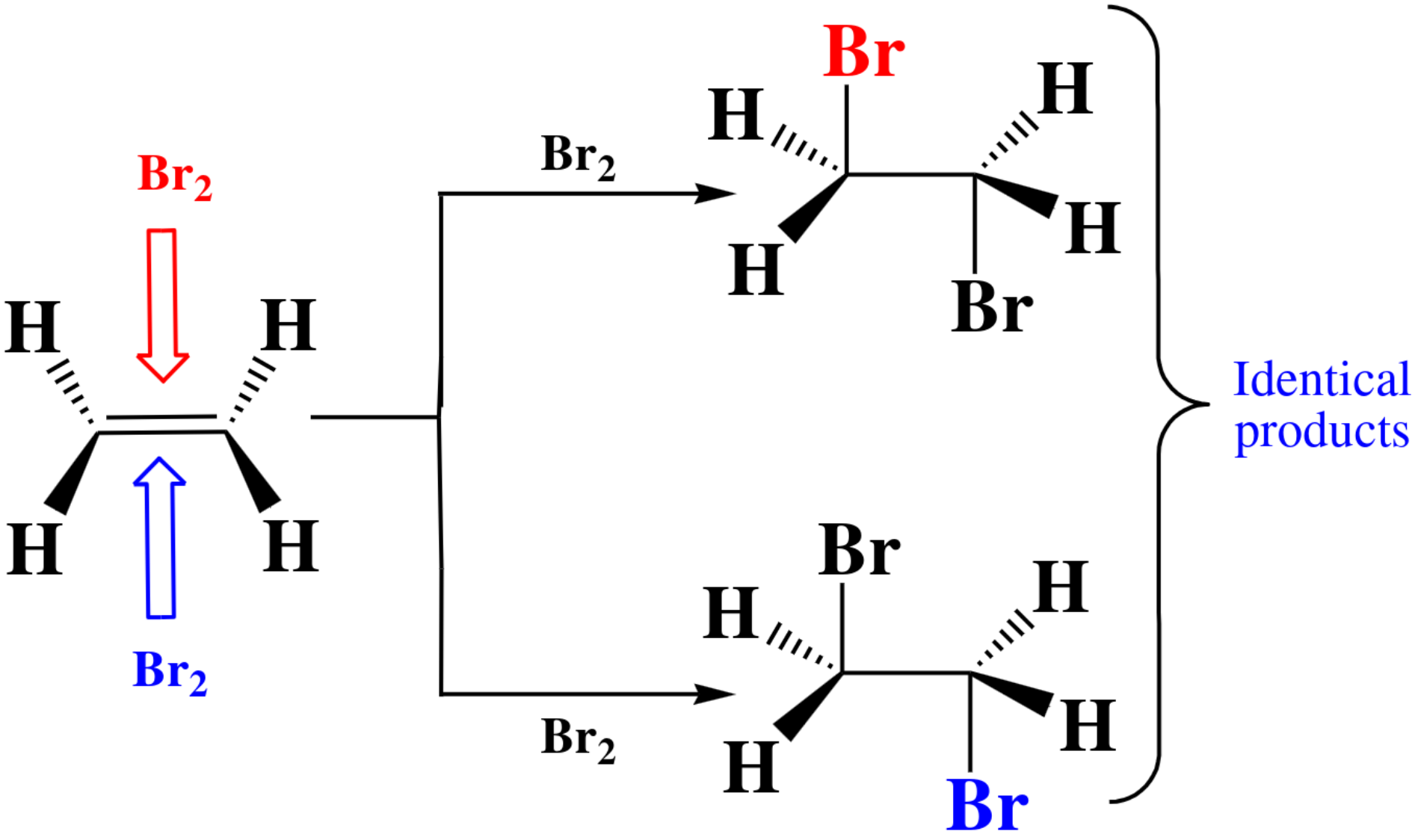
Two faces of a pi system or a double bond are homotopic if addition to either face gives same or identical product.




Top face
O
Bottom face
OR
Front face
O
Back face



Two products are homomers. Hence, acetone has homotopic face

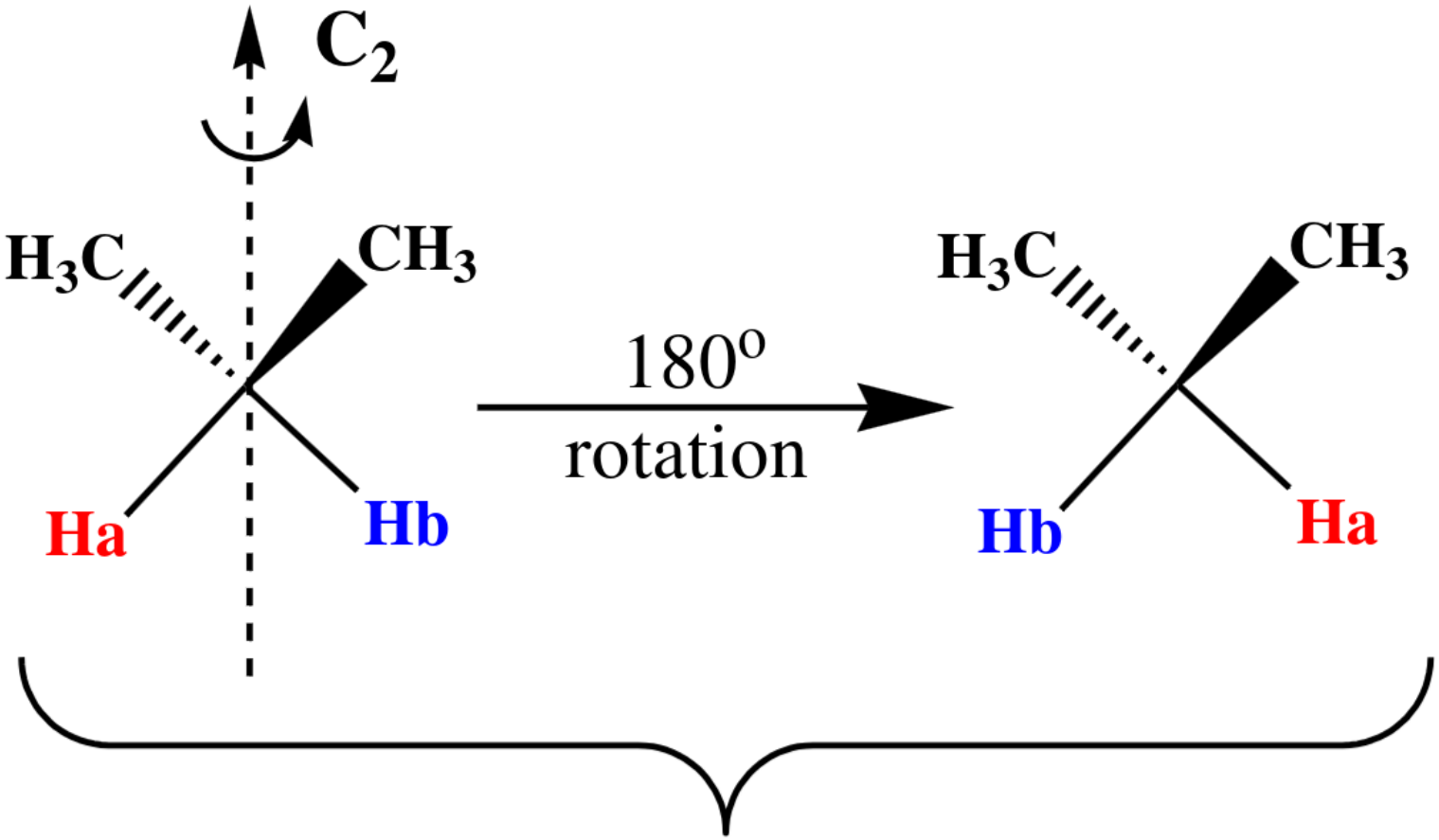


Hence, ethylene has homotopic face

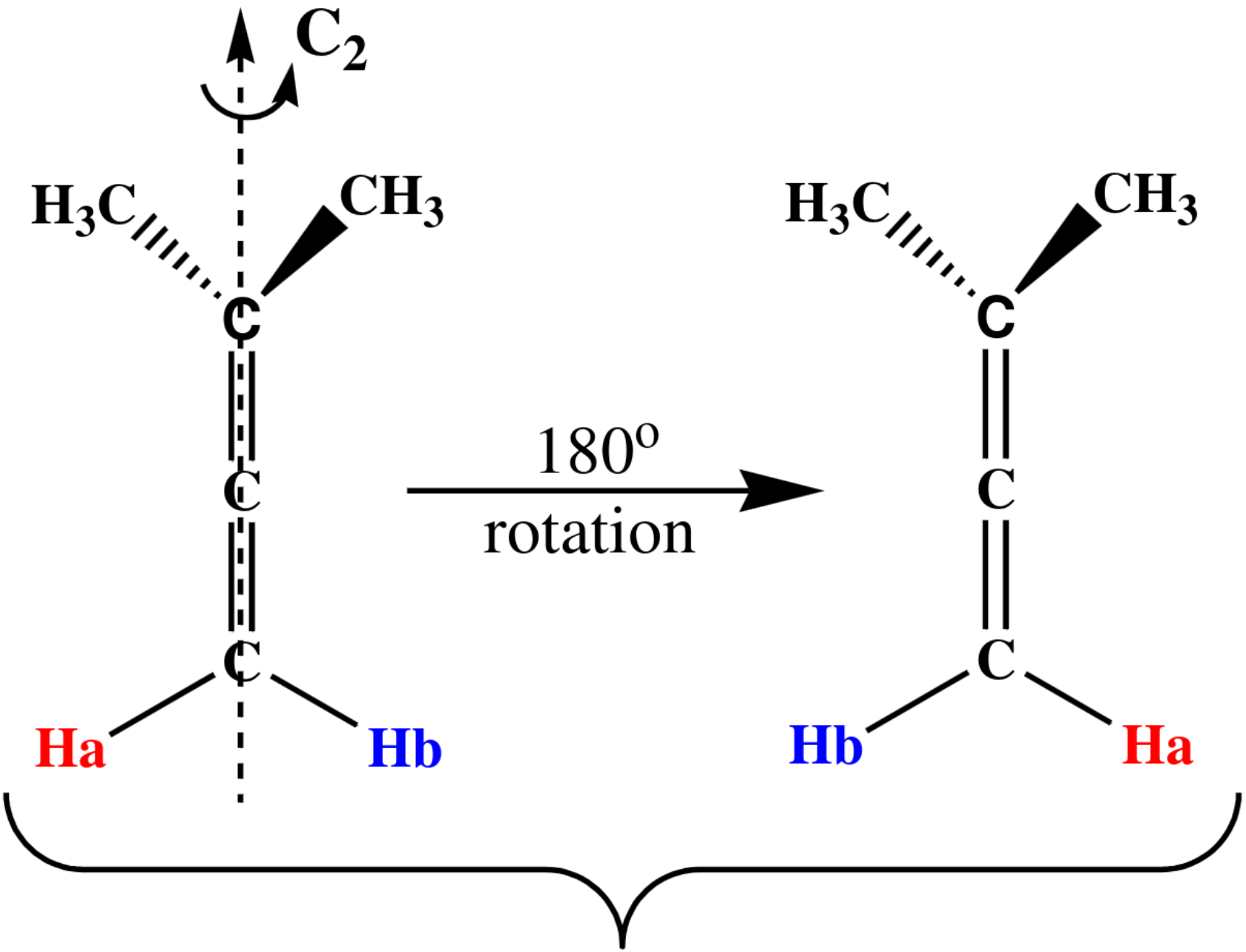
2. Symmetry criteria

2. (a) Homo topic ligands

Two homomorphic ligands are homotopic if they can interchange position by rotation around C_n axis.



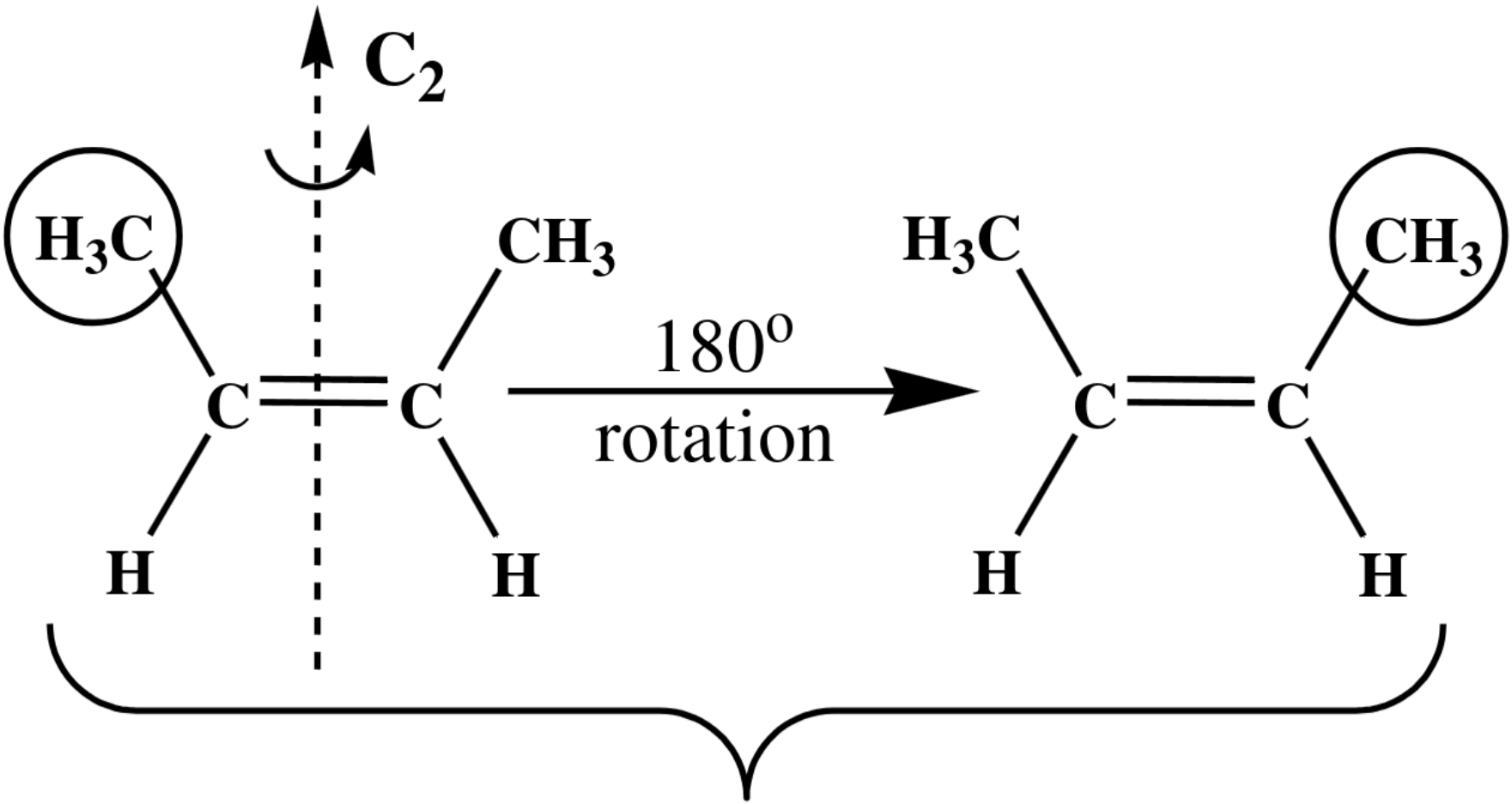
They are identical and hence homotopic ligands



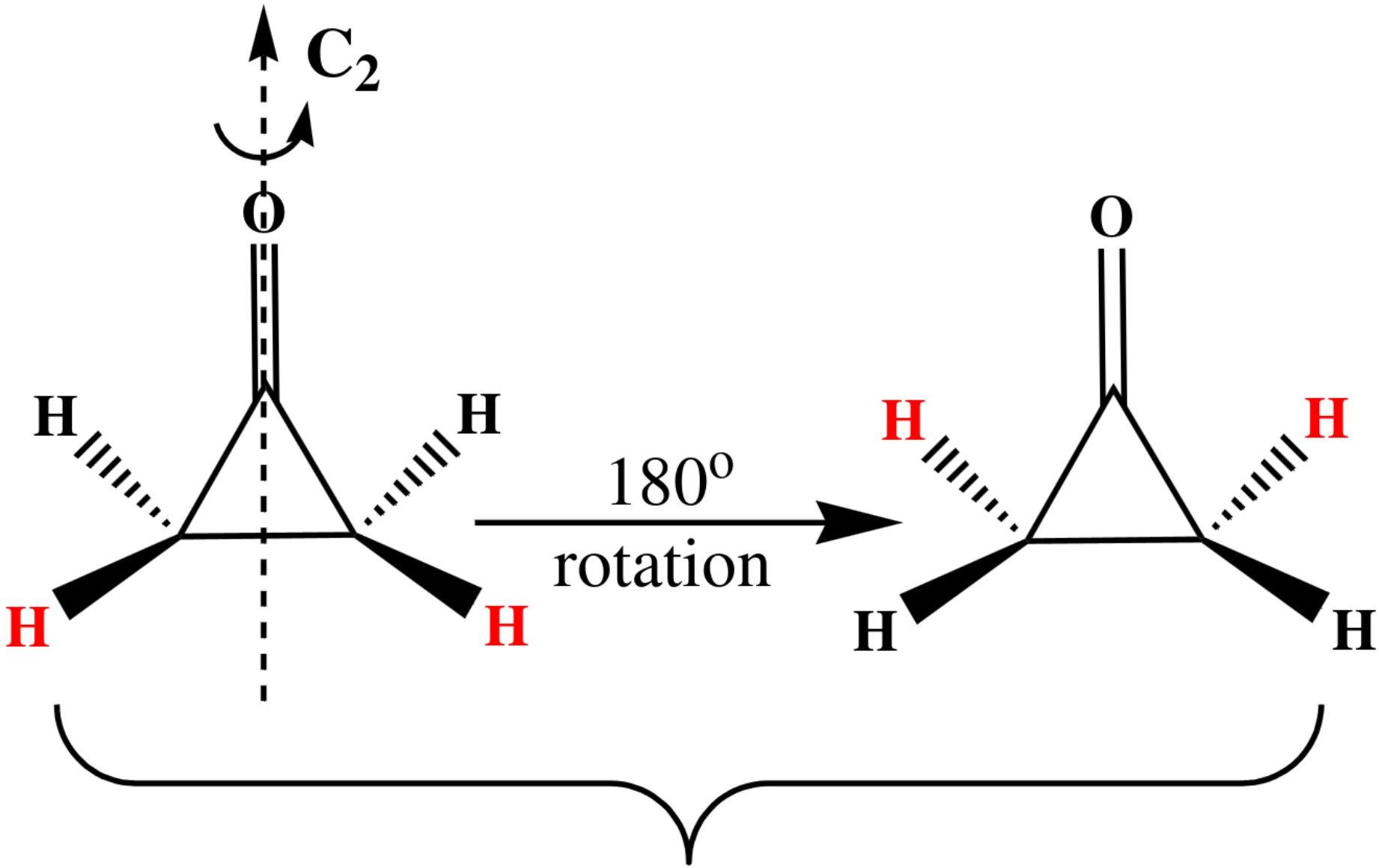
They are identical and hence homotopic ligands

2. (b) Homo topic faces

Two faces of pi system are homotopic if they can interchange face result in same structure by rotation around C_2 axis.



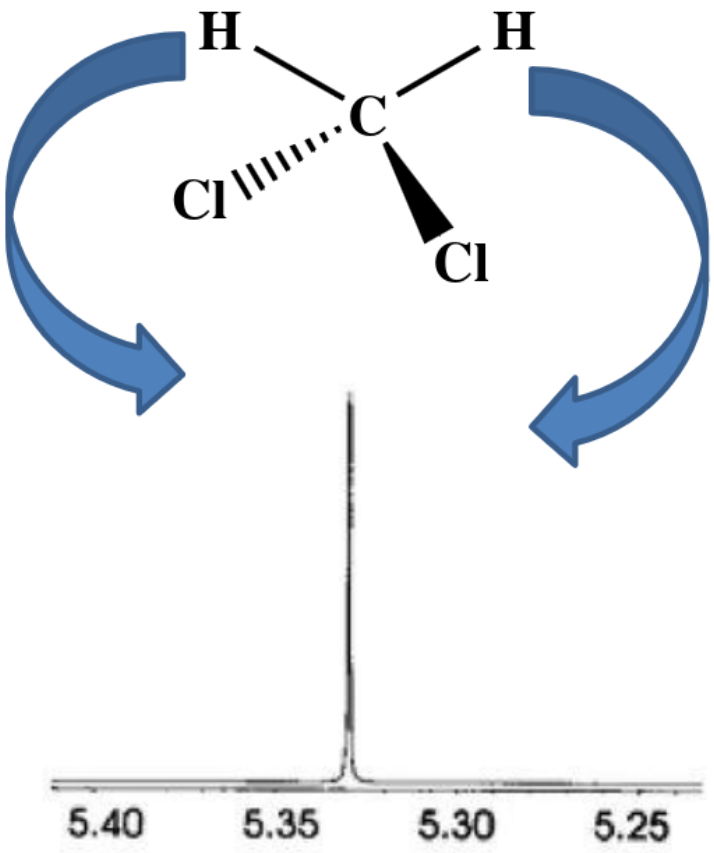
They are identical and hence it has homotopic face

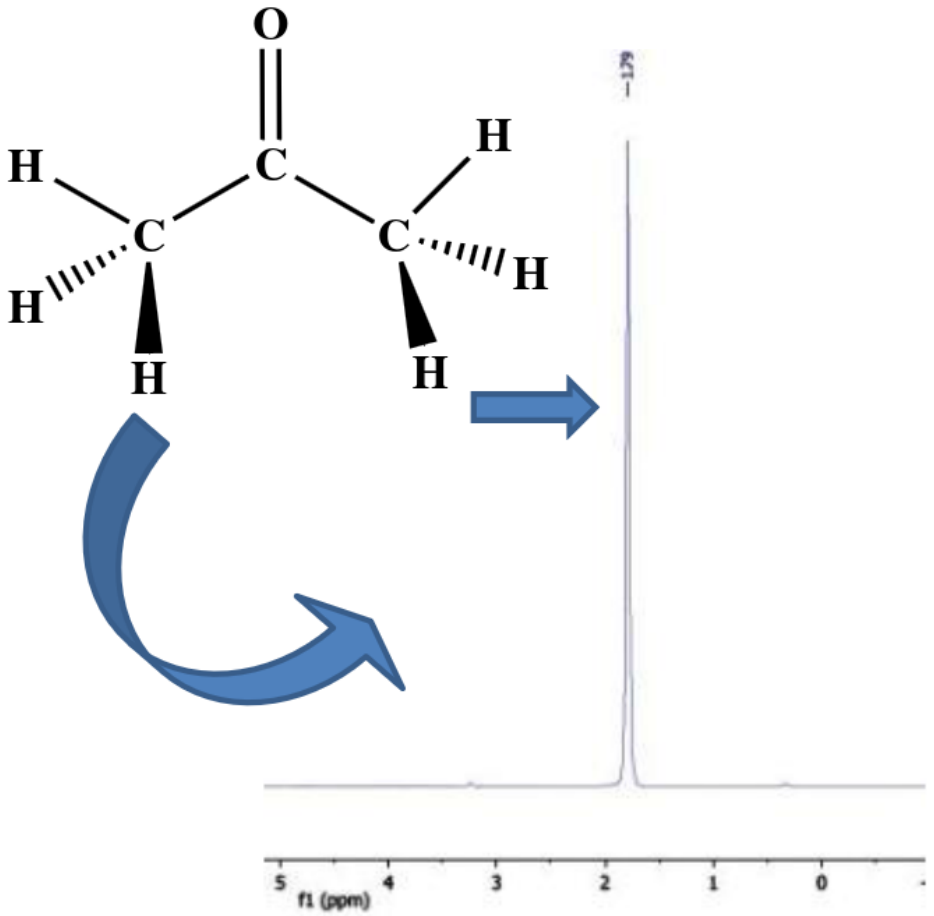


They are identical and hence it has homotopic face

NMR Spectroscopy of Homotopic Hydrogen

If the hydrogen atoms in the molecule are homotopic, then they are chemically equivalent. Hence they will resonate at same chemical shift values.





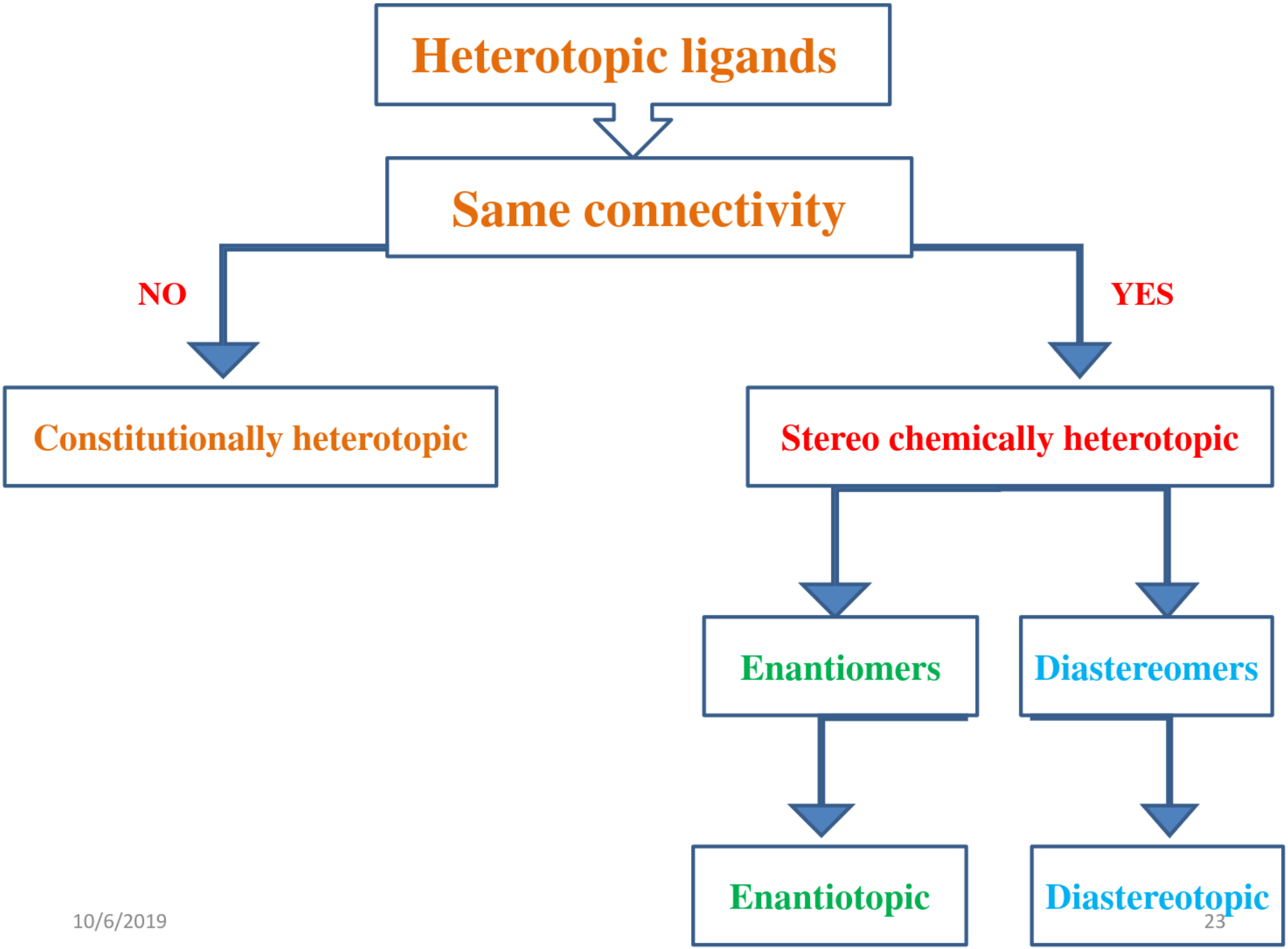
SUMMARY

Between homotopic groups and faces no differentiation is possible either by enzyme or by NMR or by human being because they are homomers or identical.

Topicity	Substitution-addition criteria	Symmetry criteria	Reactivity
Homotopic groups and faces	Homomers / Identical	C_n or C_2	No differentiation possible

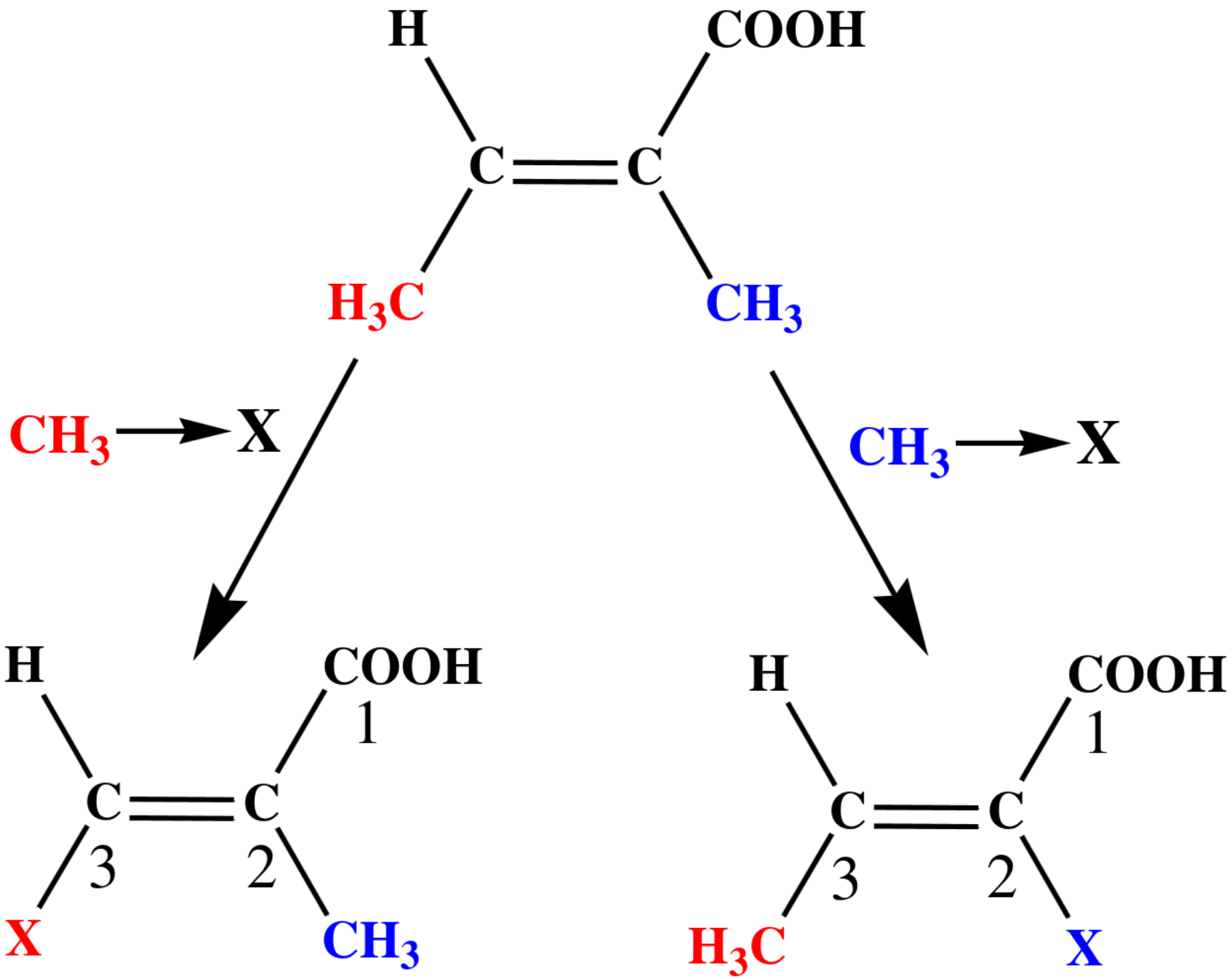
2. Hetero topic ligands

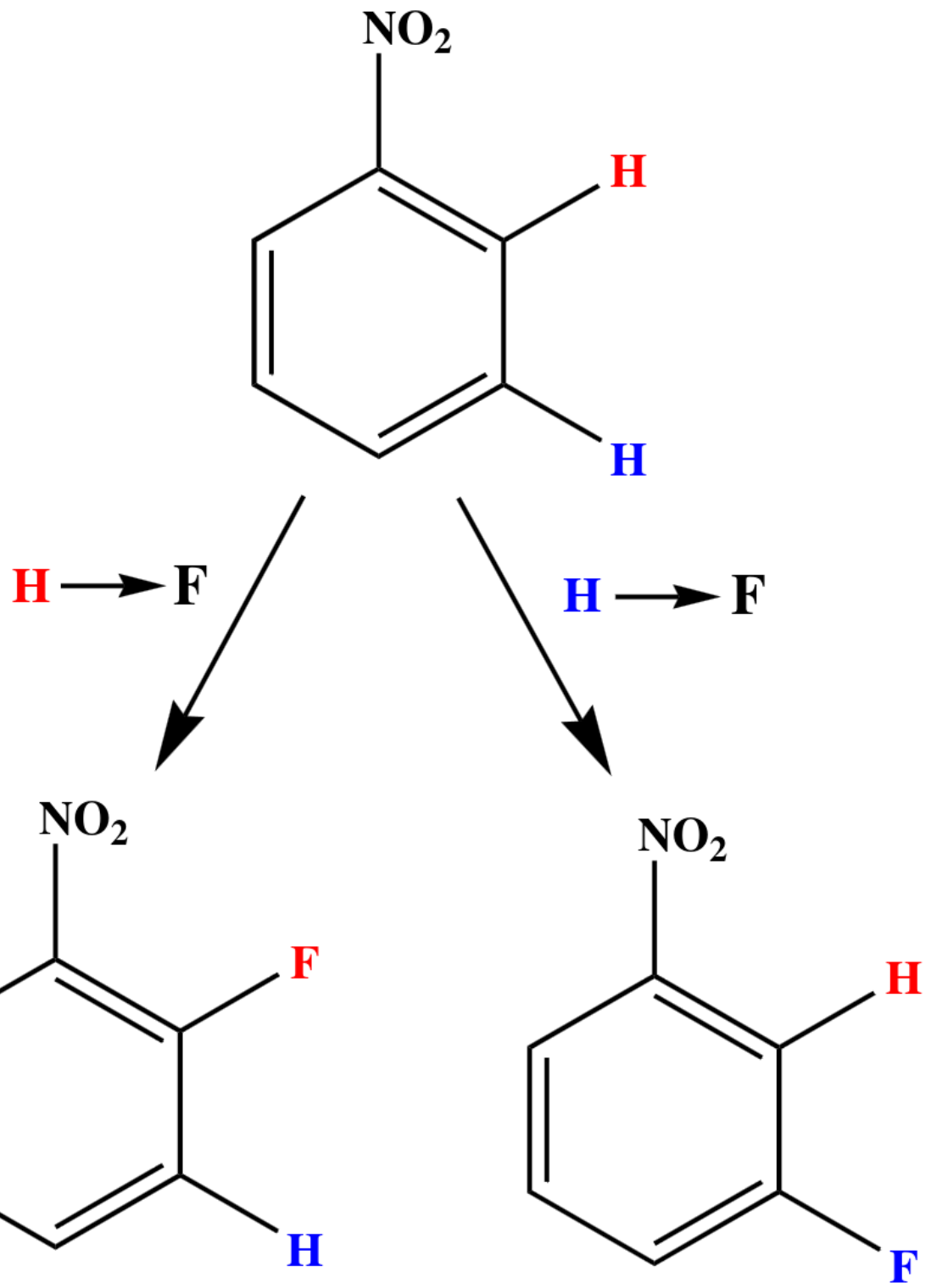
Two or more ligands that are identical when viewed in isolation but individual replacement of two identical ligands by another ligand give rise to two structurally different (isomeric) molecule, then they are called heterotopic ligands.


Heterotopic ligands
Same connectivity
NO
YES
Constitutionally heterotopic
Stereo chemically heterotopic
Enantiomers
Diastereomers
Enantiotopic
Diastereotopic

Constitutionally Hetero topic ligands

Two or more ligands in a molecule that are identical on individual replacement by another ligand give rise to two molecule that constitutional isomers of each other, then the original two ligands are said to be constitutionally heterotopic ligands.


H
COOH
C
C
H3C
CH3
CH3
X
CH3
X
H
COOH
1
C
C
3
2
X
CH3
H
COOH
1
C
C
3
2
H3C
X


NO2
H
H
H → F
H → F
NO2
F
H
NO2
H
F

Stereo chemically heterotopic

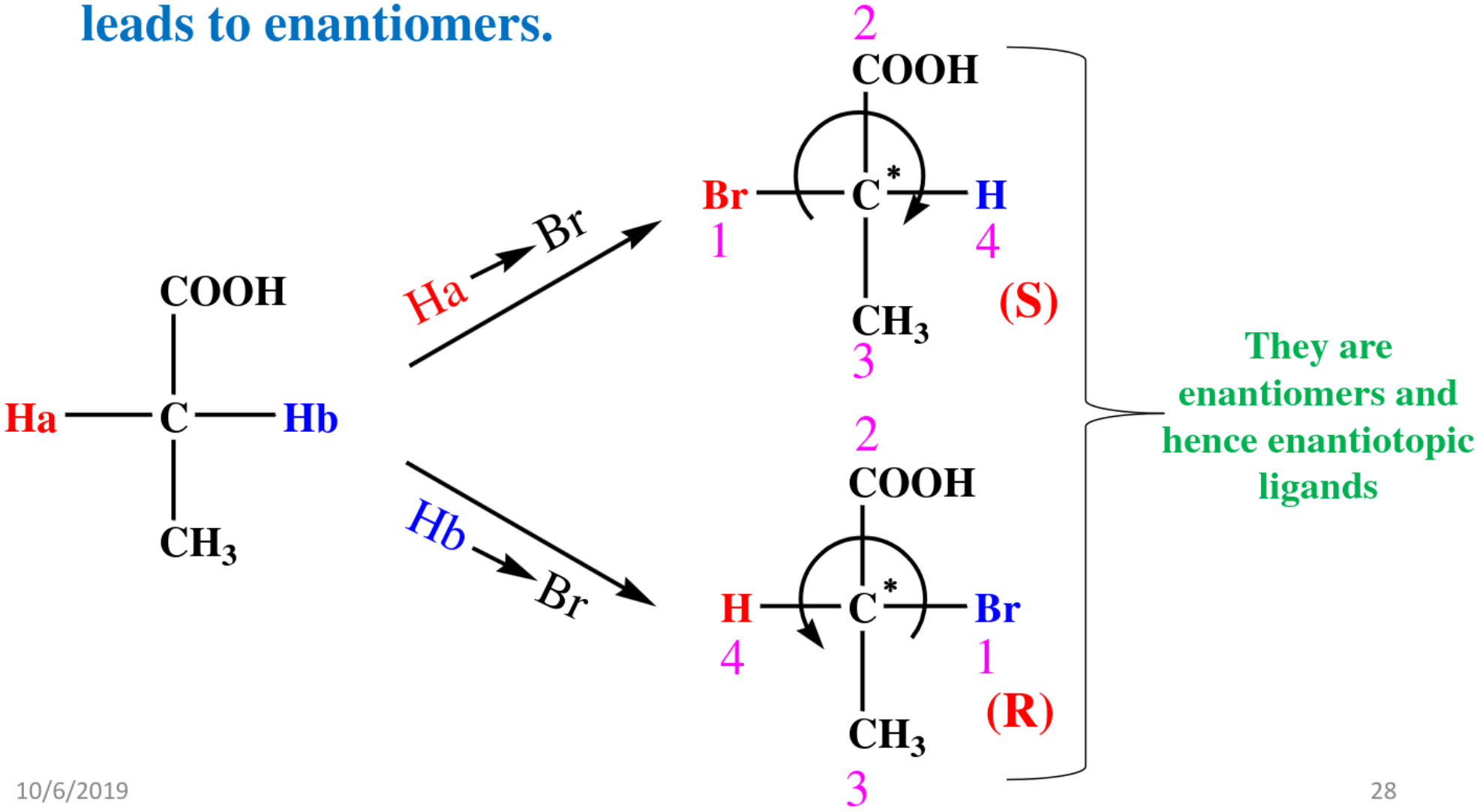
Two or more ligands in a molecule that are identical on individual replacement by another ligand give rise to two molecule that are enantiomers / super imposable mirror images of each other, then the original two ligands are said to be enantiotopic ligands.

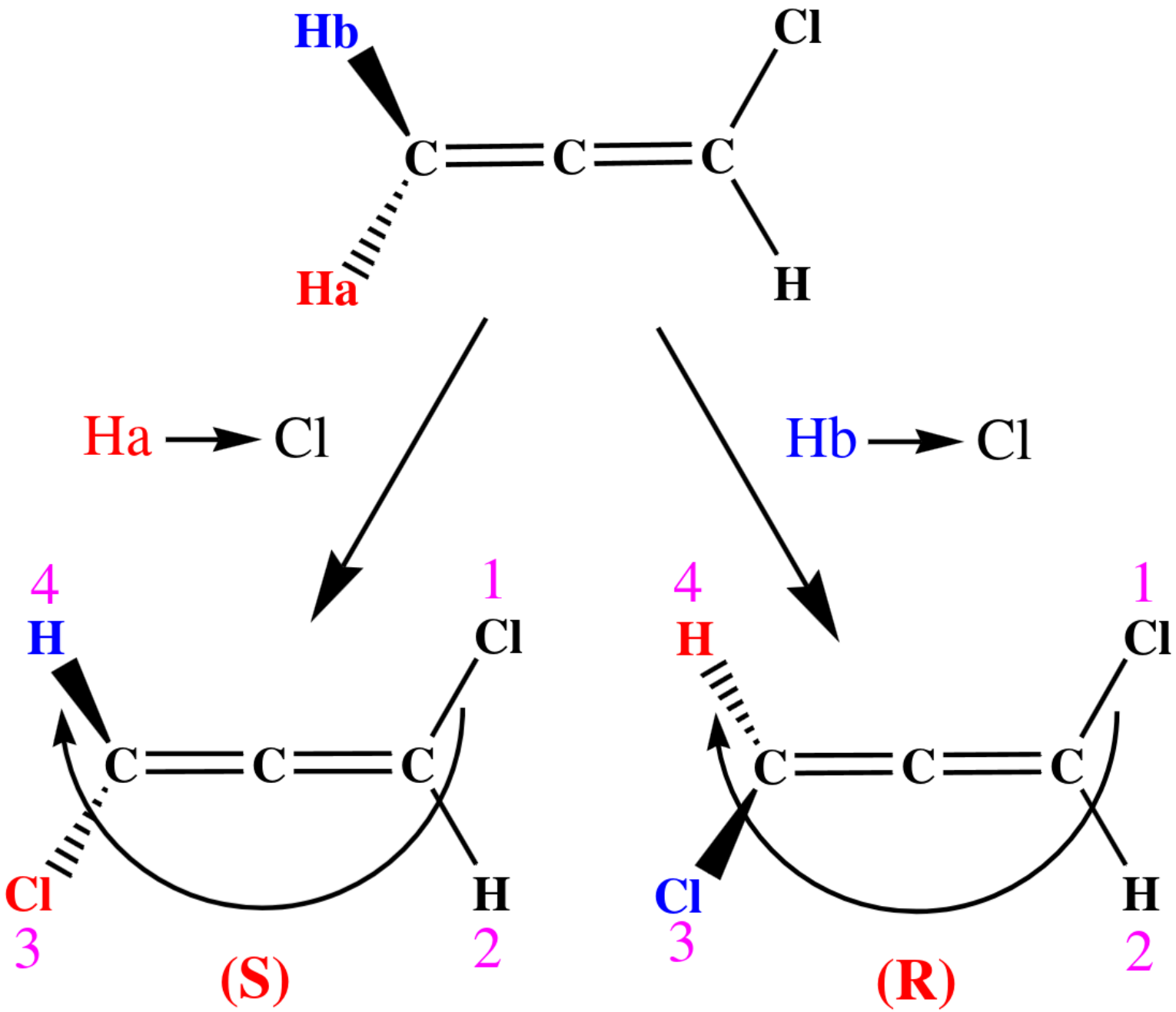
Two or more ligands in a molecule that are identical on individual replacement by another ligand give rise to two molecule that are diastereomers / non super imposable not mirror images of each other, then the original two ligands are said to be diastereotopic ligands.

(a) Enantiotopic ligands

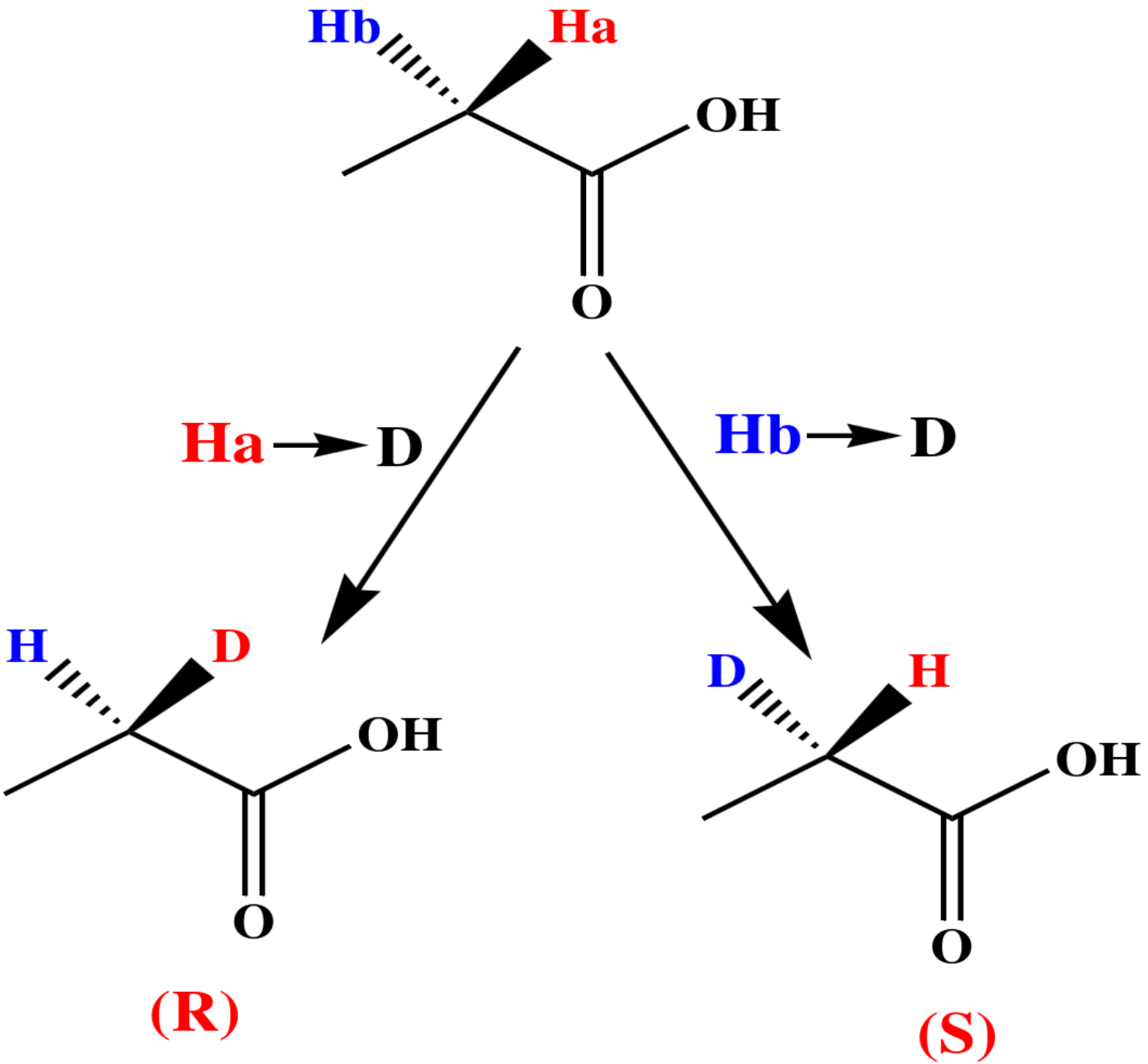
1. Substitution-addition criteria

Two homomorphic ligands are enantiotopic if substitution (replacement) of first one and other by different test ligand leads to enantiomers.

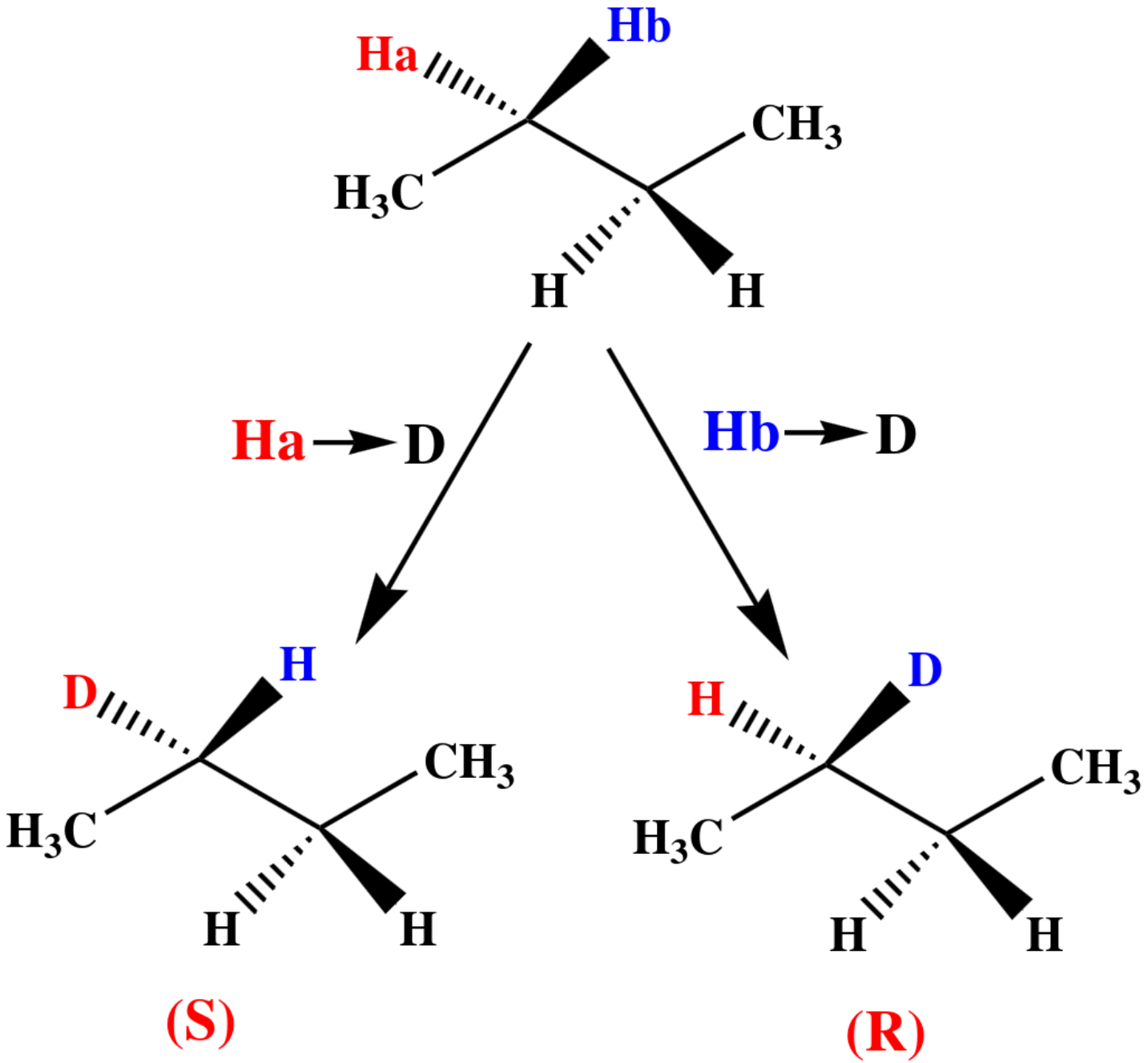




They are enantiomers and hence enantiotopic ligands



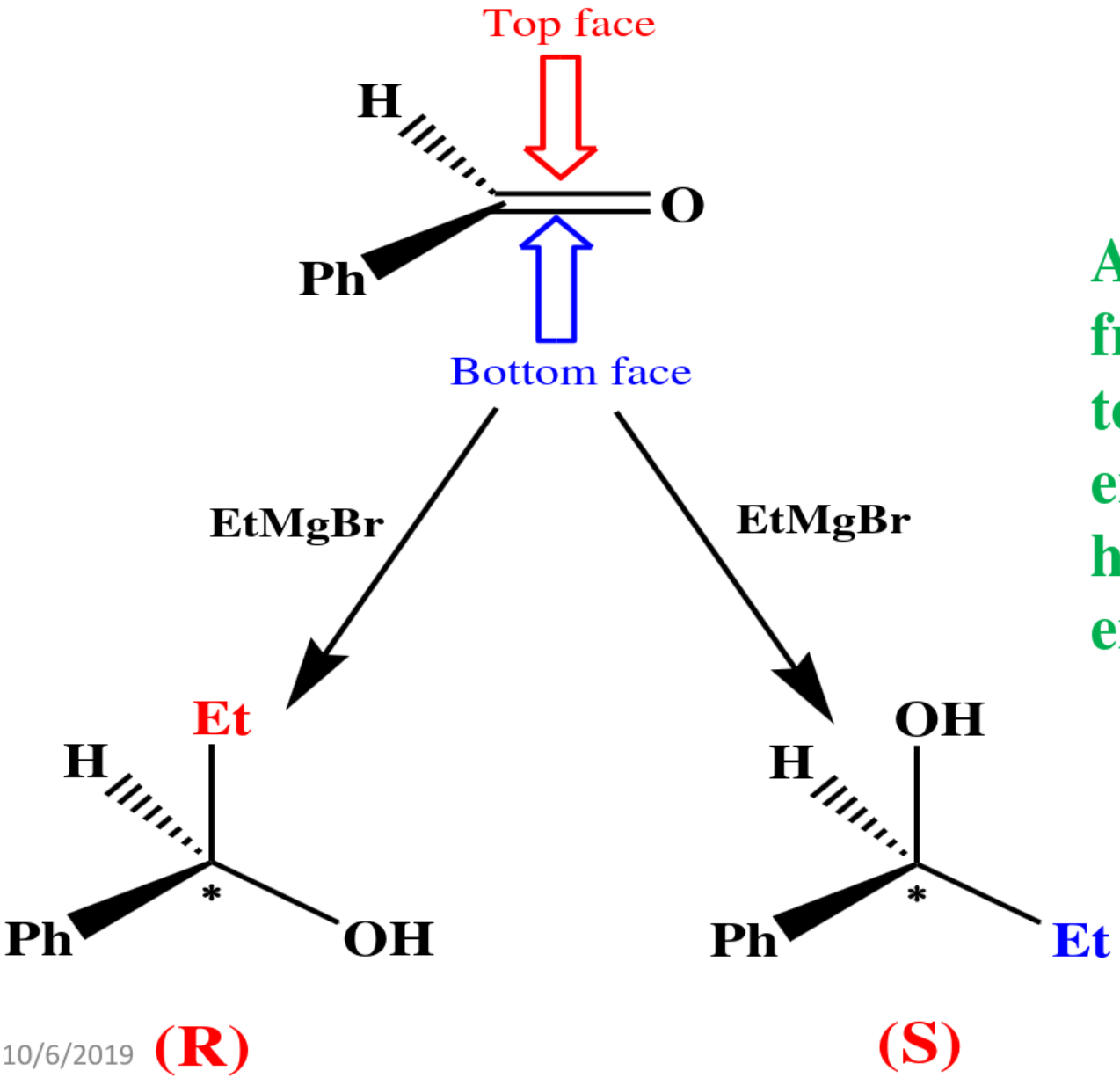
They are enantiomers and hence Ha & Hb are enantiotopic ligands



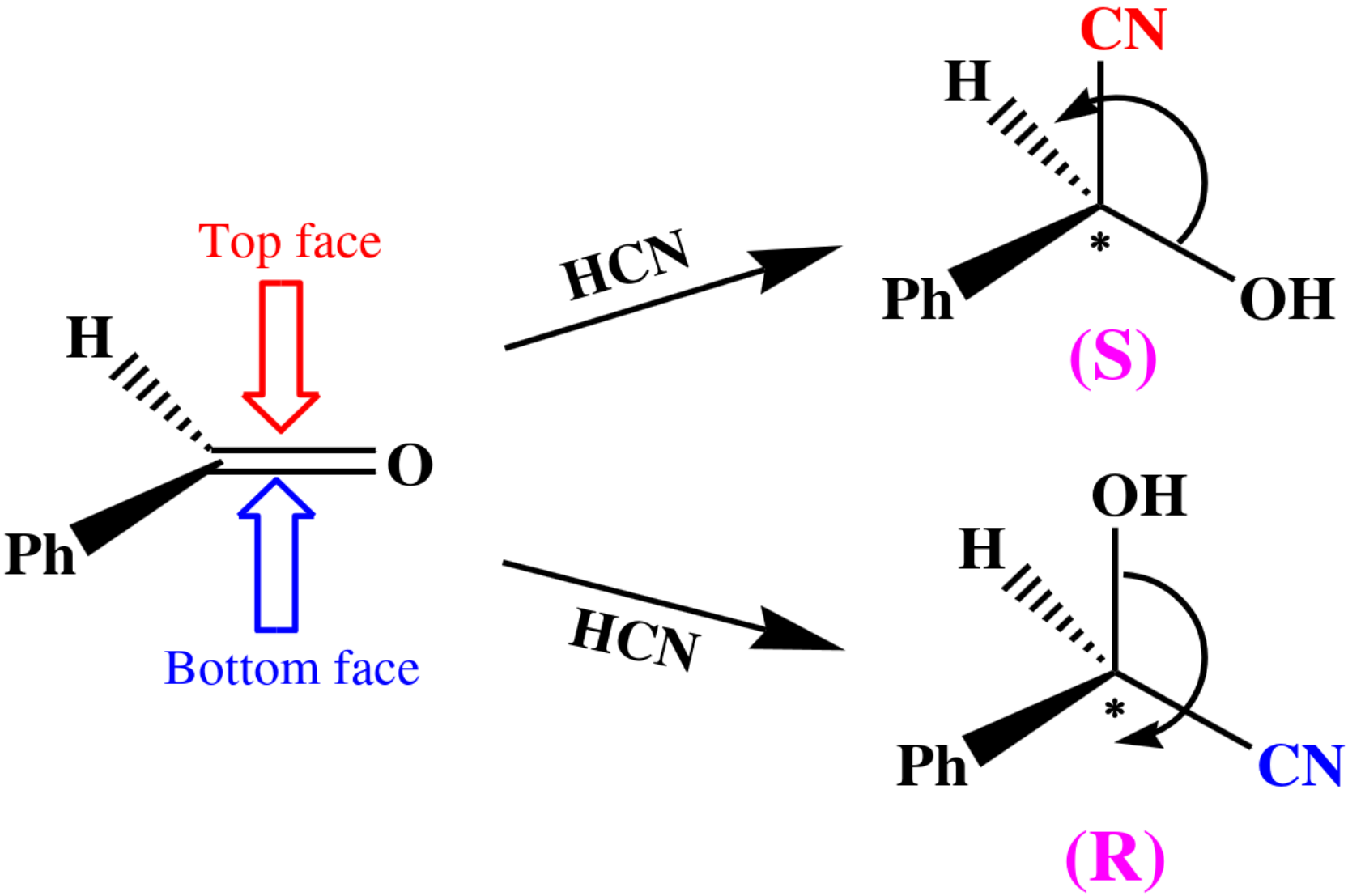
They are enantiomers and hence Ha & Hb are enantiotopic ligands

(b) Enantiotopic faces

Two faces of a pi system or a double bond are enantiotopic if addition to either face gives enantiomeric product.



Addition reaction from either face leads to formation of enantiomers and hence two faces are enantiotopic



Addition reaction from either face leads to formation of enantiomers and hence two faces are enantiotopic

Molecules having stereo heterotopic ligands (enantiotopic) exhibit prostereoisomerism or prochirality

Prostereoisomerism or Prochirality

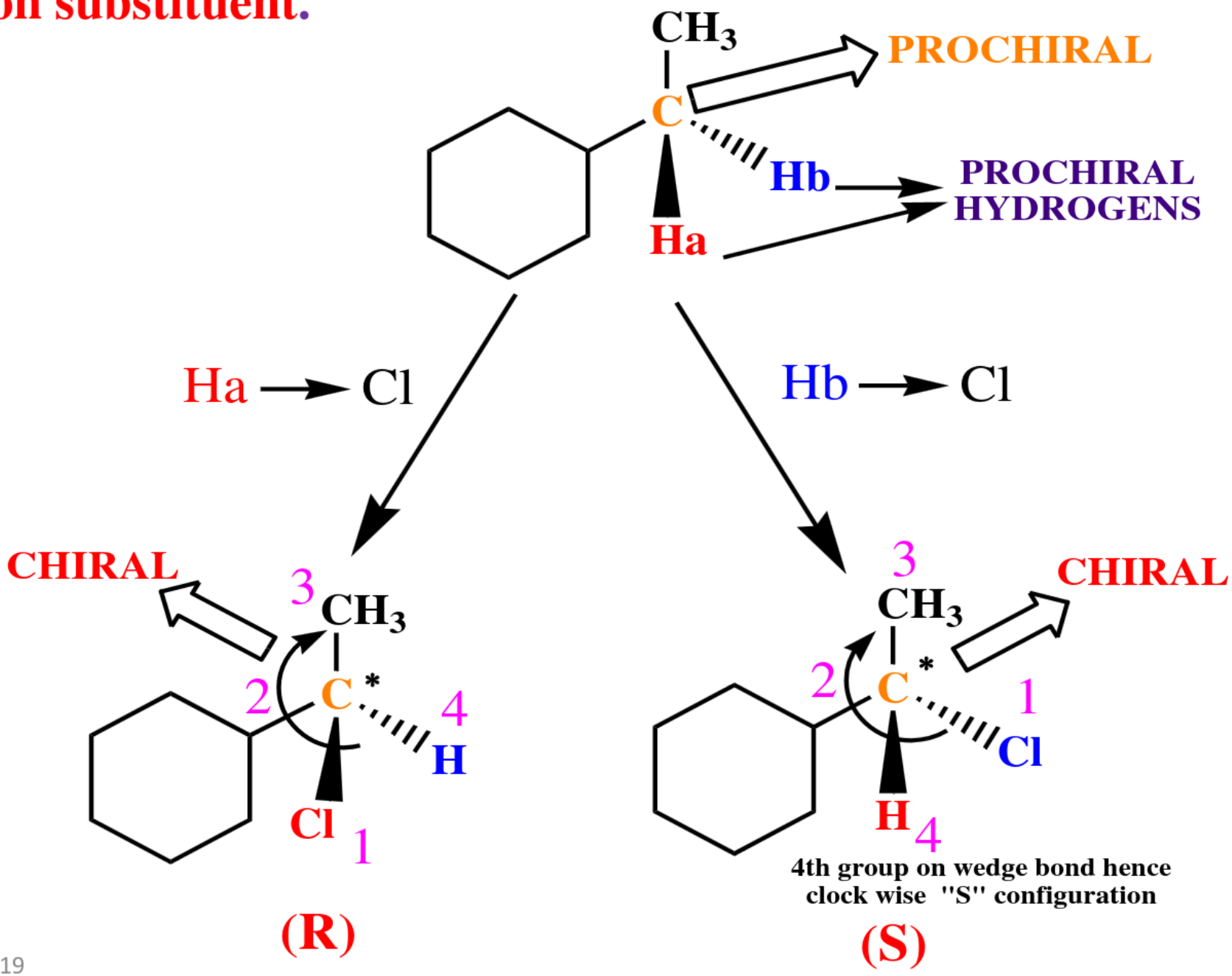
Prochiral molecules are those which are achiral can be converted into chiral molecule in a single step.

Prochirality may be the result of substitution reaction of Sp^3 carbon substituent (usually hydrogen) with other substituent results in chiral center.

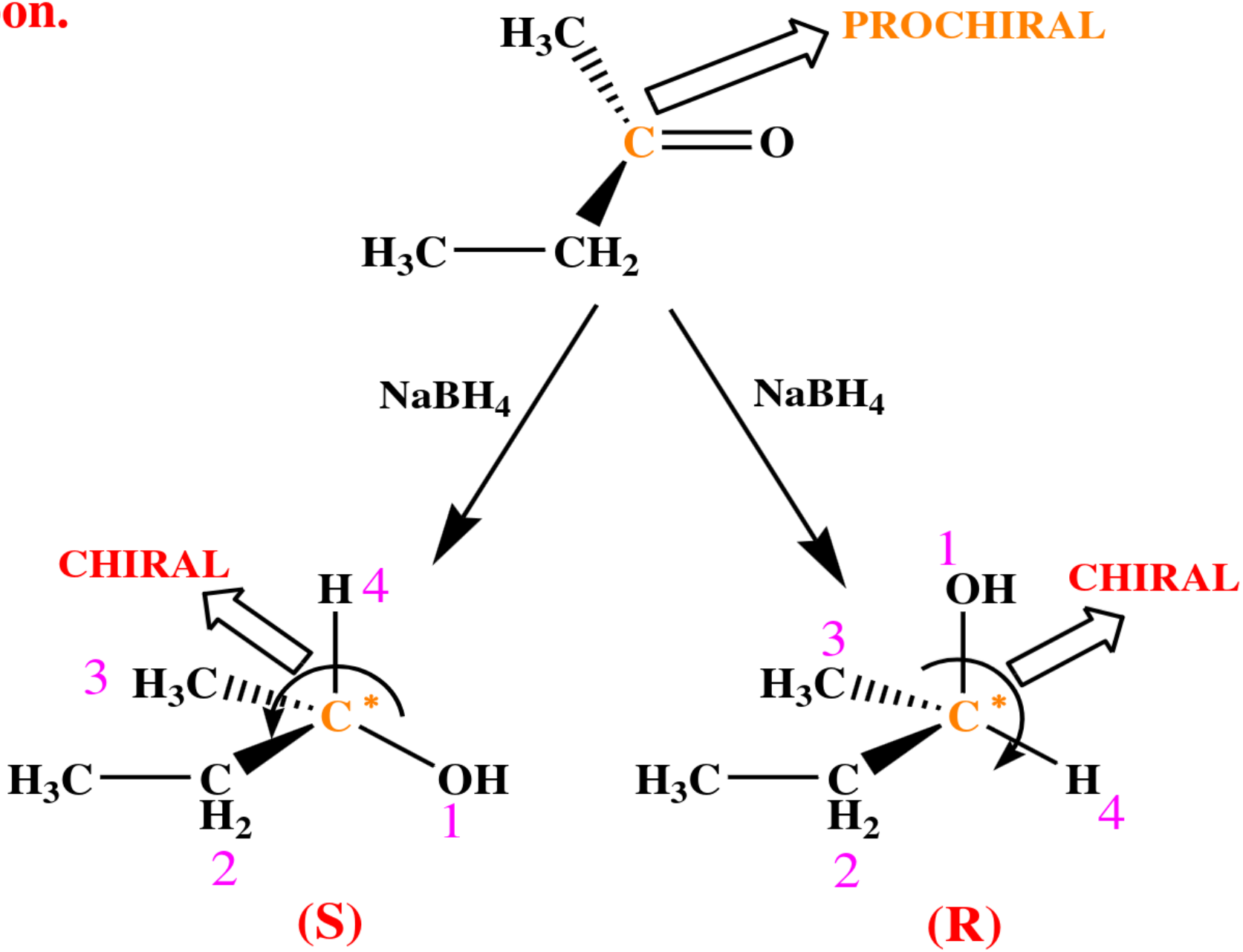
OR

Prochirality may be the result of addition reaction of an Sp^2 carbon to a chiral Sp^3 carbon with nucleophile.

Prochirality may be the result of substitution reaction of Sp^3 carbon substituent.



Prochirality may be the result of addition reaction of an Sp^2 carbon.

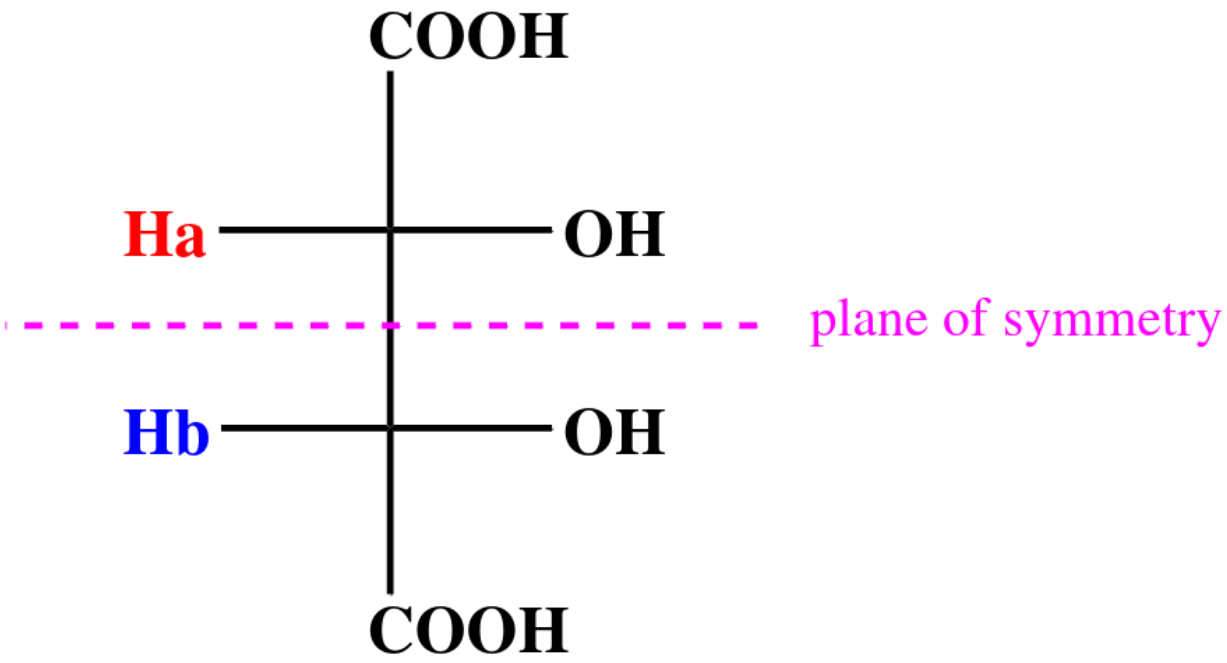


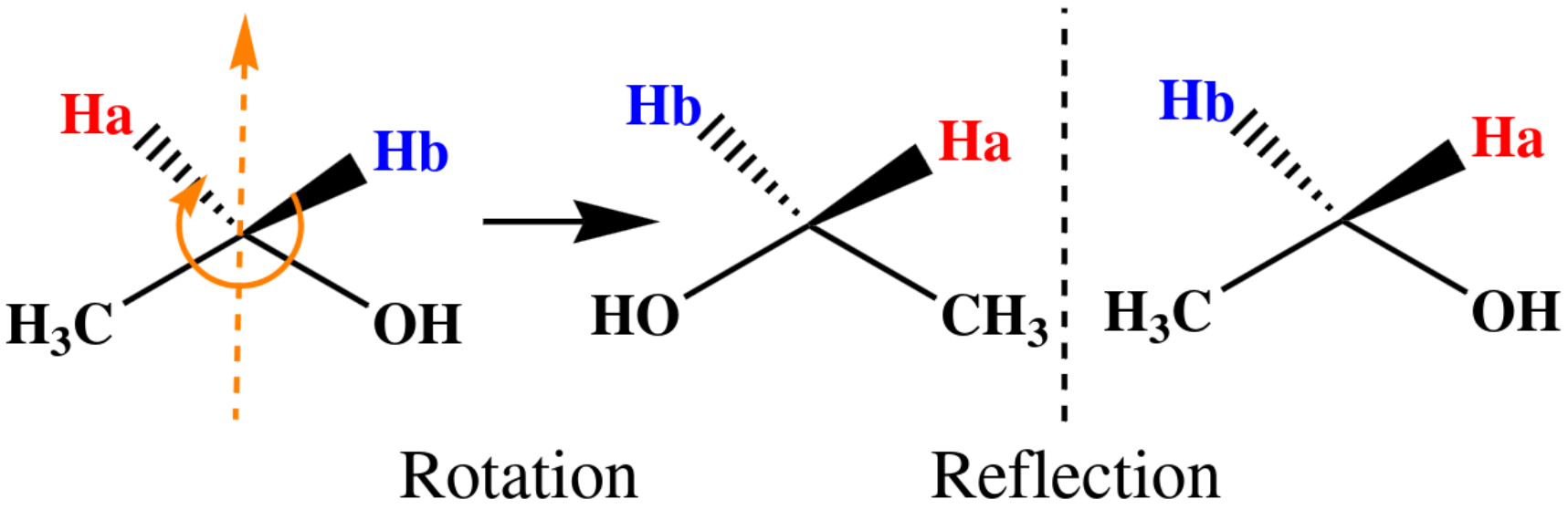
View the molecule through C-H bond for assigning the configuration

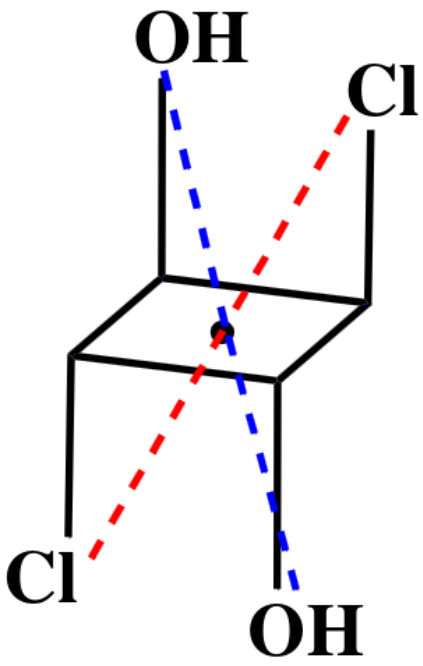
2. Symmetry criteria

(a) Enantiotopic ligands

Two homomorphic ligands are enantiotopic if they can interchangeable through plane of symmetry or center of inversion or S_n axis.



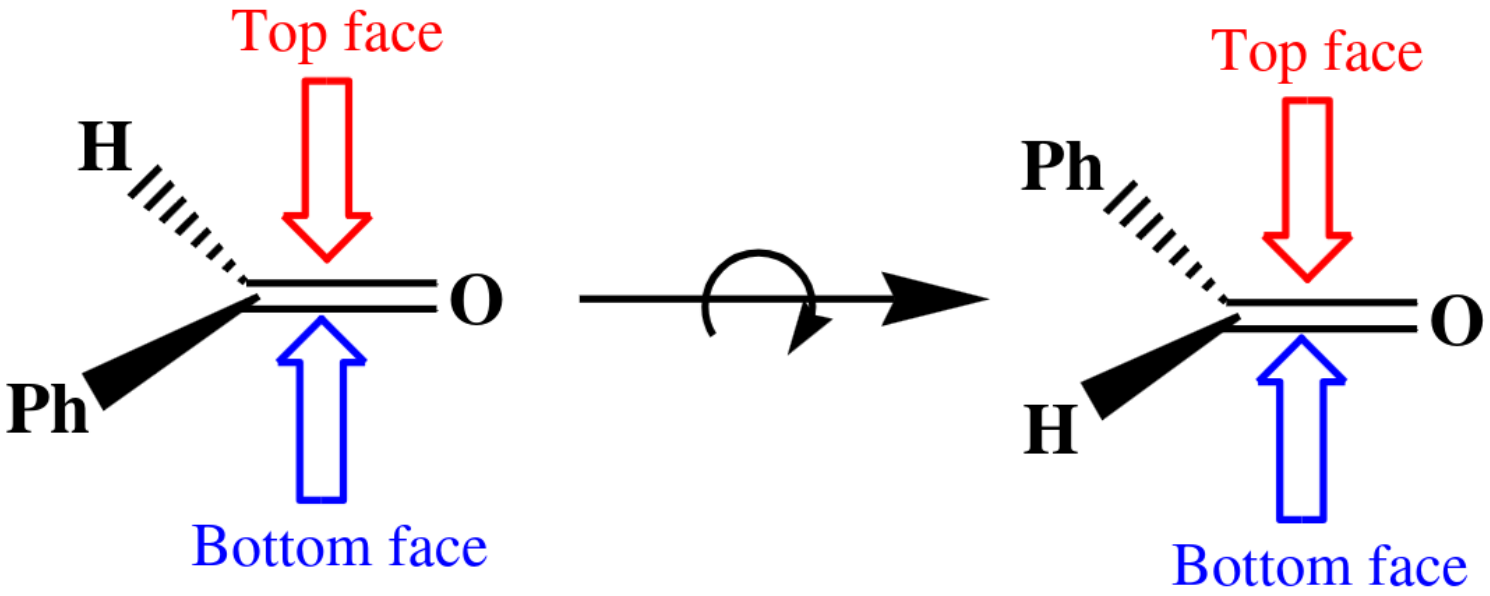




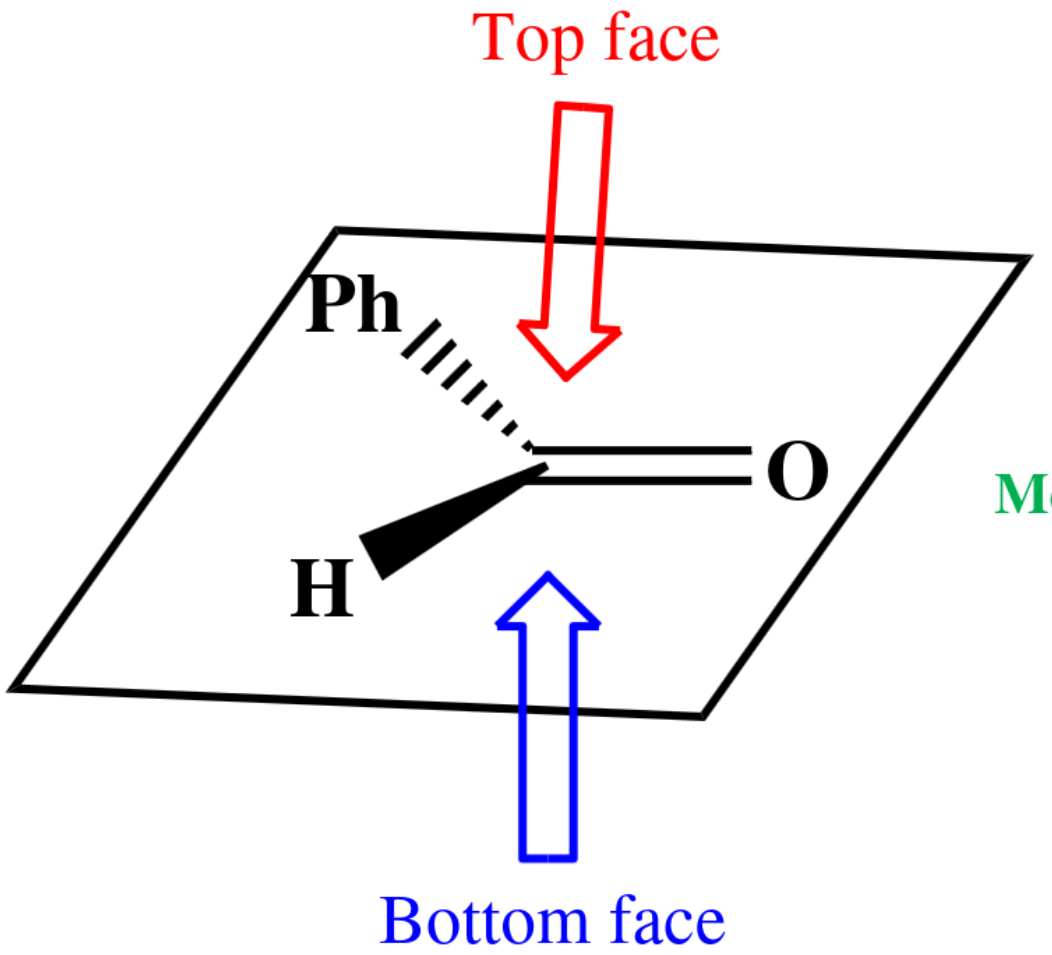
Inversion center

(b) Enantiotopic faces

Two faces are enantiotopic if they can interchangeable through plane of symmetry or center of inversion or S_n axis.



Structure is not same upon rotation hence mirror plane exists.



Molecular mirror plane exists

NMR Spectroscopy of Enantiotopic Hydrogen

If the hydrogen atoms in the molecule are enantiotopic, then they are chemically equivalent. Hence they will resonate at same chemical shift values.

SUMMARY

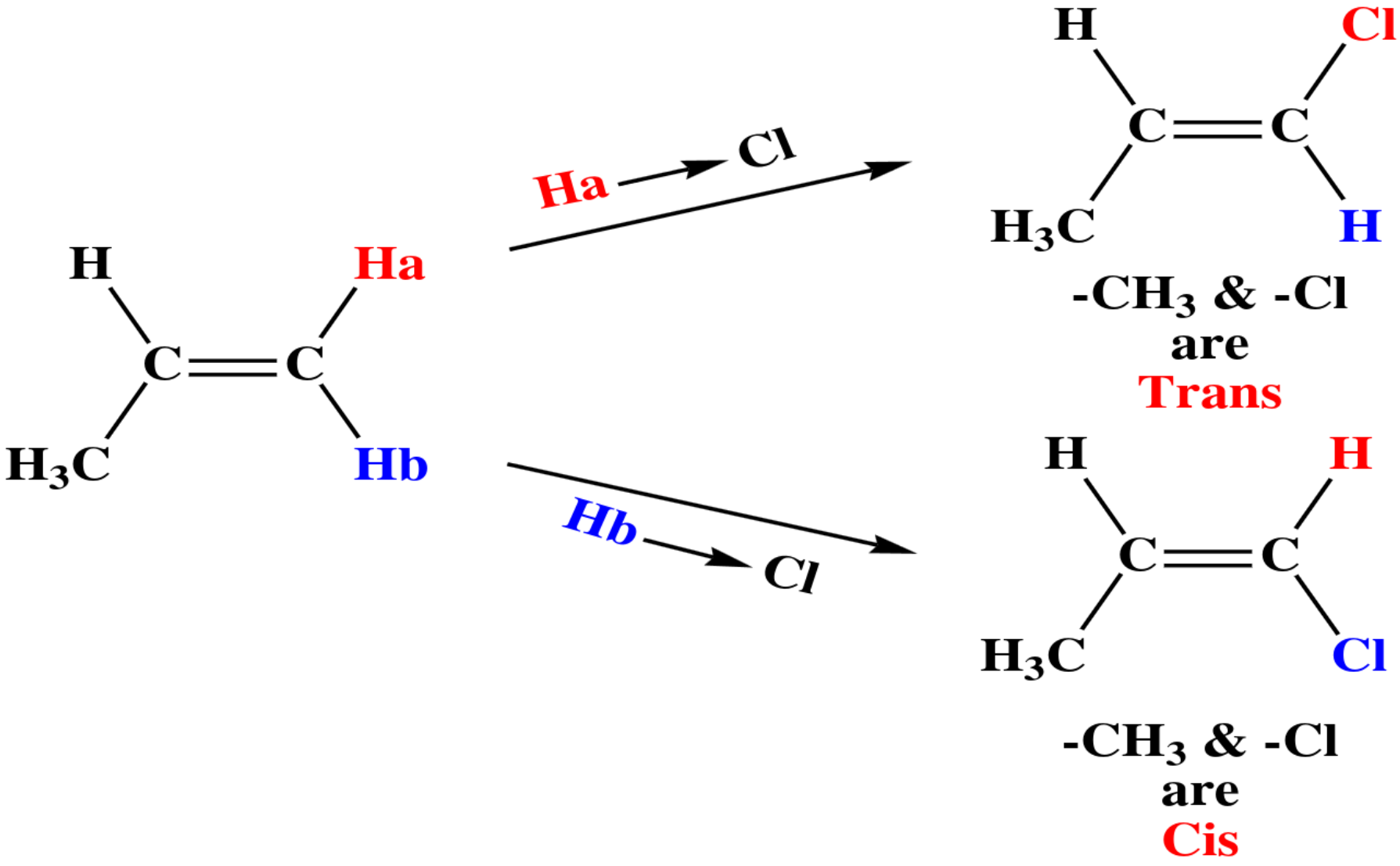
Between enantiotopic groups and faces differentiation is possible either by enzyme or by NMR in chiral reagent or catalyst.

Topicity	Substitution-addition criteria	Symmetry criteria	Reactivity
Enantiotopic groups and faces	Enantiomers	σ_h or S_n	Differentiation possible

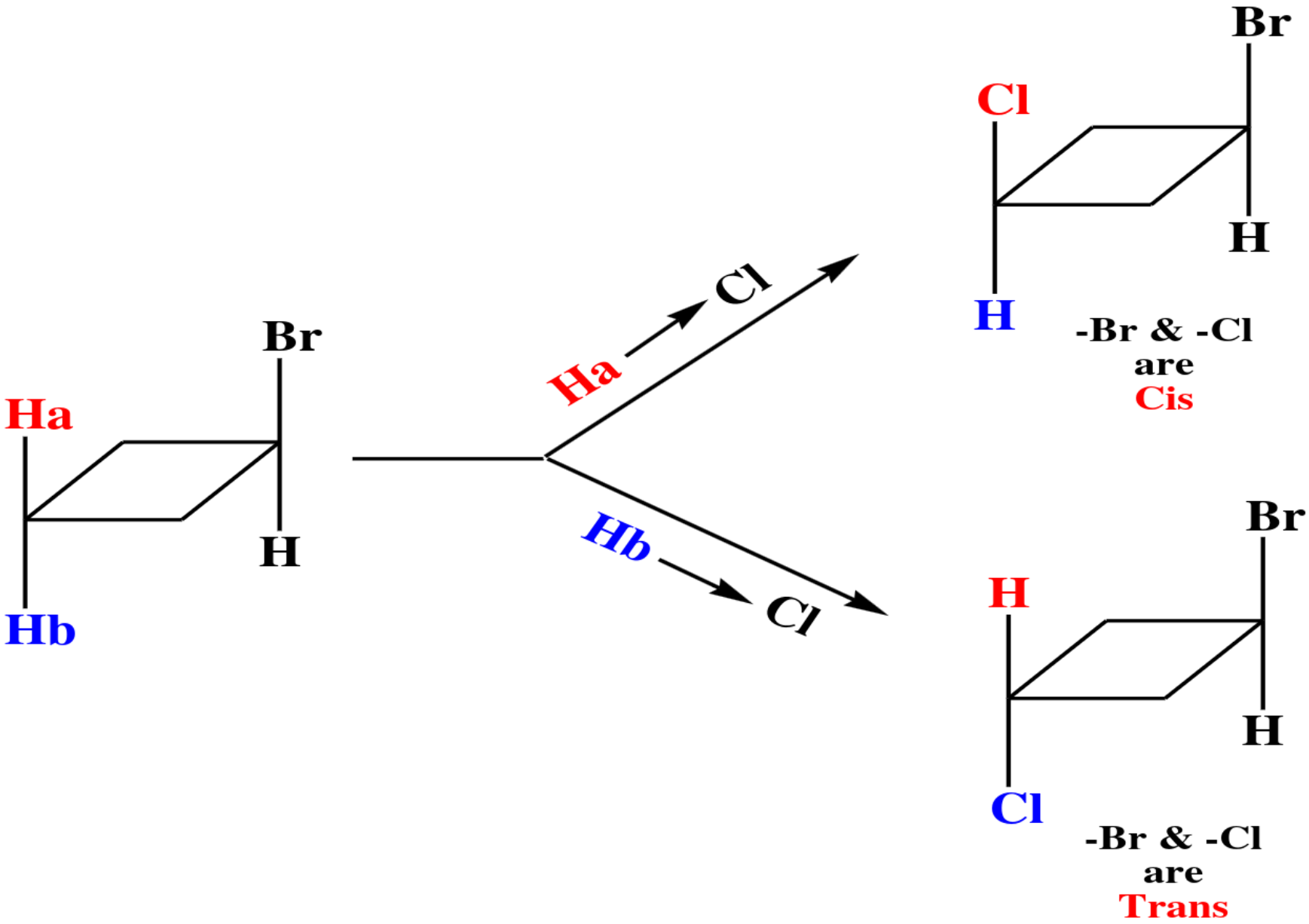
(a) Diastereotopic ligands

Substitution-addition criteria

Two homomorphic ligands are diastereotopic if substitution (replacement) of first one and other by different test ligand not already attached to the molecule leads to diastereomers / non super imposable not mirror images.

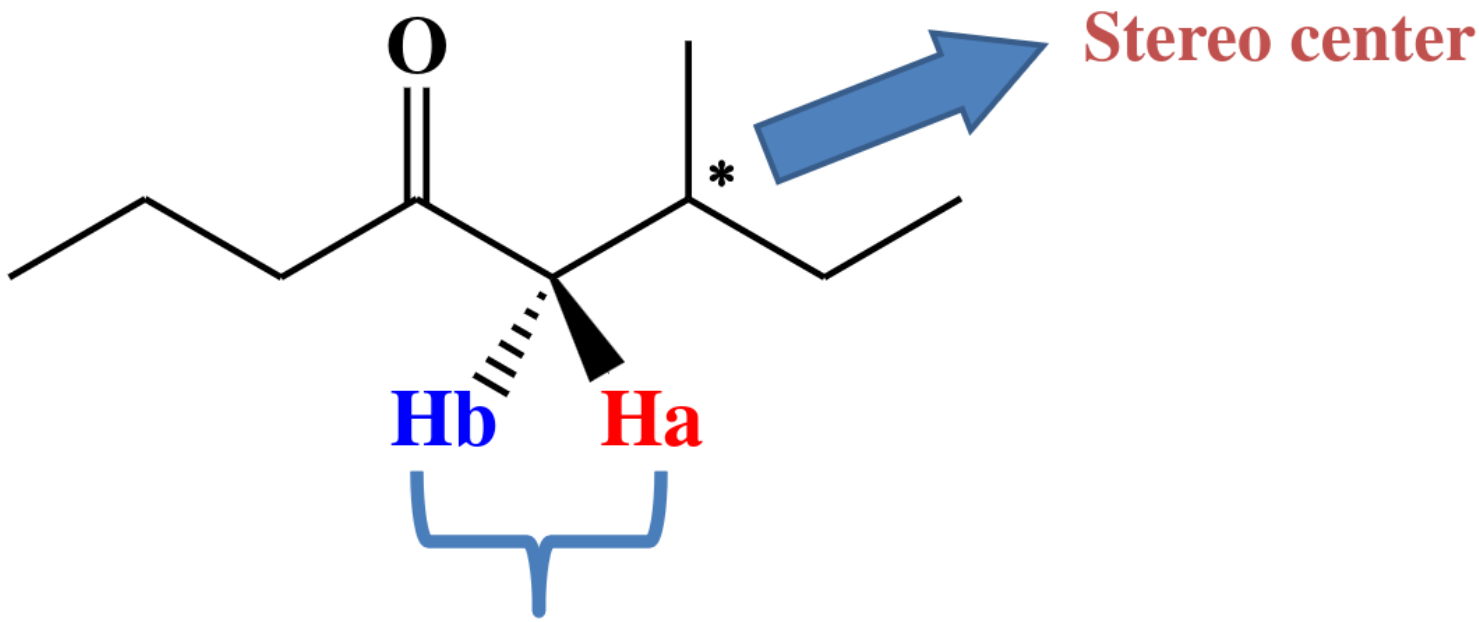


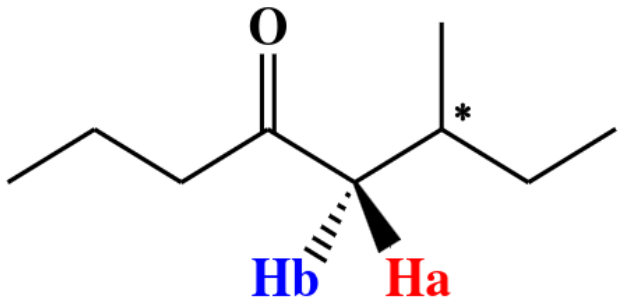
Substitution of Ha & Hb by Cl leads to formation of trans and cis products which are diastereomers and hence two hydrogens are diastereotopic

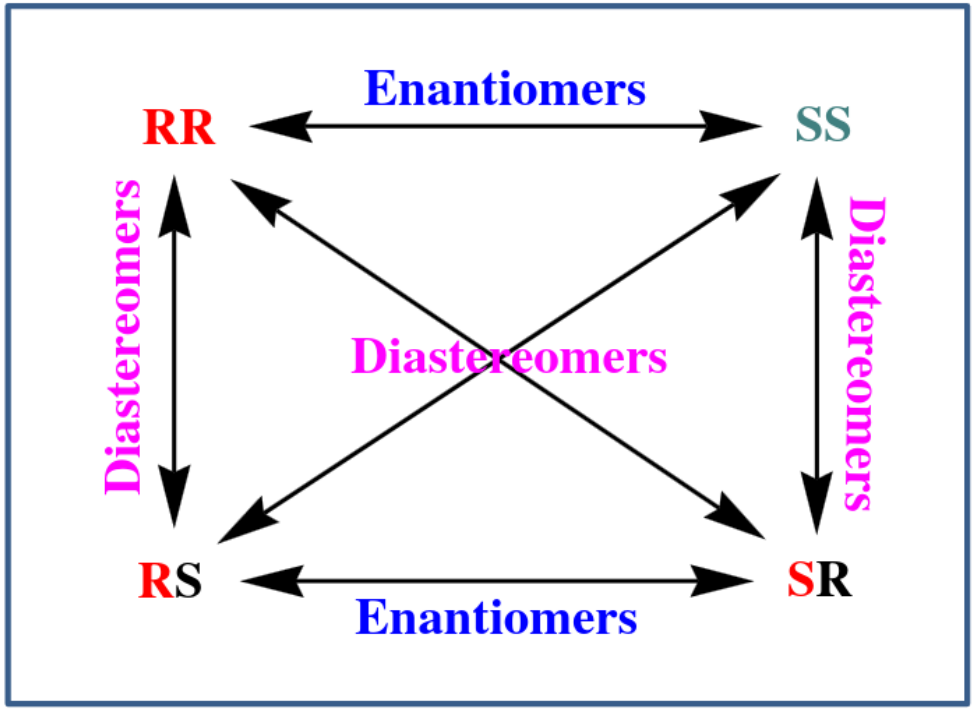


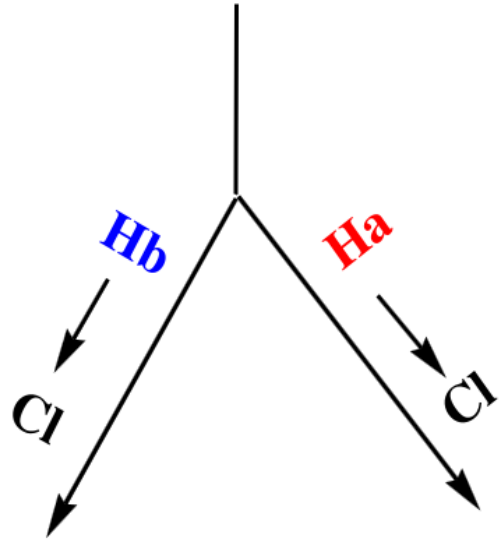
Substitution of Ha & Hb by Cl leads to formation of trans and cis products which are diastereomers and hence two hydrogens are diastereotopic

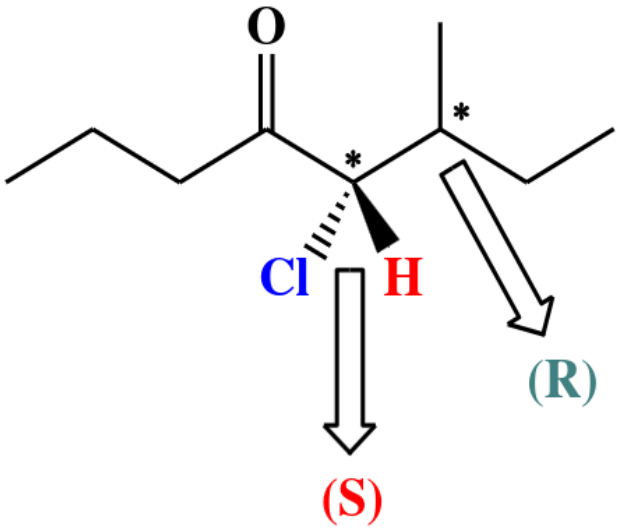
Geminal methylene protons adjacent to a stereocenter on substitution test by other ligands not already present in the molecule usually leads to diastereomers and are usually diastereotopic.

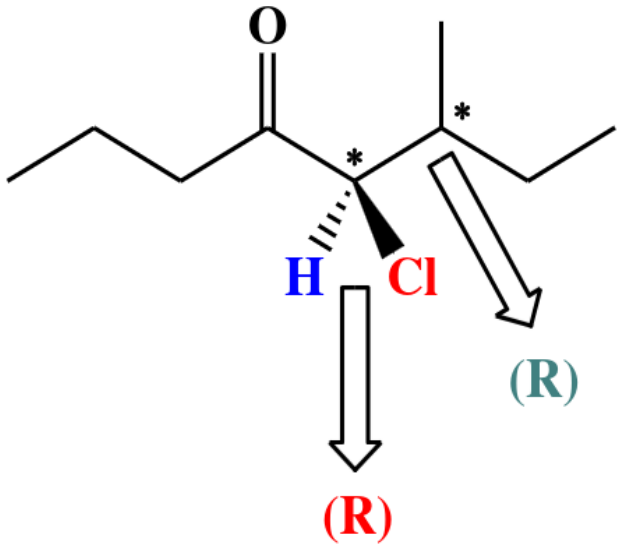




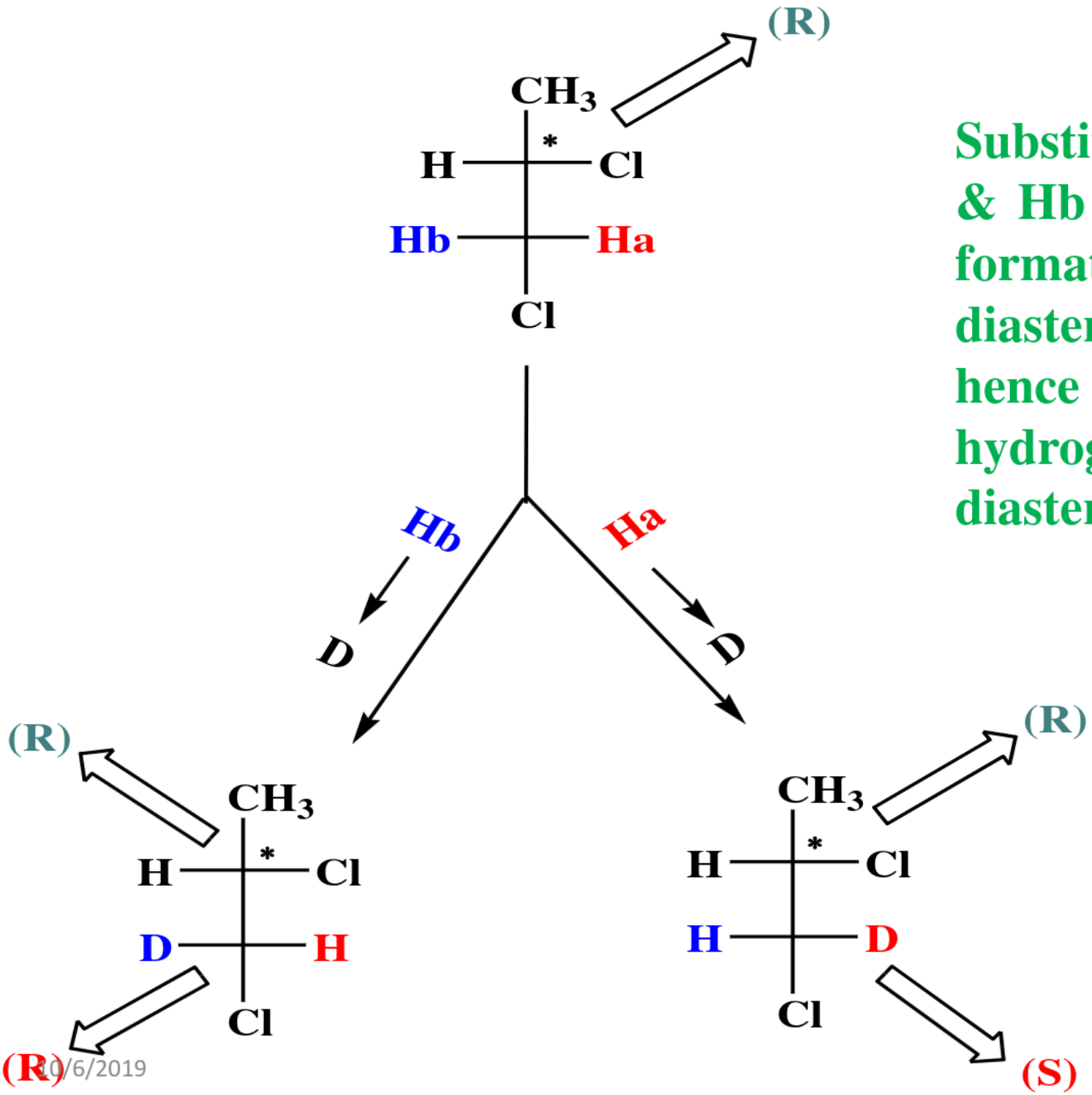








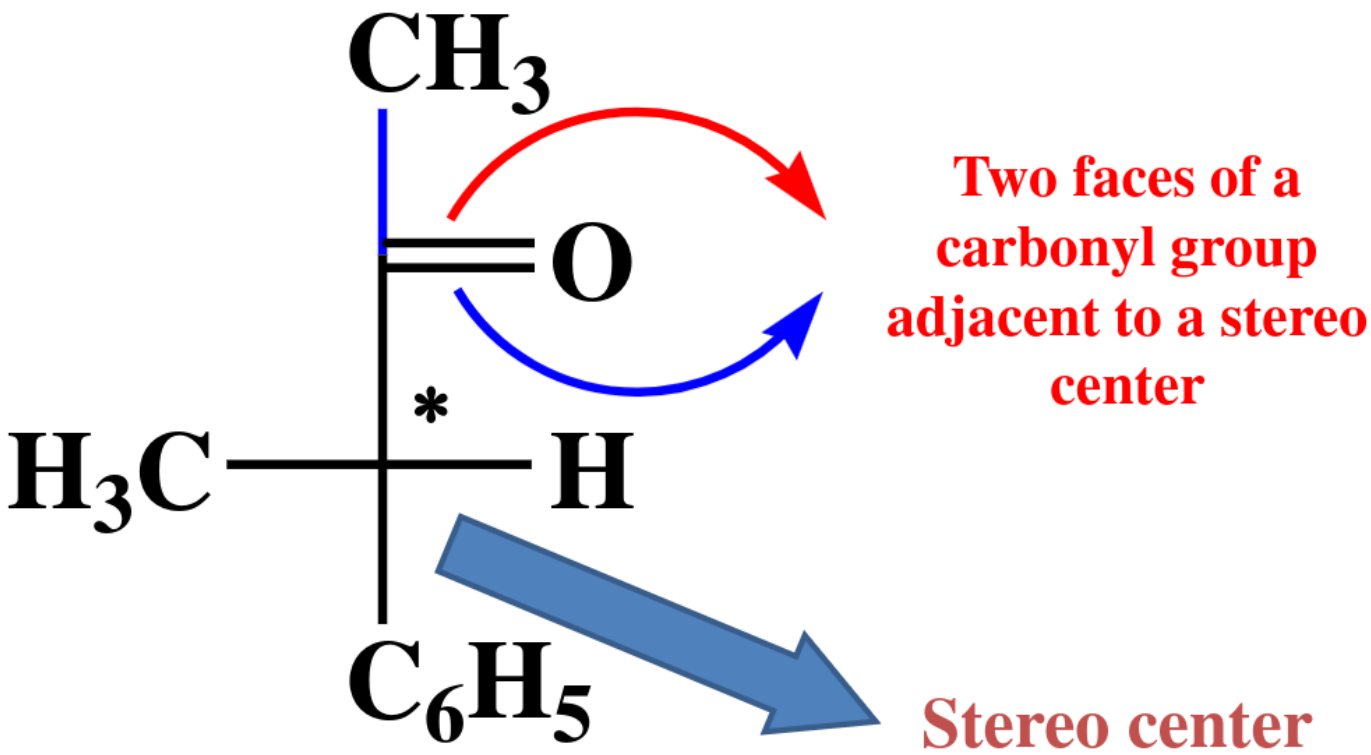
Substitution of Ha & Hb by Cl leads to formation of diastereomers and hence two hydrogens are diastereotopic

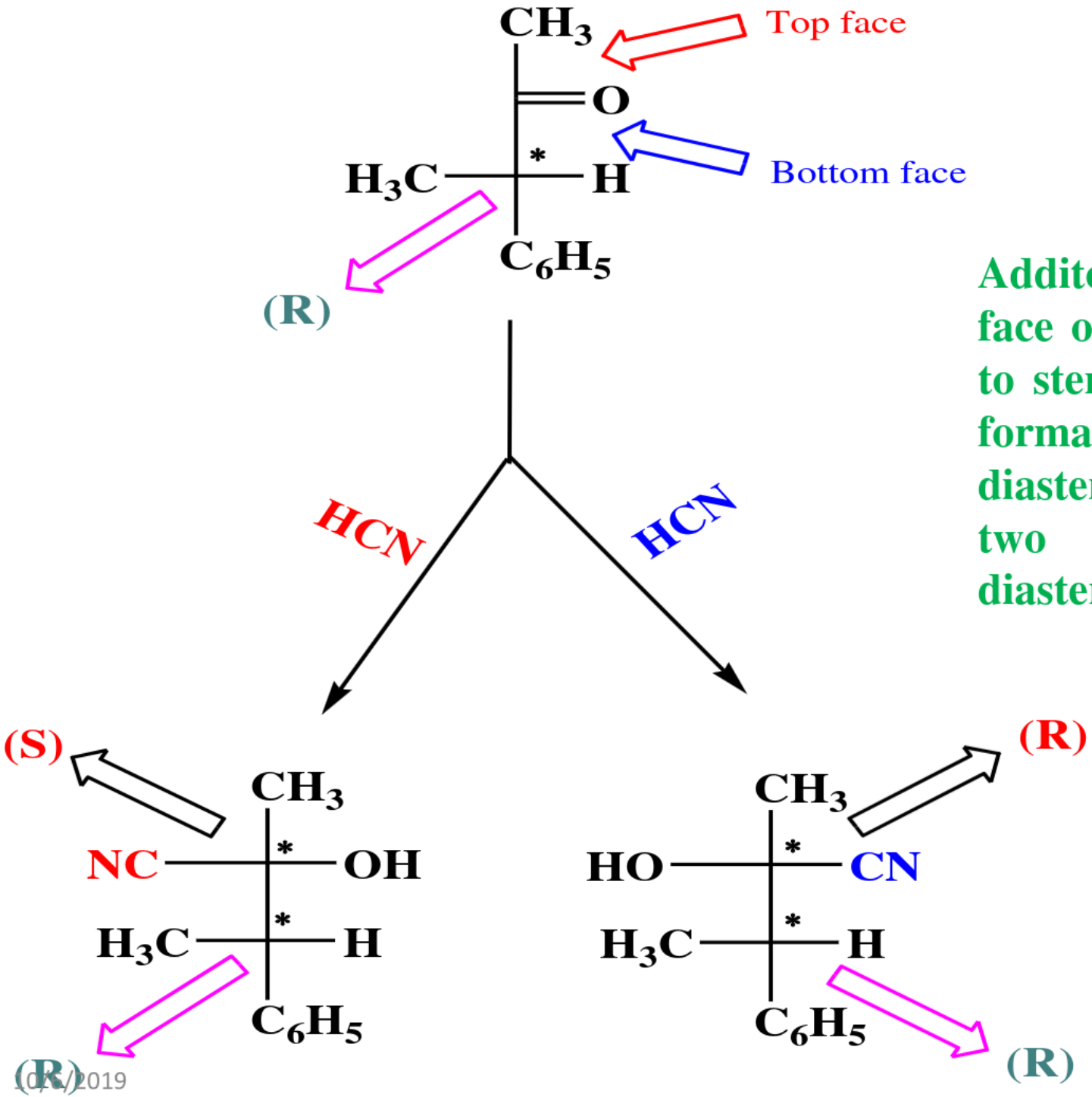


Substitution of Ha & Hb by D leads to formation of diastereomers and hence two hydrogens are diastereotopic

(b) Diastereotopic faces

Two faces of a carbonyl group adjacent to a stereo center on addition reaction leads to diastereomers and possess diastereotopic face.



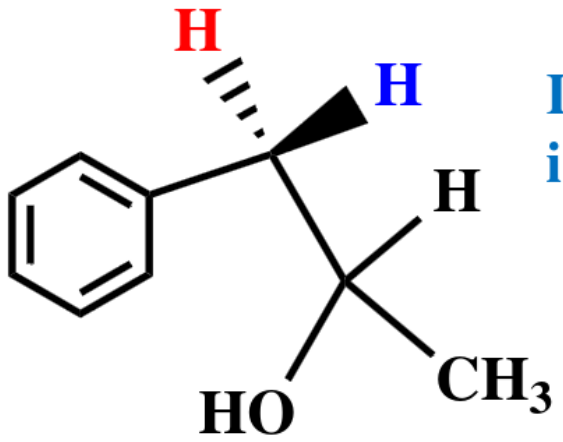


Additon of HCN two face of carbonyl adjcent to stereo center leads to formation of diastereomers and hence two faces are diastereotopic.

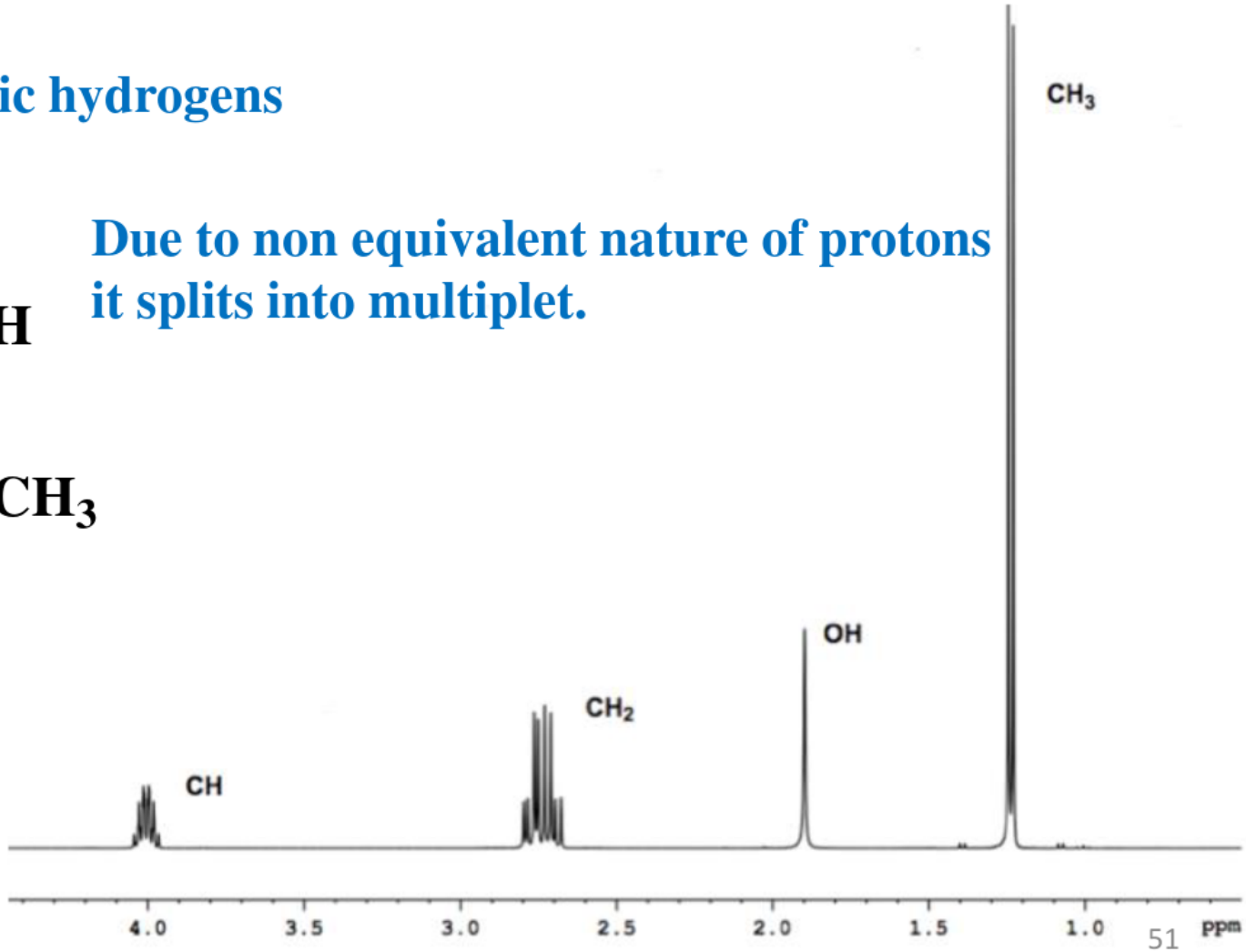
NMR Spectroscopy of Diastereotopic Hydrogen

If the hydrogen atoms in the molecule are diastereotopic, then they are chemically and magnetically non equivalent. Hence they will resonate at different chemical shift values.

Diastereotopic hydrogens



Due to non equivalent nature of protons it splits into multiplet.

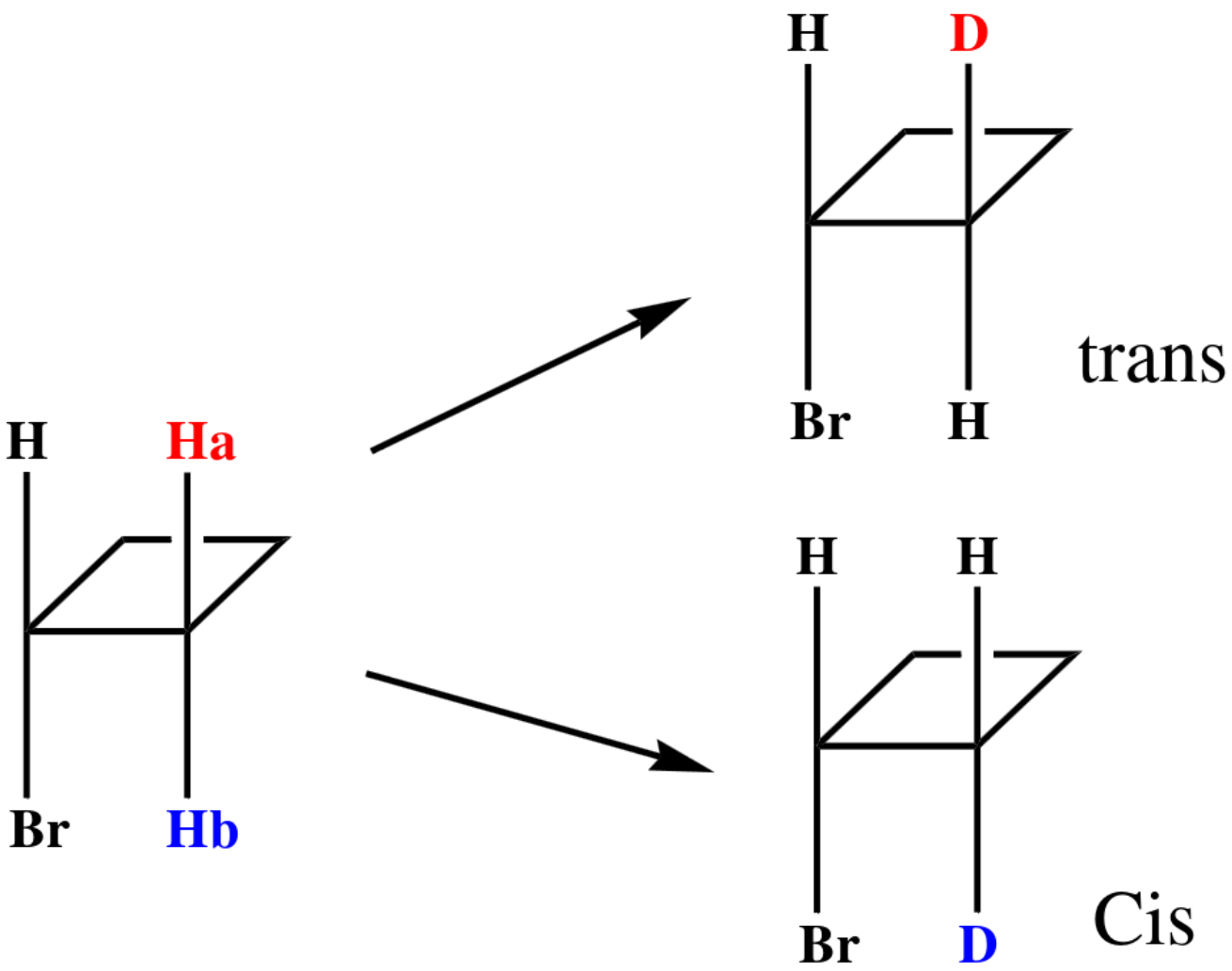


SUMMARY

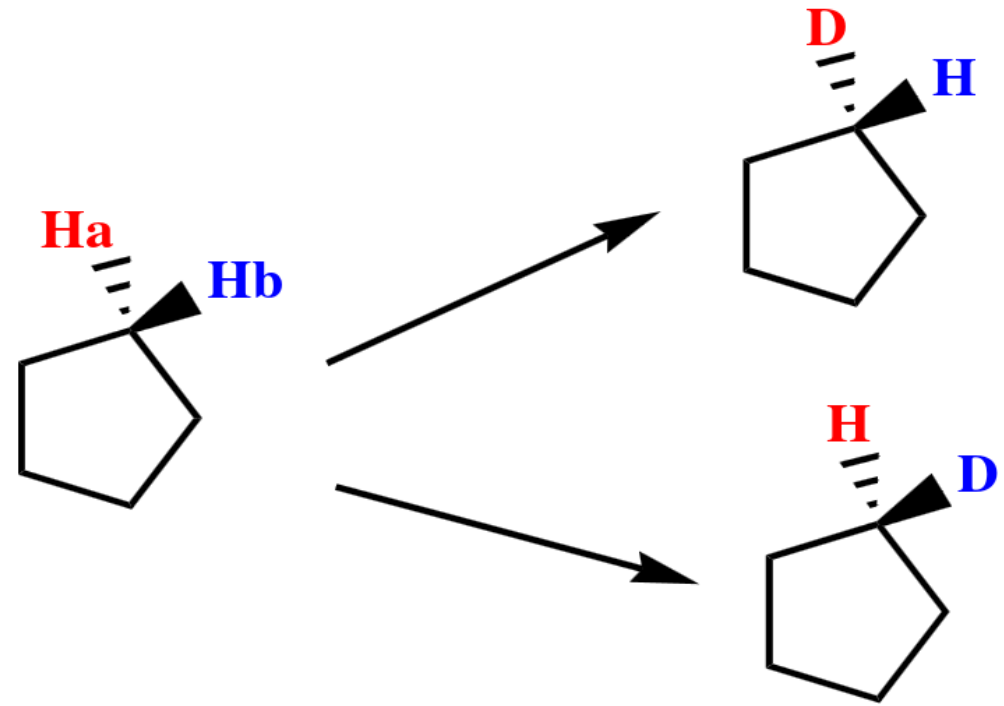
Between diastereotopic groups and faces differentiation is possible either by enzyme or by reagent or by NMR.

Topicity	Substitution-addition criteria	Symmetry criteria	Reactivity
Diastereotopic groups and faces	Diastereomers	Not applicable	Differentiation possible

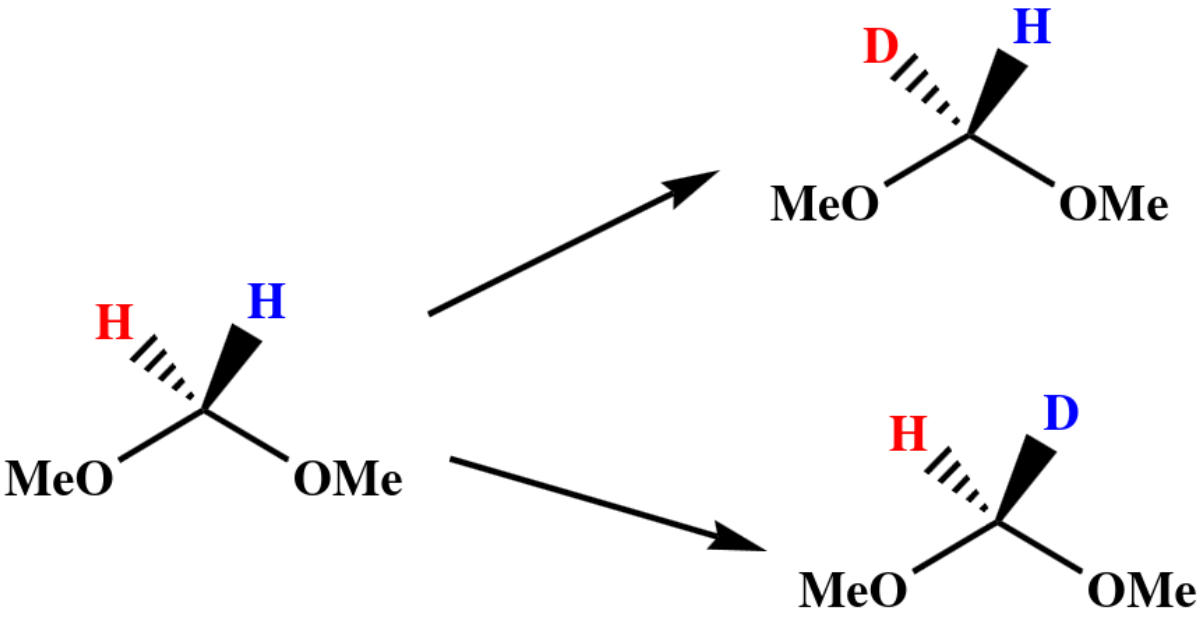
EXAMPLES



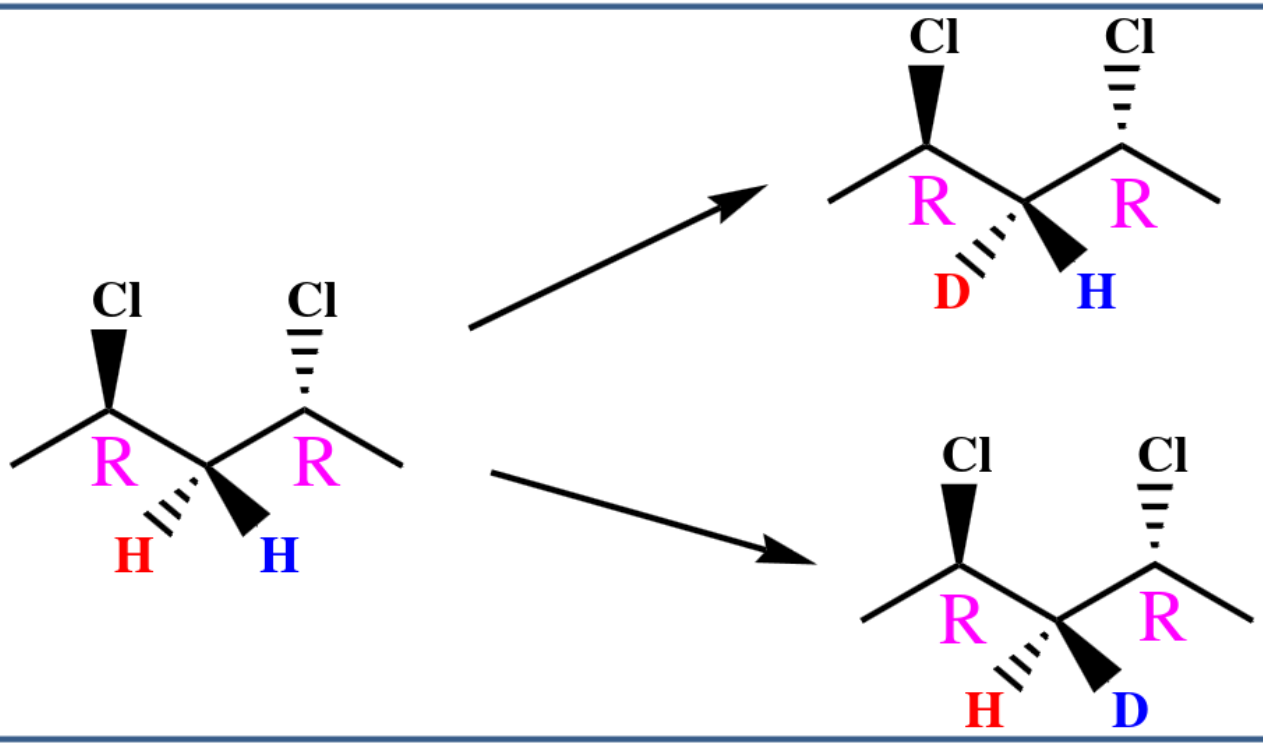
Substitution of Ha & Hb by D leads to formation of diastereomers and hence two hydrogens are diastereotopic.



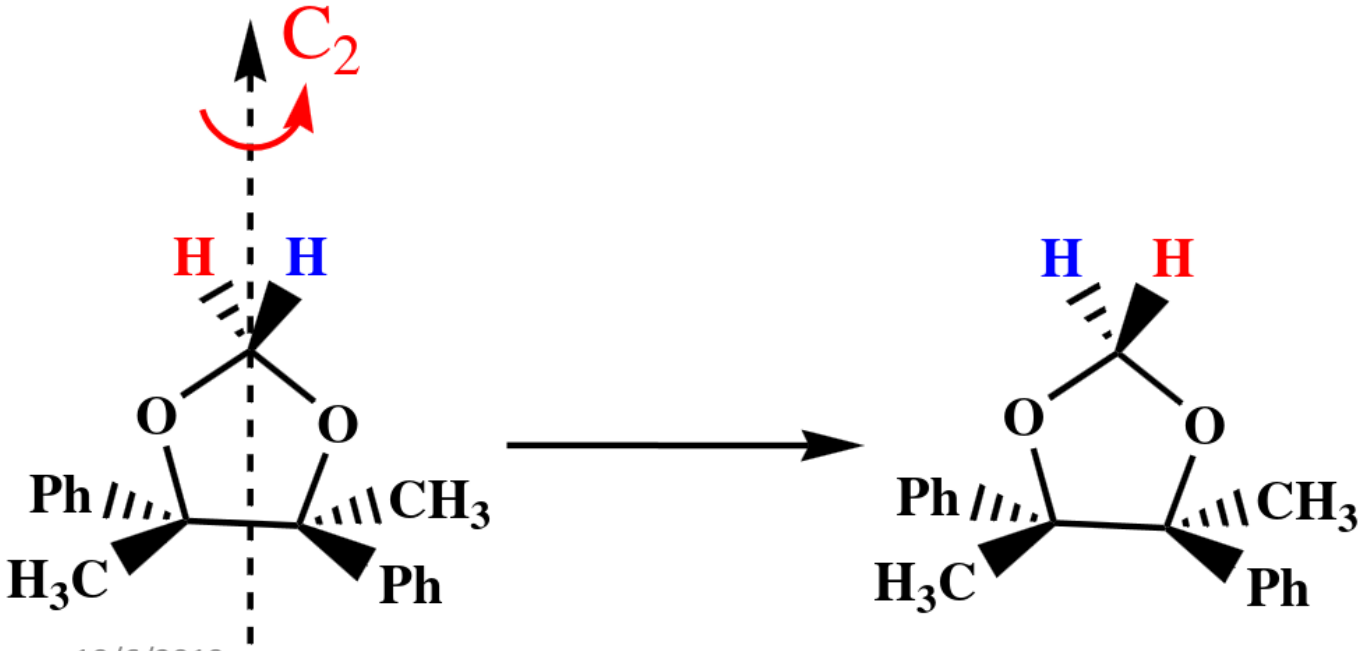
Substitution of Ha & Hb by D leads to formation of homomers and hence two hydrogens are homotopic.



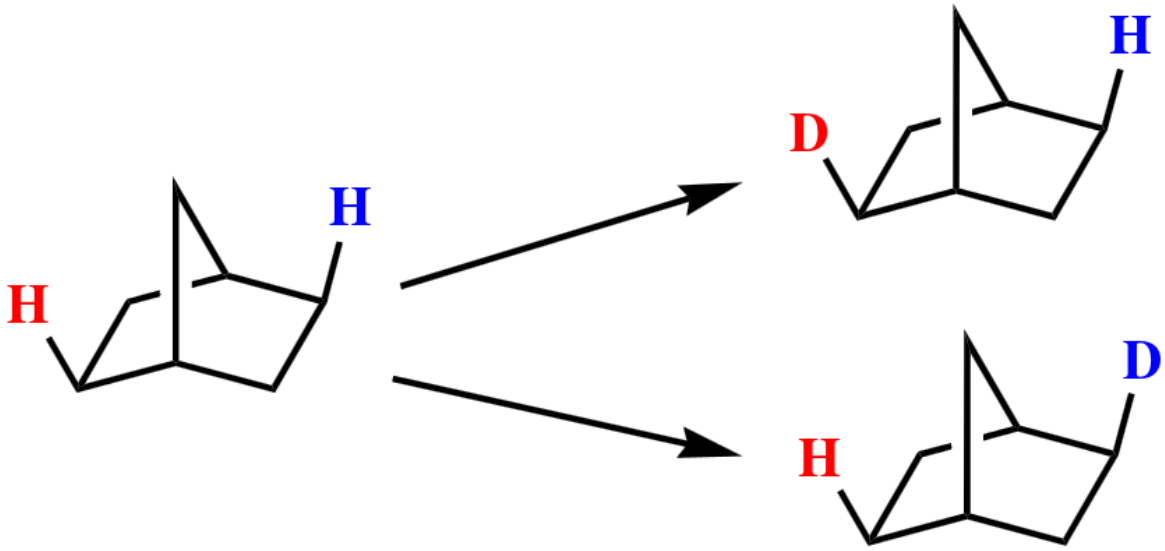
Substitution of H & H by D leads to formation of homomers and hence two hydrogens are homotopic.



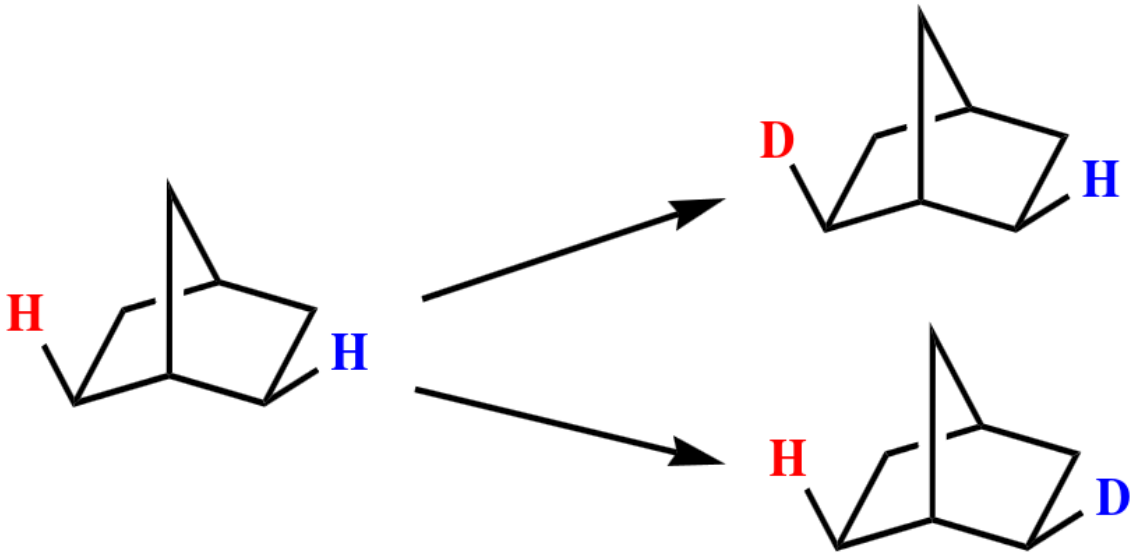
Substitution of H & H by D leads to formation of homomers and hence two hydrogens are homotopic.



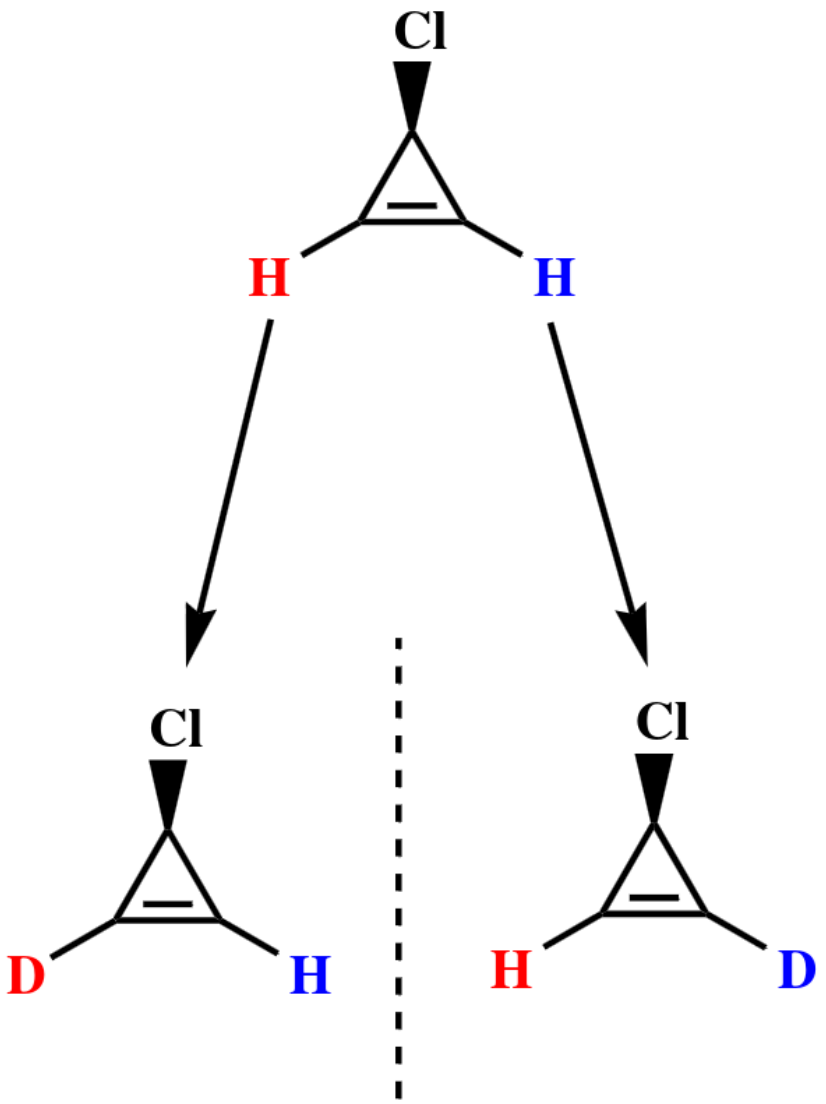
H & H are interchangeable by C2 rotation and hence two hydrogens are homotopic.



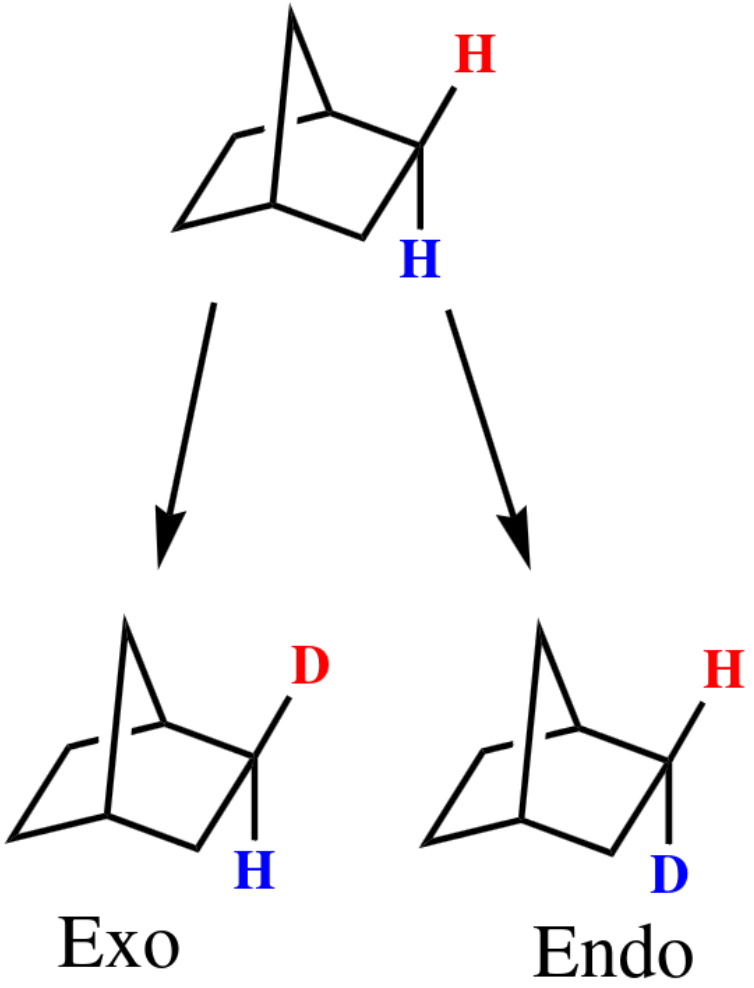
Substitution of H & H by D leads to formation of homomers and hence two hydrogens are homotopic.



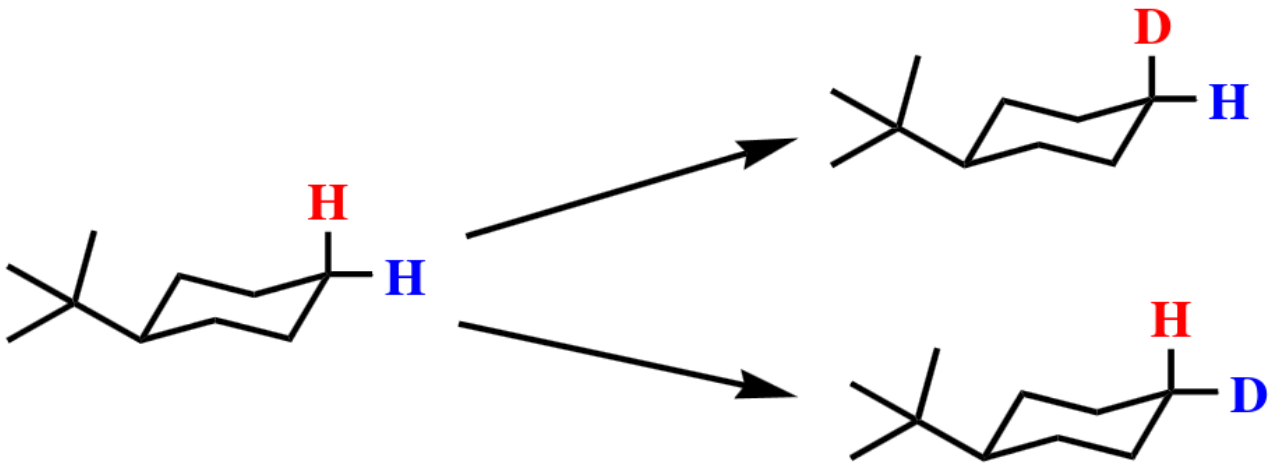
Substitution of H & H by D leads to formation of enantiomers and hence two hydrogens are enantiotopic.



Substitution of H & H by D leads to formation of enantiomers and hence two hydrogens are enantiotopic.



Substitution of H & H by D leads to formation of diastereomers and hence two hydrogens are diastereotopic.



Substitution of H & H by D leads to formation of diastereomers and hence two hydrogens are diastereotopic.