Organic Chimestry

Chapter 5 notes

written by:
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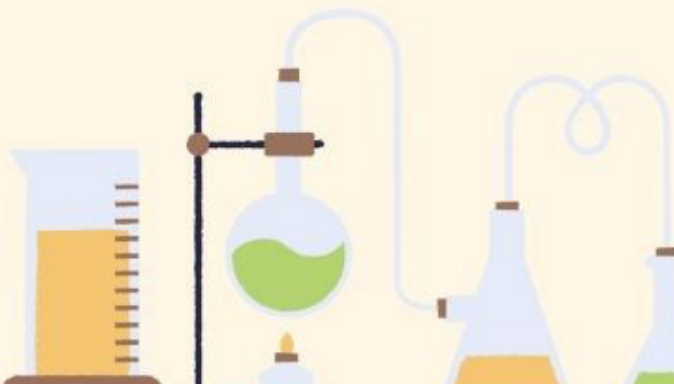


Chapter Five
Stereoisomerism

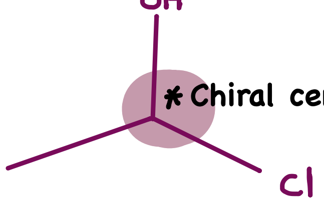
Stereochemistry: Branch of chemistry that deals with arrangments
كيفية توزيع الذرات بالفراغ

Section 5.1-5.2

Chiral molecule is defined as molecule that contains at least one Chiral center (it is a SP3 Carbon that has 4 different atoms (or group)).

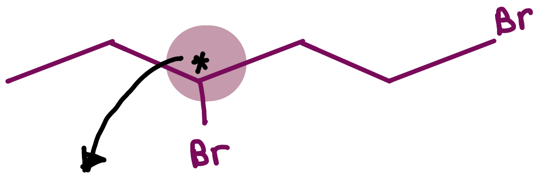
4 segma bonds around the carbon

Ex1



*Chiral center has : CH3 , H , OH , Cl

Ex2



Chiral center has : H , Br , CH2CH3 , CH2CH2Br

Remember this called 1,5-DiBromo Pentane

Note : Don't look just on adjacent atoms , Look on the whole chain

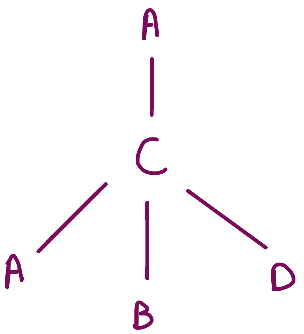
The molecule is chiral since it had 1 chiral center and we can called it stereogenic center

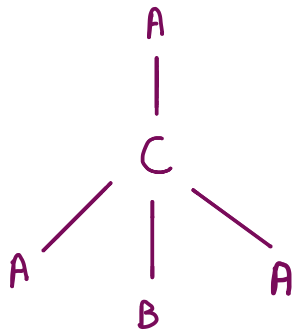
Chiral molecule can be defined as : molecule that has no plane of symmetry

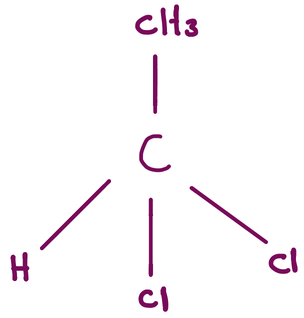
لا يمكن أن نقسم المركب إلى جزئين متماثلين ، ولكن من السهولة أن تحدد المركب (Chiral) من خلال البحث عن (chiral center)

Achiral molecule : molecule that has no chiral center (No SP3 carbon that has 4 different atoms) or it's defined as the molecule that contains plane of symmetry

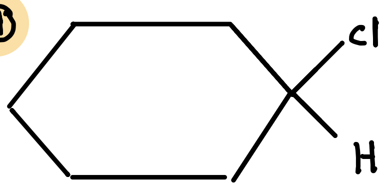
Examples

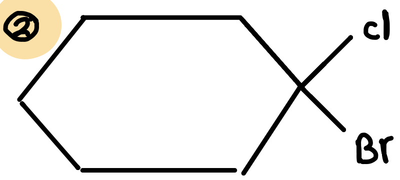


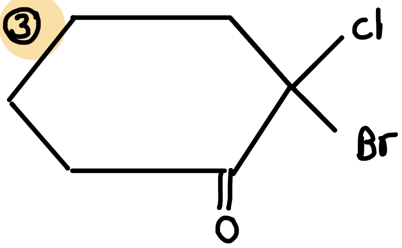




Exercise : which molecule contains a chiral center?

① 

② 

③ 

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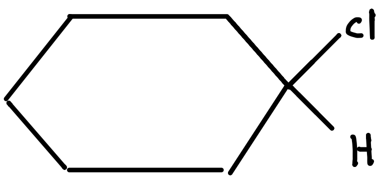
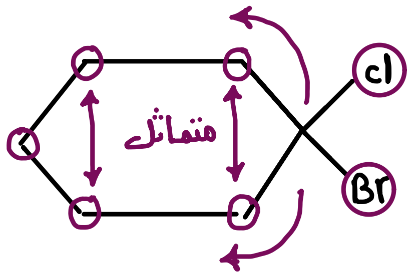


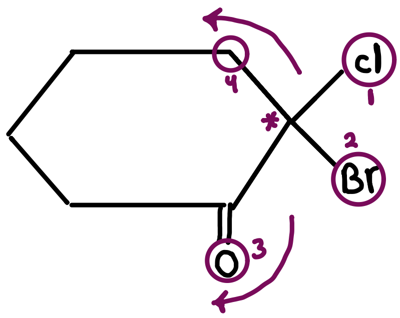
No chiral center

- achiral molecule -



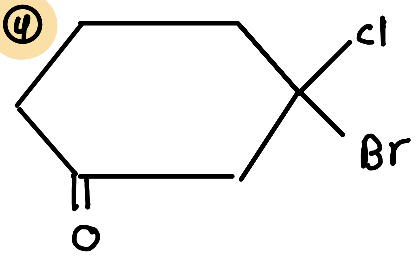
No chiral center

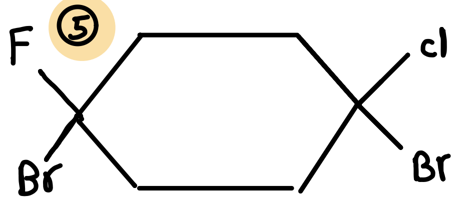
- achiral molecule -

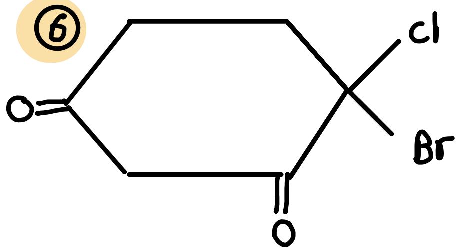


4 different groups

- chiral molecule -

④ 

⑤ 

⑥ 

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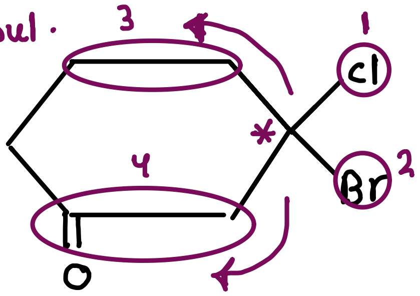
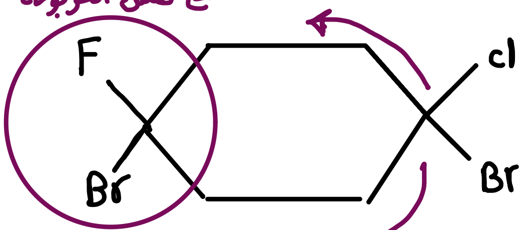


4 different groups

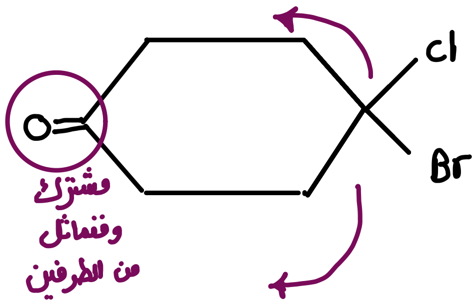
- chiral molecule -

مشتركين من الطرفين
على نفس الكربونة



No chiral center

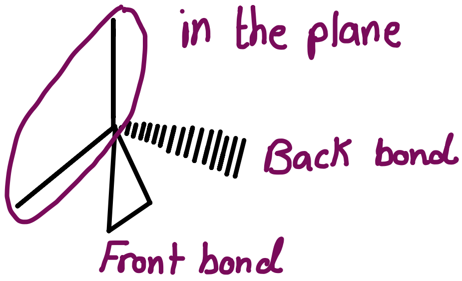
- achiral molecule -



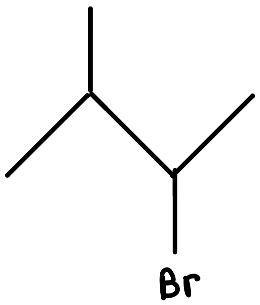
No chiral center

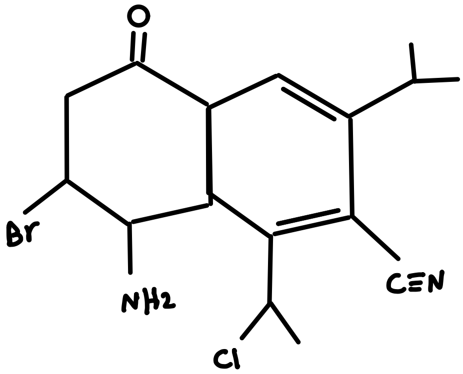
- achiral molecule -

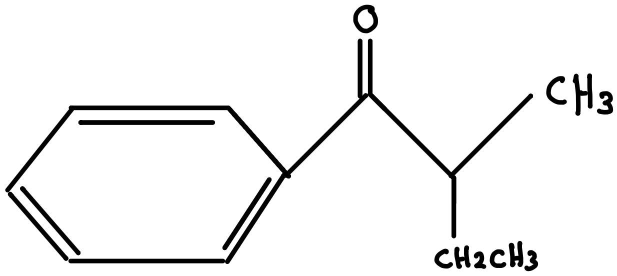
Note: Drawing of 6 – Bonds in the space of 3 Dimension

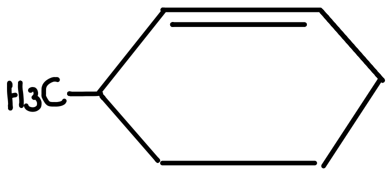


Assign Chiral center(s) in the following :



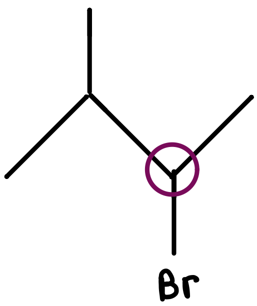


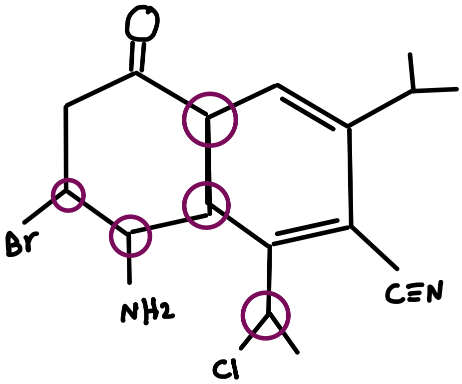


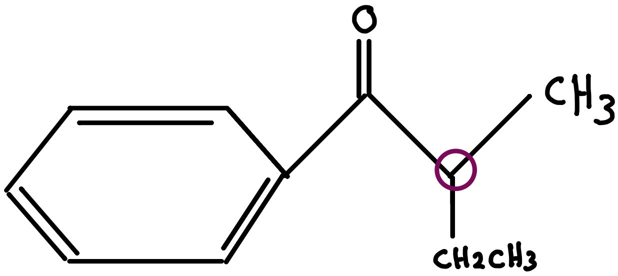


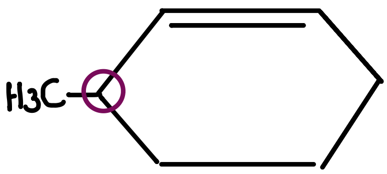
Sul.

* All of these molecules are chiral molecules









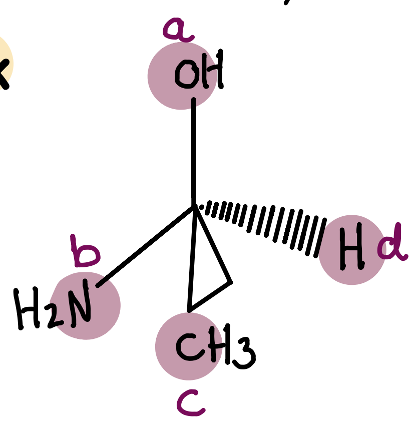
5.3 : Configration of a Chiral center

Each chiral center should have a configration either R-Configration or S-Configration , no configration is exist if the Carbon is not Chiral center.

Rules to assign the configration :

1.Give the priority for each atom (group) around the chiral center according to the atomic number of the atom that is attached directly to chiral center → increases → | ↓ in the periodic table

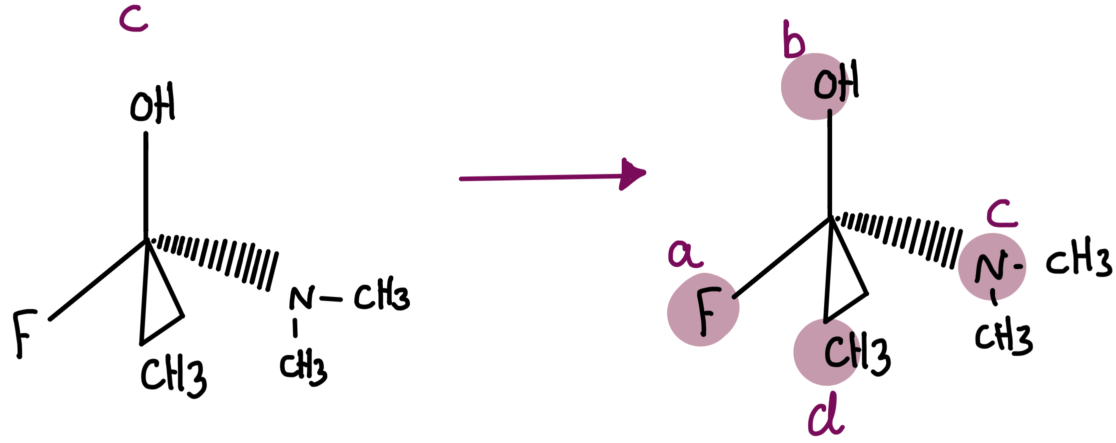
Ex



Highest atomic number (a)
Lowest atomic number (d)

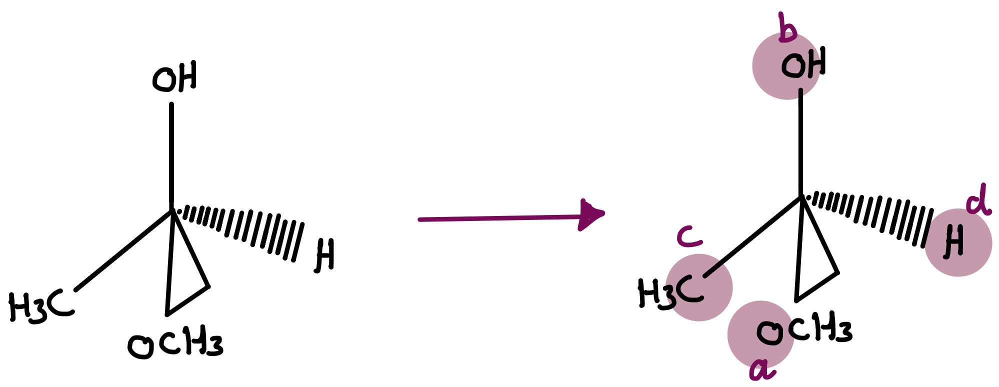
a > b> c> d

Ex



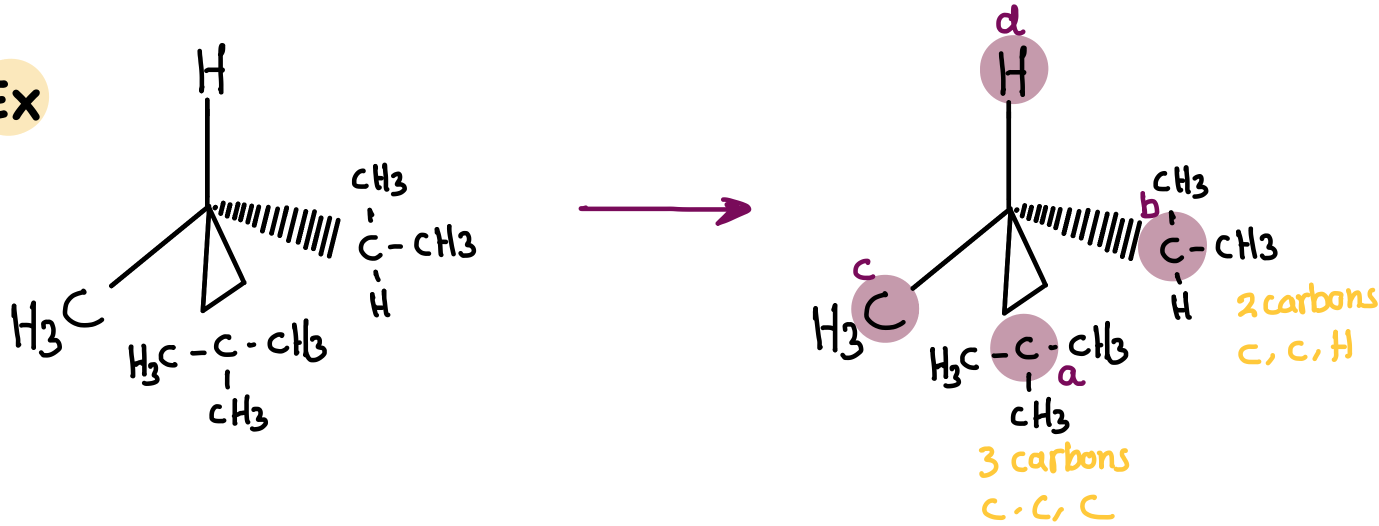
2.If two atoms that attached directly to a stereogenic center are identical = observe the 1st point of difference

Ex

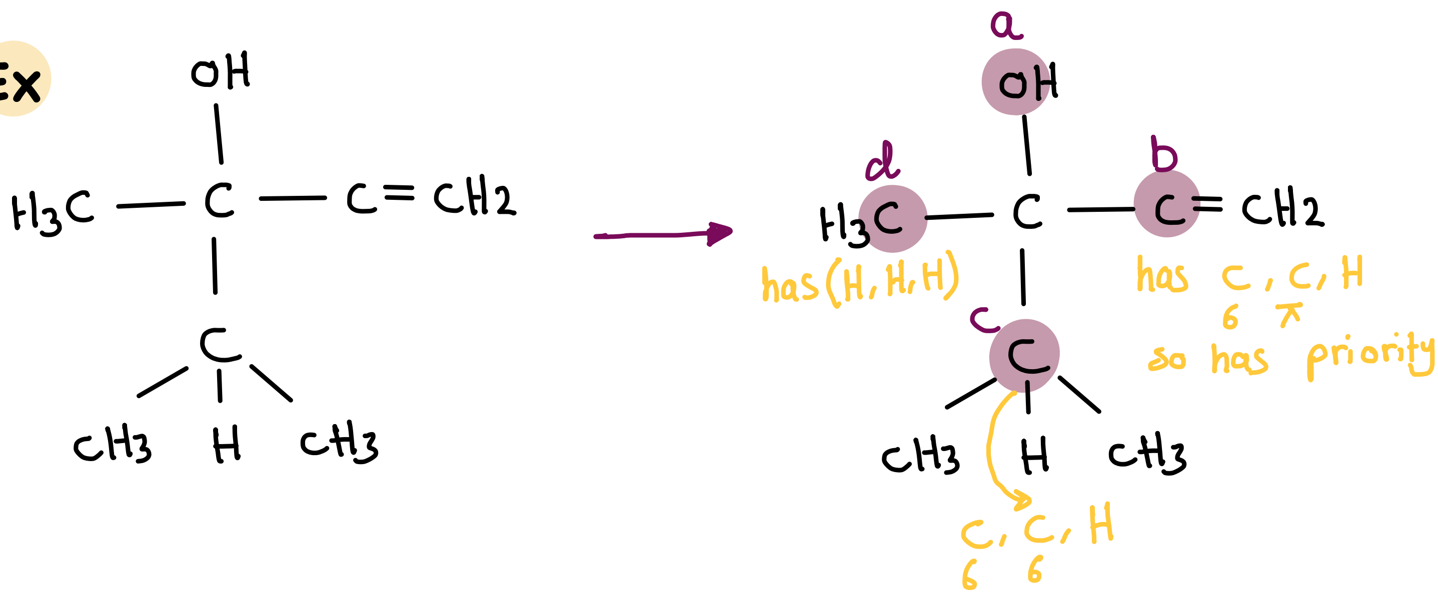


Same Oxygen atoms but
O – H   O – C
and C > H
in atomic number

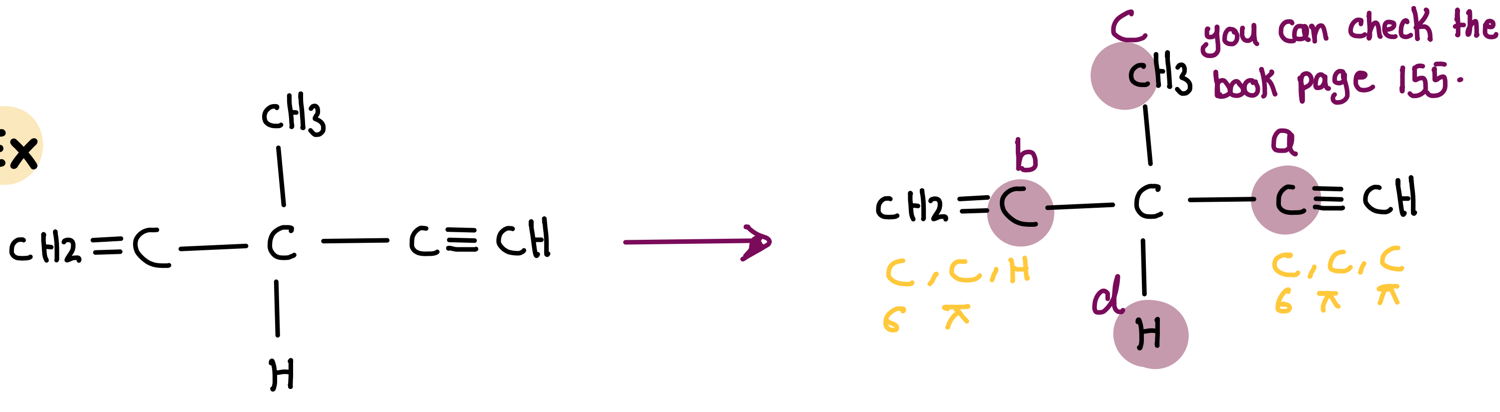
Ex



Ex



Ex



3.The group (d) should be directed away from us (it means group d is located on. Back bond .
But if group (d) is located on front bond then invert the configration.

4.Finally look to the path a → b → c

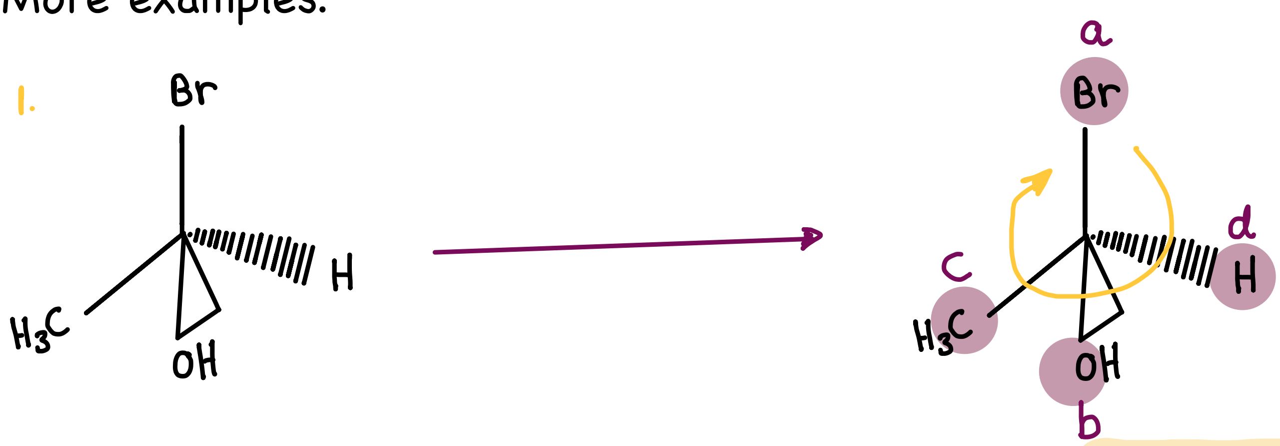
If the direction is Clockwise then the Chiral center has R-Configration

If the direction is Counter Clockwise then the Chiral center has S-Configration

These rules are called **Cahn-Ingold-Prelog**

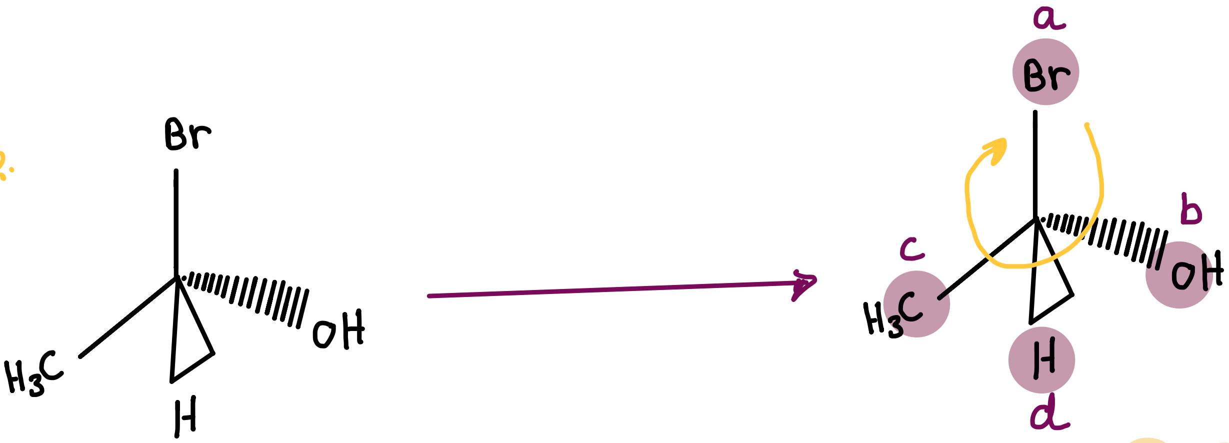
More examples:

1.



clock wise so R-configration

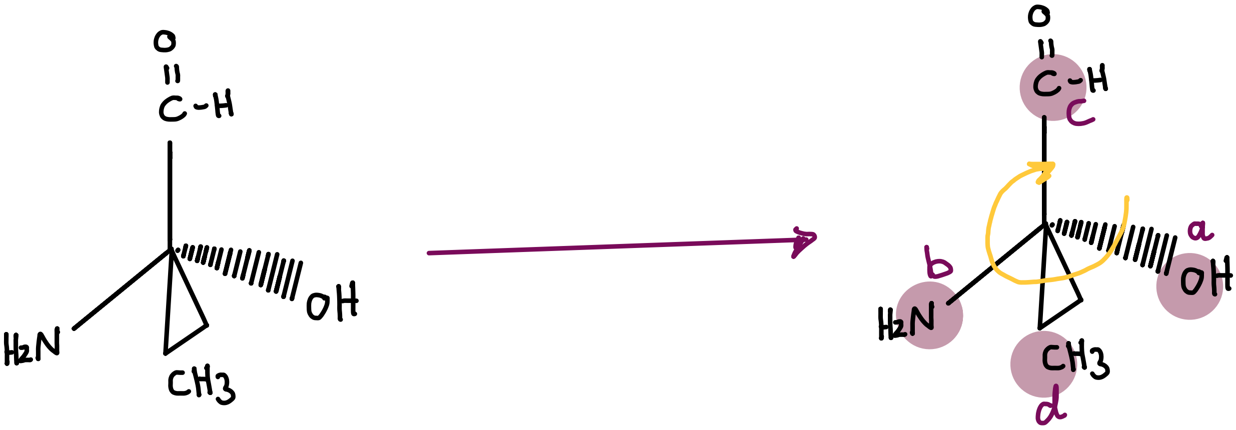
2.



Clockwise so R-configration but d is located on front bond then invert the configration
The final answer is S-configration

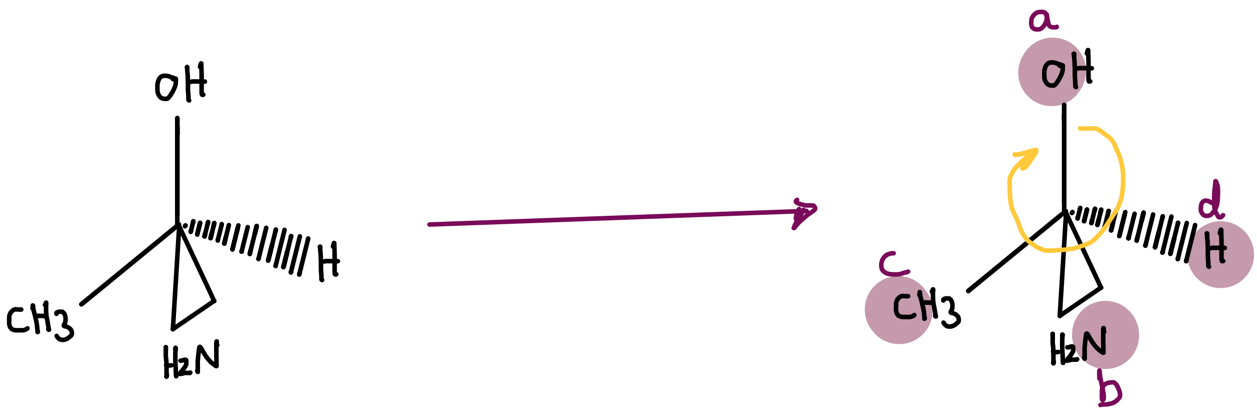
Note : You can pass from a to b through d but you can't pass through c

3.



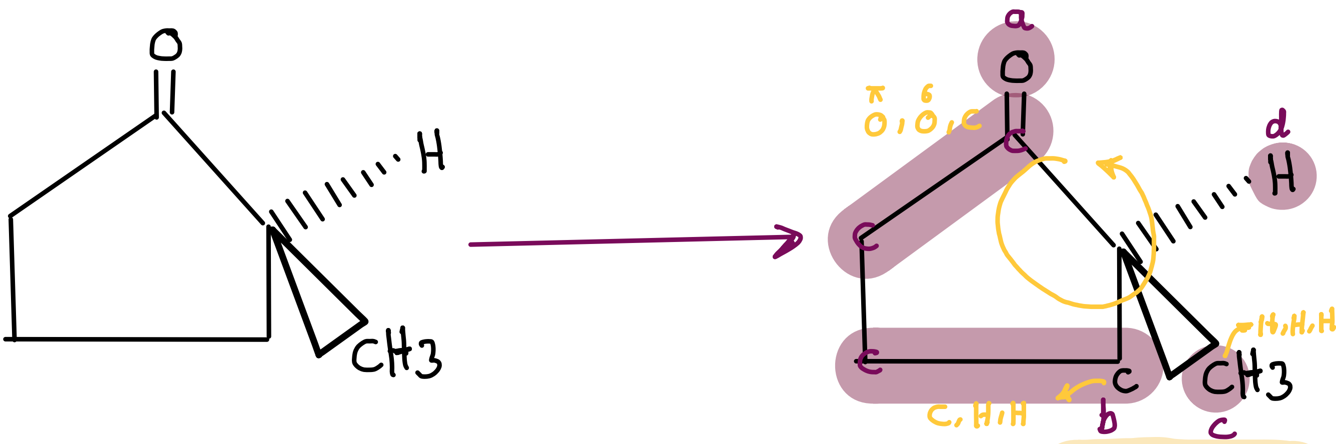
Clockwise so R-configration but d is located on front bond then invert the configration
The final answer is S-configration

4.



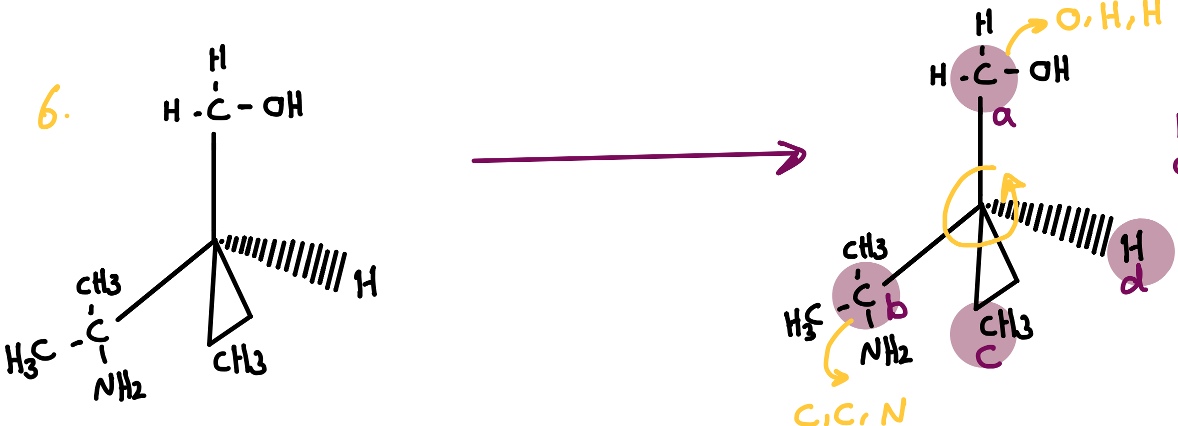
clock wise so R-configration

5.



counterclock wise so S-configration

6.

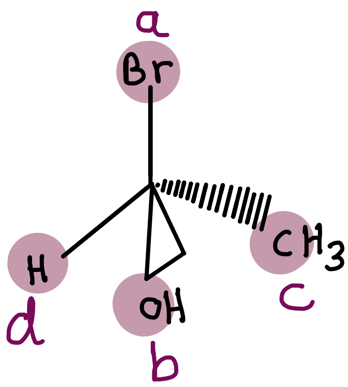


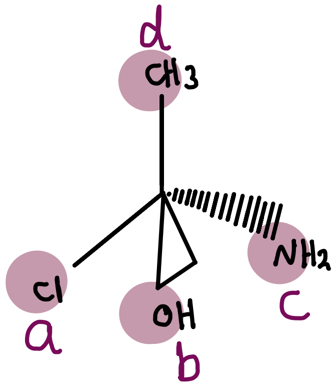
which one is a?
H, H, O → highest is O
C, C, N → highest is N
O is higher than N
So a is CH_2OH

بنقارن أعلى وحدة بالمركب الأول
مع أعلى وحدة بالمركب الثاني

counterclock wise so S-configration

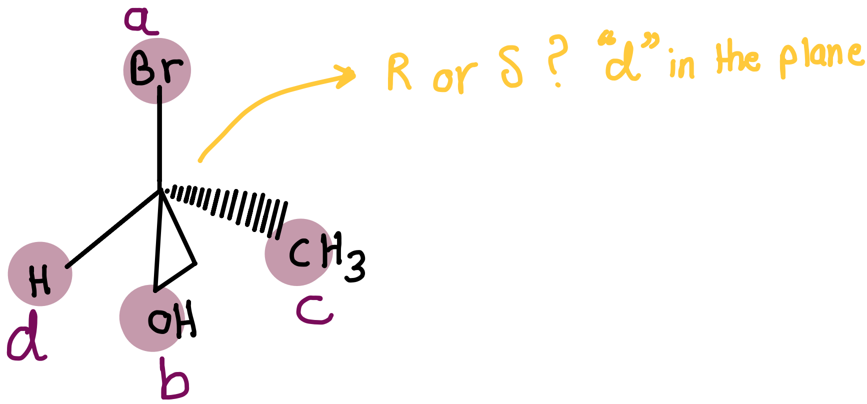
Special case : If group "d" is located on the plane



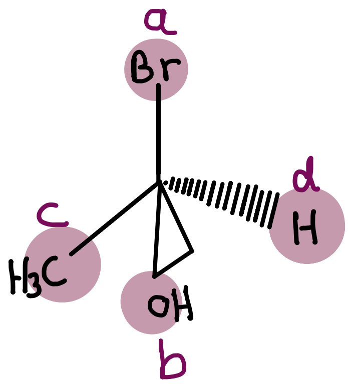


How can we determine the configration ?
Let's explain this point on this example
Assign the configration for this molecule

الملخص 8
اعكس بين d و الخلفية
جد ال configration ثم اعكسه

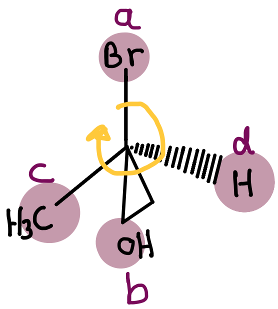


Step 1: exchange between group d "H" and group c "CH3" , then the new drawing is:



Note: we select CH3 group since it locates on the back bond

Step 2 : Find configuration for the new drawing



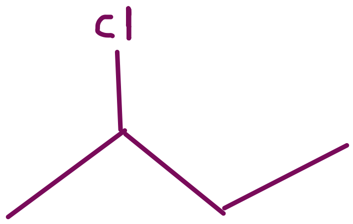
R - configration

Step 3 : invert the configuration that observed in step 2 to get an original configuration of the given molecule then final configuration is S

ملاحظة التبديل الحاصل يكون بين الرمز d و المجموعة الموجودة في الرابطة الخلفية بغض النظر عن ترتيبها (b ، a ، c)

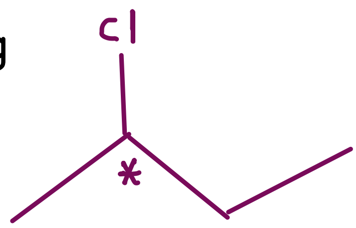
Example: Draw (S)-2-Clorobutane in 3-Dimension

Step 1 : Draw a molecule

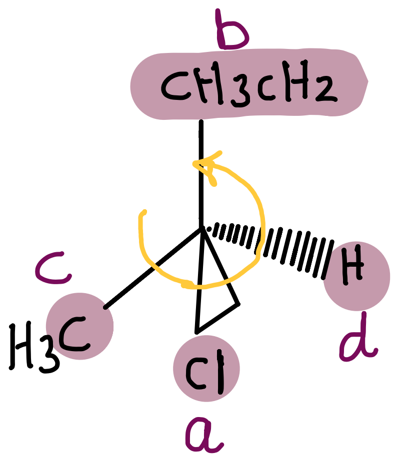


Not 3 dimension

Step 2 : Assign a Chiral center in the above drowing



Step 3 : Draw it in 3 Dimension and locate the 4 groups (atoms) around a chiral center in which the configration is (S)

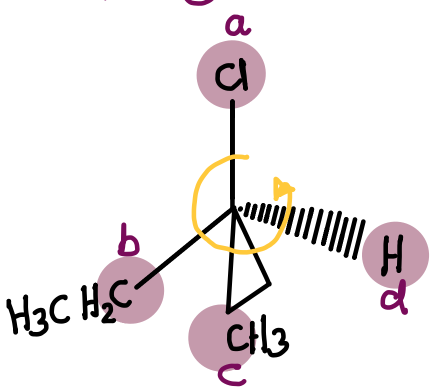


Four groups are : H, Cl, CH3, CH3CH2

It is easier to put group "d" on the back bond, then put the three groups in which a Final configration is S

نضع الأقل وزن عـ //// ثم نوزع الباقي بحيث يعطي توزيع S

Another correct structure



Note : R & S is written before the name , such as Cis & trans

Enantiomers

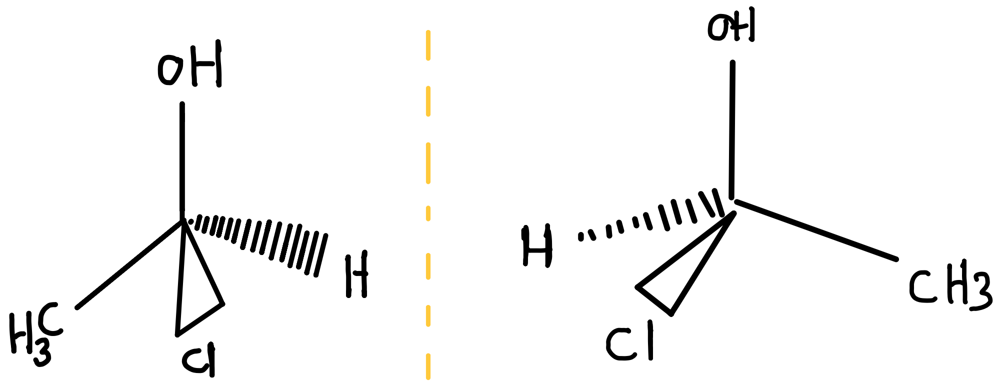
Pair of molecules which are mirror image to each other but no superimposable (لا يتطابقان)

Examples

1.one person : left-right hands

اليد اليمنى واليسرى لنفس الشخص بعتبروا مرآة لبعضهم ولكن ما بنطبقوا على

2.

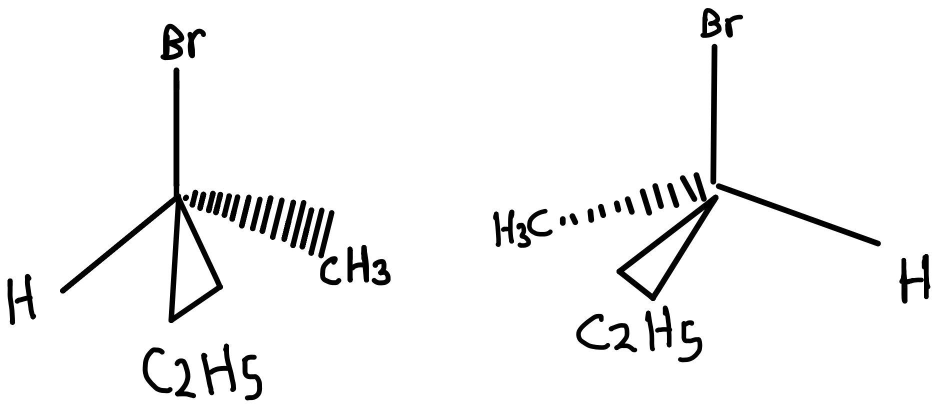


Mirror

Relationship between these 2 structures is Enantionmers

Any Chiral molecule with its mirror image are Enantiomers

3.Draw enantiomers of 2-Bromobutane

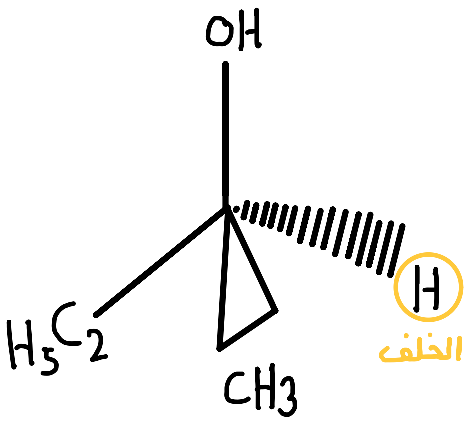


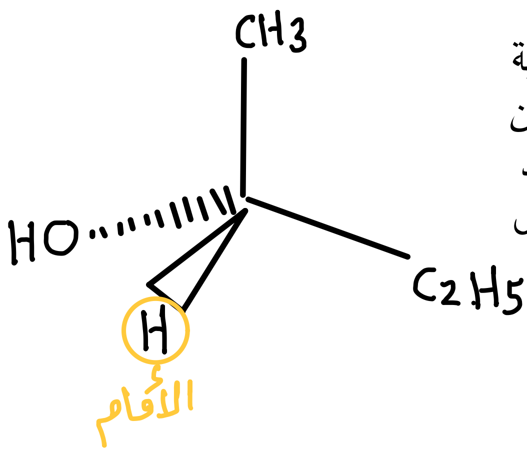
Locate groups as you want but should be mirror image

بتأكد اذا همه isomers وليس constitutional ثم بنطلع الconfigrations

اذا عكس بعض بكونوا enantiomers اذا زي بعض بكونوا identical

Example : Are they enantiomers?





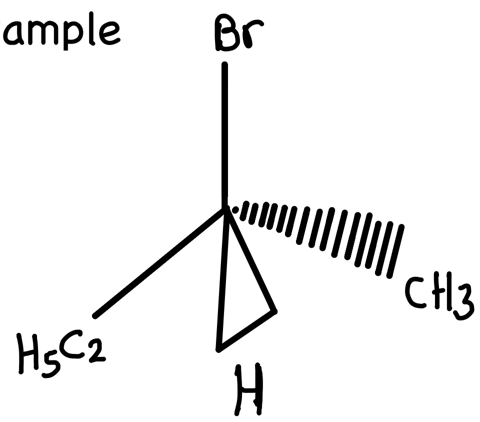
للوهلة الآولى تبدو الرسمة الثانية
ليست مرآة للرسمة الآولى ، ولكن
في هذه الحالة ، يجب أن تحدد
الconfigration في كل شكل

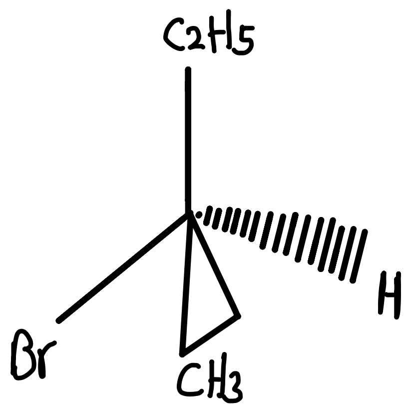
S-configration R-configration

If the configration is opposite to each other = we have **enantiomers** relationship.

But if configrations are the same the relationship is **identical**

Example





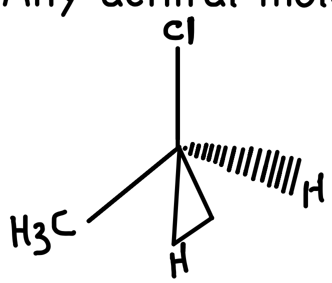
R- configration R-configration

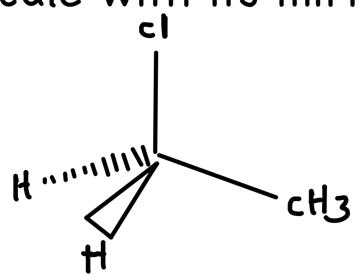
They are identical

Notes:

1.Enantiomers should have the same molecular formula (isomers) and the same arrangments of atoms (not constitutional isomers).

2.Any achiral molecule with its mirror image are identical





Identical

5.5 Properties of Enantiomers

1.They have identical physical properties such as melting point , boiling points , ...

They can not separated using physical methods

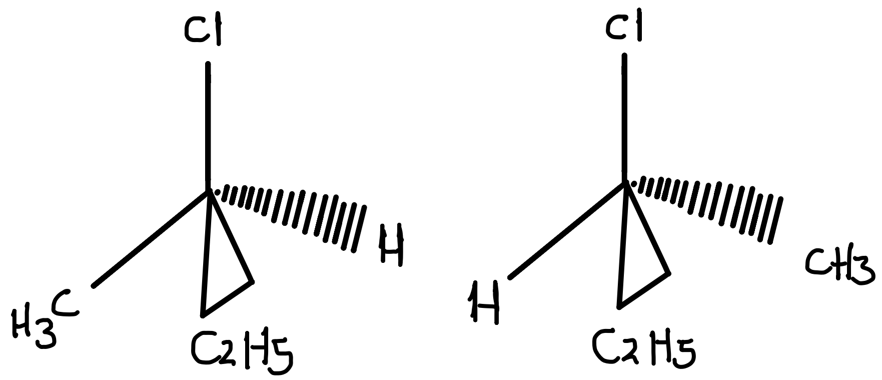
2.They are differ in two concepts:

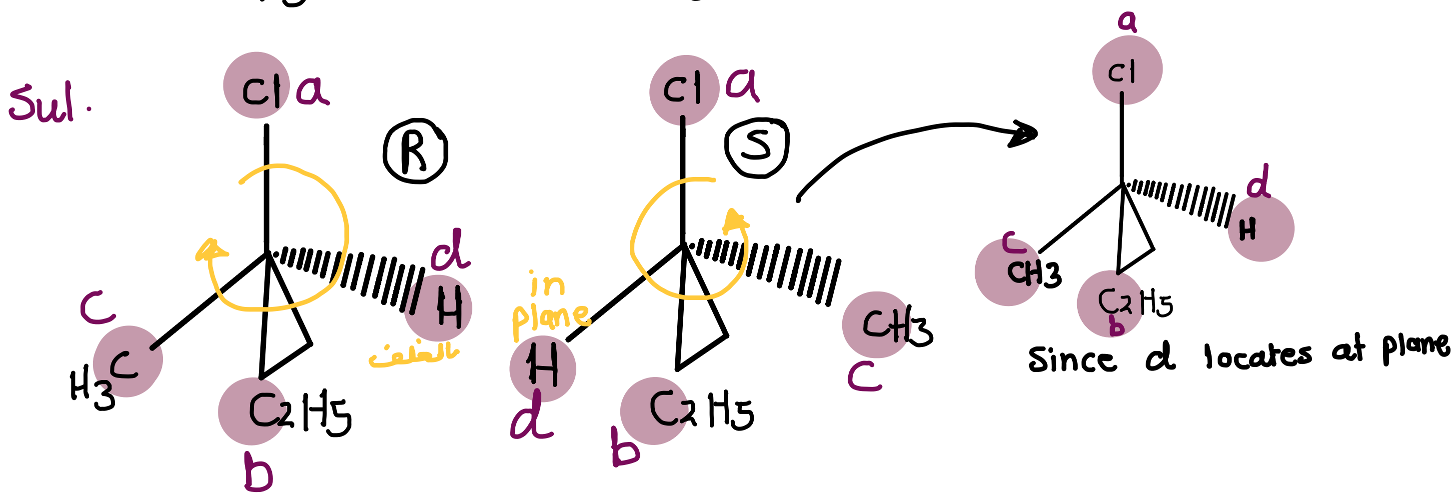
A.Reaction with Chiral reagent

B.Direction of rotation for a plane polarized light (section 5.5)

Now, let's take general examples

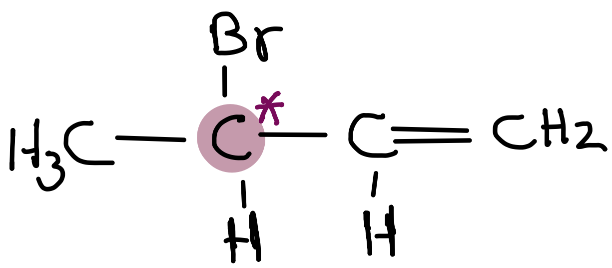
Q.Are the following structures identical or enantiomers?



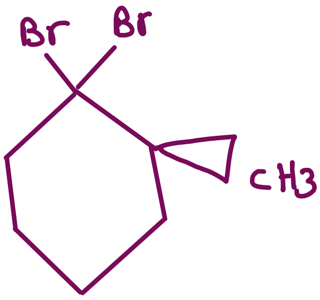


They are enantiomers

Q:Draw a chiral molecule that has a molecular formula C4H7Br



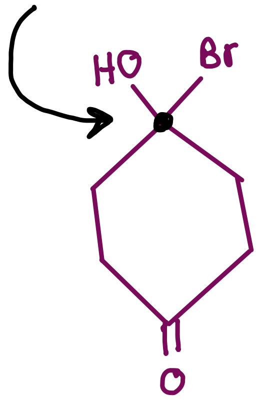
Q:Assign the configration



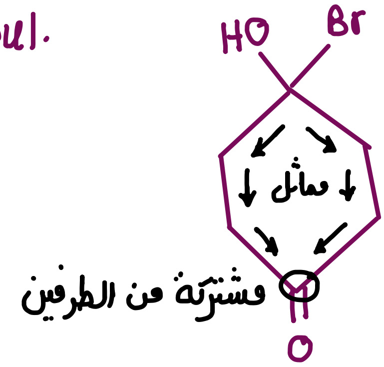
answer 8
S- configration

More examples regarding cyclic molecules

Ex1: Is it Chiral center?

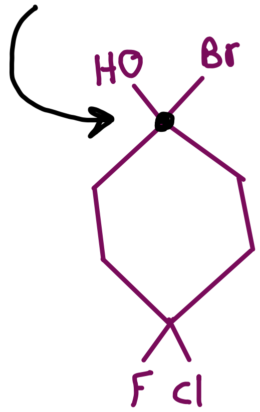


Sul.

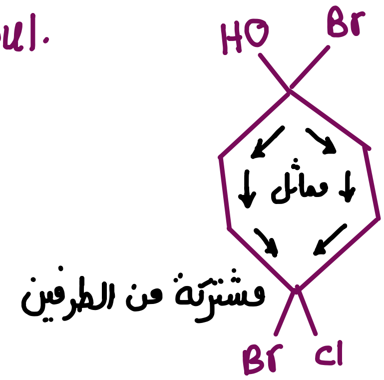


No 4 different groups is present so this molecule is achiral

Ex2 : Is it Chiral center?



Sul.



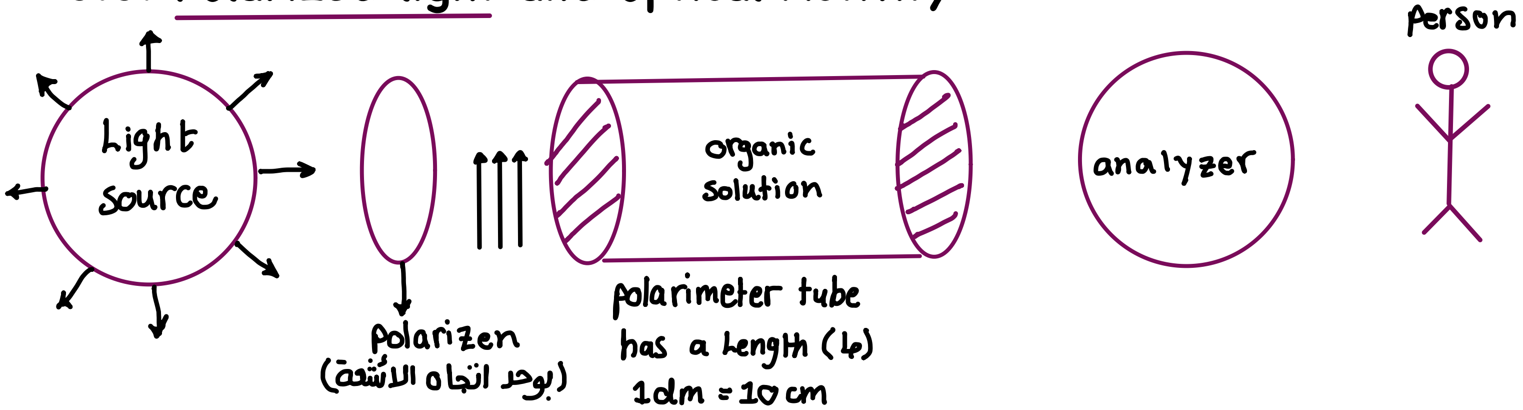
No 4 different groups is present so this molecule is achiral

The relationship

- **Enantiomers** → -2 molecules are mirror to each other and Chiral
  -2 molecules have opposite configurations
- **Identical** → -2 molecules are mirror to each other and AChiral
  -2 molecules have same configurations

5.5: Polarized light and optical Activity

→ Light radaition in Single plane



1.An instrument called "Polarimeter" is consisting of above parts

A.light source emits light into different diirections

B.Polarizen : makes light beam (waves) vibrat in parallel planes ↑↑↑↑↑↑

C.Polarimeter tube : has 2 windows

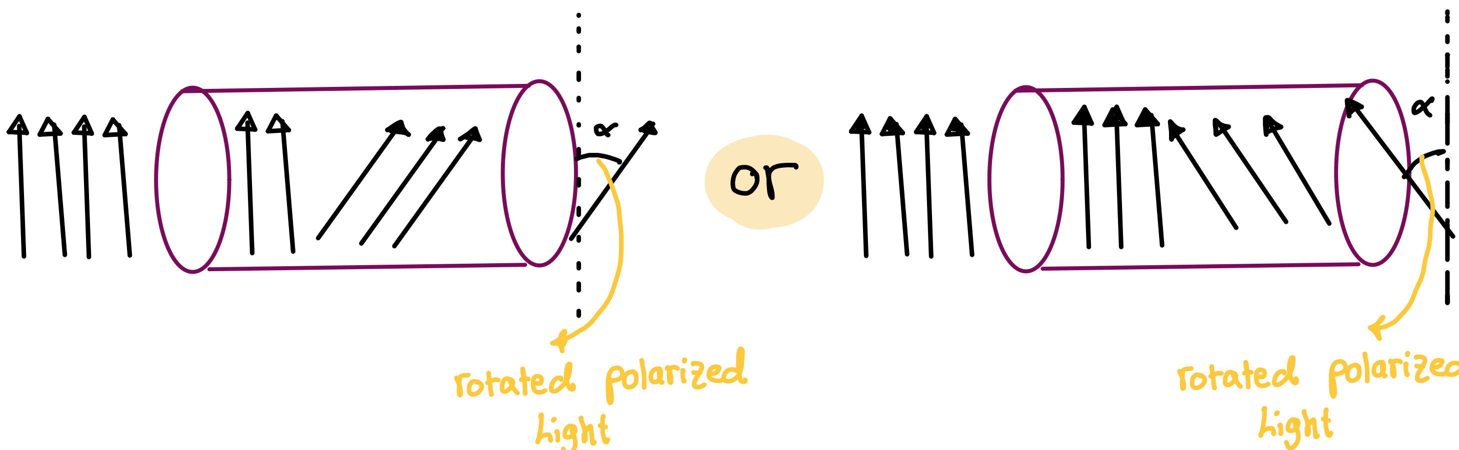
*Polarized light will enter from the first window and exit from the second window (both windows are glass & colorless)

*In this tube we have a solution of organic compound , for example 2-Bromobutane in Ethanol

D.Analyzer person will use analyzer to dekct the polarized light after it goes out from a second window

Principle of this insrument :

1.When we add certain organic solution into a polarimeter tube, these molecule may affect on the direction of polarized light and when they exit from a second windiw , they (polarized lights) have been rotated.



*هي للمركب نفسه D or L

2.Direction of the polarized light could be

- Clockwise = Organic molecules are said to have D or (+)
  Dextrorotatory

- Counterclockwise = Organic molecules are said to have L or (-)
  Levorotatory

*There is also : α Amount of rotation : Observed rotation
قيمة من التجربة

3.Specific rotation $[\alpha]$: physical property of optically active substance

$$[\alpha] = \frac{\alpha \text{ (observed rotation)}}{(\text{length of tube in dm}) * (\text{concentration of organic substence } (g/mL))}$$

4.Some organic molecules have no effect on the direction of polarized light (it means α = Zero) . No rotation is observed

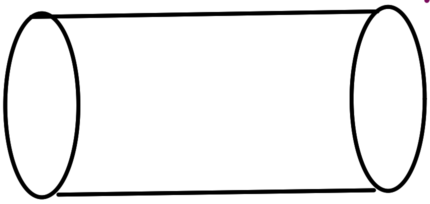
Now, let's talk in more details : Assuming the polarimeter tube is filled with following molecules : Individually

1.(R)-2-Chlorobutane "Chiral molecule"

2.(S)-2-Chlorobutane "Chiral molecule"

3.Butane "Achiral molecule"

4.Mixture of R & S 2-Chlorobutane in ratio at 50:50



ملاحظة : chiral molecules هنا هي من باب طرح أمثلة فقط وغير صحيح ربط R & - أو S & + إذ لا يمكن تخمين ذلك بغير التجارب.

* فقط يجب تمييز امتلاكهم إشارات متعاكسة دائمًا

- Chiral molecules
  - (R)-2-Chlorobutane
    Example : $\alpha = -15^{\circ}$ → Known by exeperament only
    It means this molecule rotates light conterclockwise by is degree.
  - (S)-2-Chlorobutane
    Example: $\alpha = +15^{\circ}$
    It means this molecule rotates light clockwise by is degree.

  Since R and S -Chlorobutane are enantiomers they have same value of α But opposite sign

  *No relationship between Configration and D&L

  لا علاقة بين المركب (R & S) و المركب (+ , -)

  كيف نعرف أن المركب سيعمل على دوران الضوء مع عقارب الساعة أو عكس عقارب الساعة ؟

  We can't determine unless we do an experiment

- Achiral

  Example : Butane

  α =Zero

- 50:50 : ratio of R & S

  α =Zero

This mixture is called Racemic mixture and it's optically inactive

عبارة عن Opposite configrations بنفس النسب

General conclusion :

1. Achiral molecule has. α =Zero , it is optically inactive.
2. Chiral molecule has. α ≠Zero , it is optically active
3. Racemic mixture is same ratios of enantiomers

Ex1.Calculate the specific rotation of (S)-2-Chloropentane knowing yhat 1 g was dissolved in 20 ml ethonol, and polarimeter tube is 20 cm and observed rotation of (R)-2-Chloripentane is +20°?

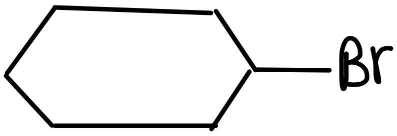
Sul.

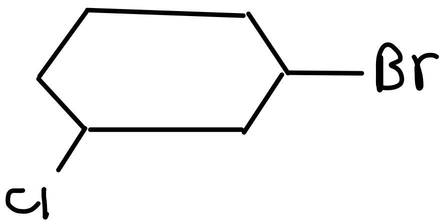
$$[\alpha] = \frac{\alpha}{l * con} = \frac{-20}{2dm * \frac{1}{20}} = -20^{0}$$

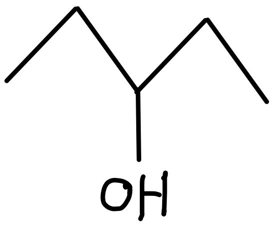
أعطانا ل R وطلب ل S لذلك يجب أنه تعاكسها بالإشارة

Ex2.Which of the following is optically active ?

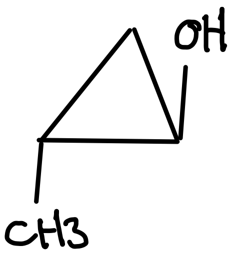
Should be chiral

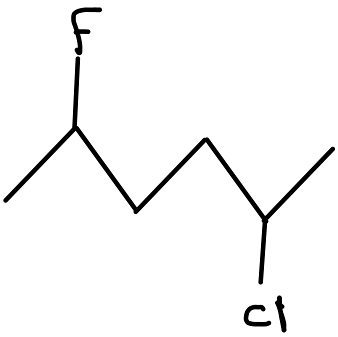






✗ ✓ ✓





✓ ✓

Ex3.Which one is a Racemic mixture ?

A.90:10 of R-2-Chlorobutane and S-2-Chlorobutan

B.50:50 of R-3-chlorohexane and hexane

C.50:50 of R-2-Chlorobutane and S-2-bromobutane

D.None of the above

Answer : D

Q.5.29 (page 176) : what happen to the α And $[\alpha]$ If -in measuring the optical activity of a solution of suger in water- we:

A. Doubled the concentration of the solution ?

B.Doubled the Length of the sample?

Answers:

A. $\alpha \rightarrow 2\alpha$

$[\alpha] \rightarrow$ Nothing

B. $\alpha \rightarrow 2\alpha$

$[\alpha] \rightarrow$ Nothing

5.4 : E - Z convention for cis-trans isomers

★ E: opposite side   Z: same side

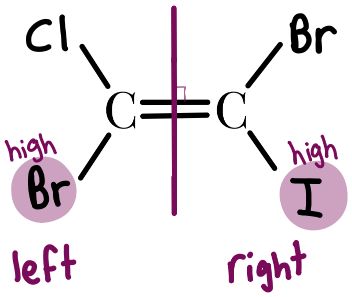
1) This type of isomer is only for alkenes ⟶ DOUBLE BOND

2) E and Z are included in naming just like cis, trans, R, S.

3) We apply rules of Cahn-Ingold-Prelog to find the higher priority

Note:
Trans is the same as E
Cis is the same as Z
If each carbon of the double bond had a hydrogen atom

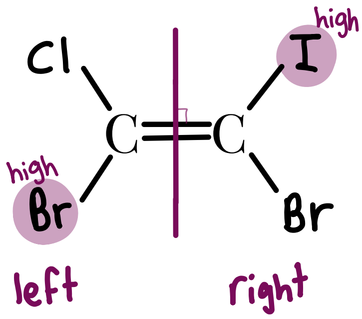
How to figure out whether it is E or Z ??



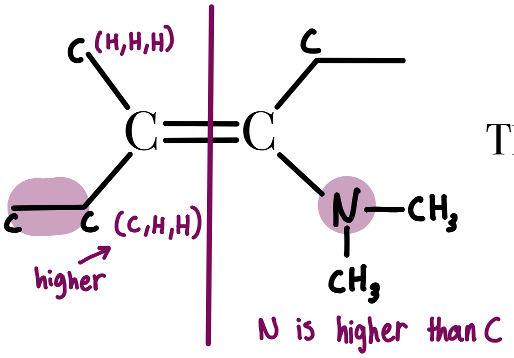
1) Draw a perpendicular line on the double bond

2) Decide which atom has the priority (higher atomic number) on left side and right side

3) Since both groups with higher atomic number are on the same side, this is a Z-isomer



This is an E-isomer since the atoms with higher atomic number are on opposite side.

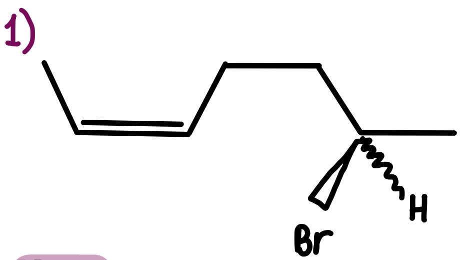


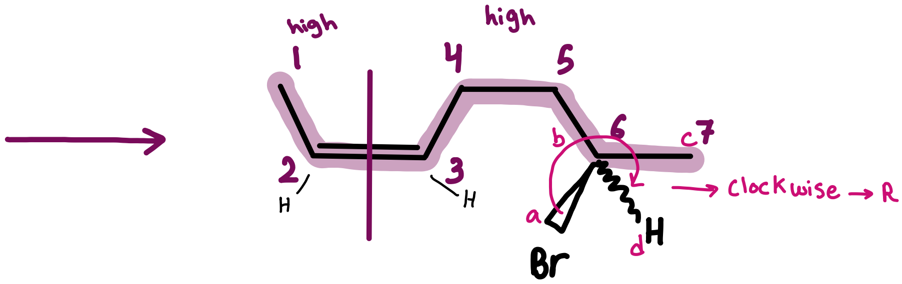
This is a Z-isomers since the atoms with higher atomic

Remember!!
C N O F →
Cl, Br, I ↓
Atomic number increase in these directions.

Q: name the following molecules

1)



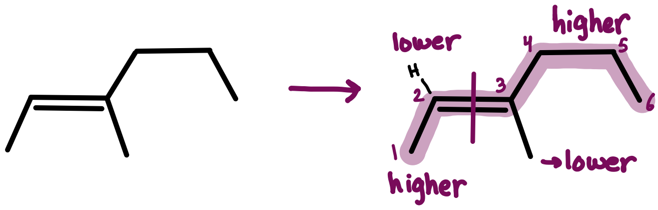


(Cis,R)-6-Bromo-2-heptene

Since each carbon of the double bond has a hydrogen, we can use cis or Z.

Notes:
Name the coumpound based on iupac, then take in consideration the steriochemistry part by determining whether the chiral center is R or S configuration, and whether the alkene is cis or trans.

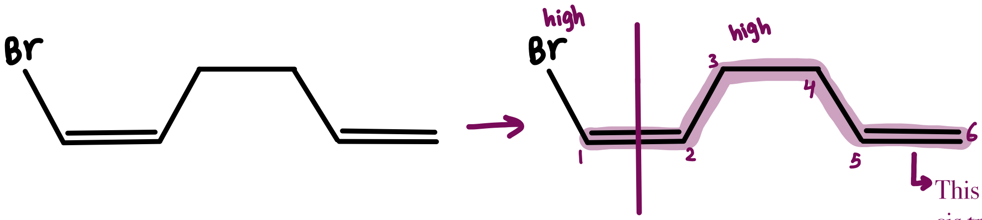
2)



E-3-methyl-2-hexene

In this case we can't replace E with trans because one of the double bond carbons do not have a hydrogen

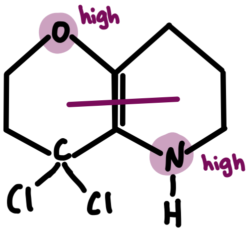
3)



Cis-1-Bromo-1,5-hexadiene

↳ This bond is not considered in the cis trans naming because one of the carbons has two hydrogens

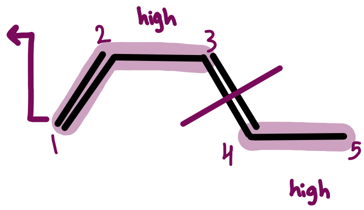
- Is this E or Z ??



It is an E-isomer

- draw : E-1,3-pentadiene
  ↳ opposite

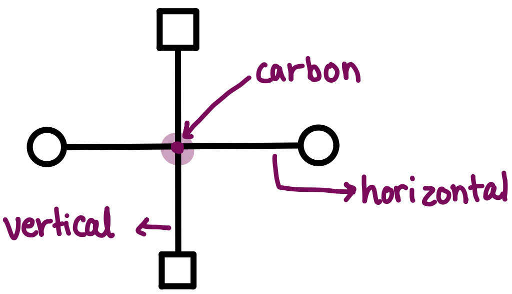
This bond is not considered in the cis trans naming because one of the carbons has two hydrogens

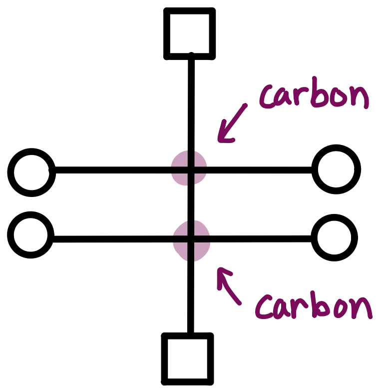


5.7: Fischer projection formulas

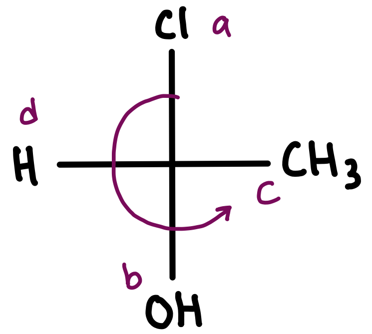
The representation of chiral or achiral molecules in 2 dimensions instead of 3 dimensions.

★Each intersection point represents a carbon





How to decide whether the compound is or R or S configuration when it is in 2 dimentional shape?



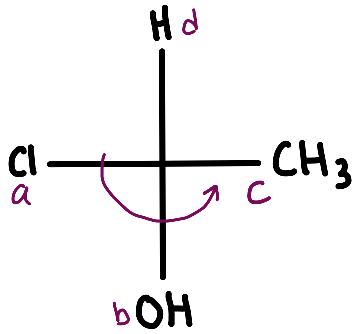
1) Determine a,b,c,d

2) If a,b,c were clockwise it is R, if the were counterclockwise it is S.

3) If d was on the horizontal line we inverse the configuration

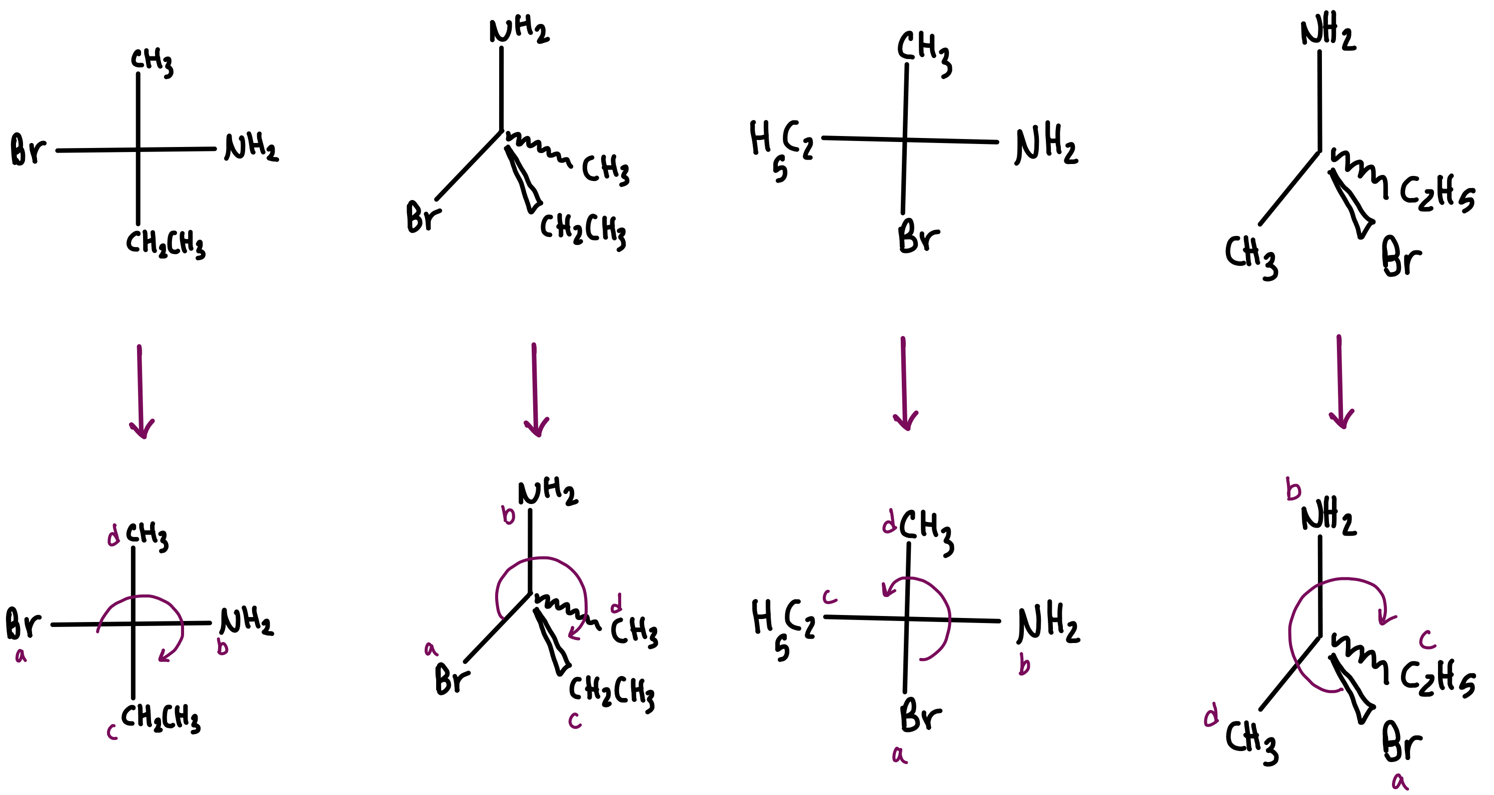
Since it is counterclockwise, it should be S-configuration but we inverse the configuration because d is on the horizontal line

It is R-configuration



In this example, d is on the vertical line and a,b,c are counterclockwise so it is S-configuration.

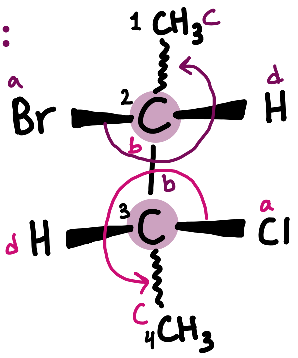
Q: Which has s-configuration.



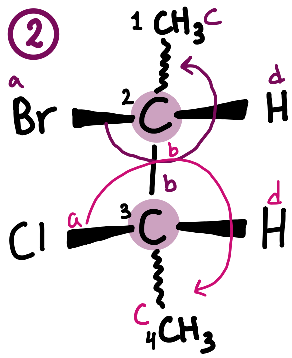
R-configuration **R-configuration** **S-configuration** **R-configuration**

5.8: compounds with more than one chiral center; Diastereoisomers

Ex:

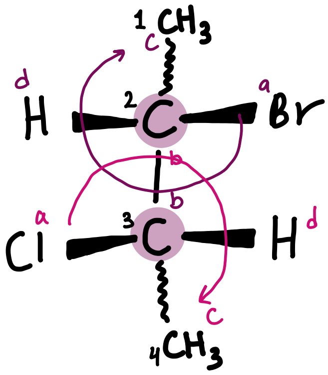
① 

Notice:
In both carbons, d is towards the front, so we invert the configuration
Both chiral centers are R-configuration.

② 

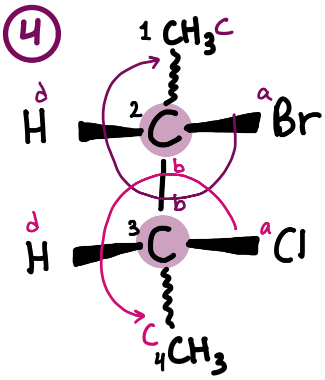
Carbon 2: R-configuration.

Carbon 3: S-configuration

③ 

2: S-configuration

3: S-configuration

④ 

2: S-configuration

3: R-configuration

* Name the previous molecules:

1) (2R,3R)-2-bromo-3-chlorobutane

2) (2R,3S)-2-bromo-3-chlorobutane

3) (2S,3S)-2-bromo-3-chlorobutane

4) (2S,3R)-2-bromo-3-chlorobutane

Notice that we include the configuration of each chiral center in the naming

* What is the relationship between the ex 1&2, and 2&4 ??

1&2

Carbon 2: in the first ex it is R and the second ex it is still R → **No change**

Carbon 3: in the first ex it is R and the second ex it is S → **There is change**

When one carbon change configuration and the other doesn't, we have diastereoisomers

2&4

Carbon 2: in the second ex it is R and the fourth ex it is S → **There is change**

Carbon 3: in the second ex it is S and the fourth ex it is R → **There is change**

When both carbons change configurations, we have enantiomers because they are like a

Notes:

- If one of the carbons changed configurations then the two compounds are diastereoisomers
- If both carbons changed configurations then the two compounds are enantiomers, because they are like a mirror

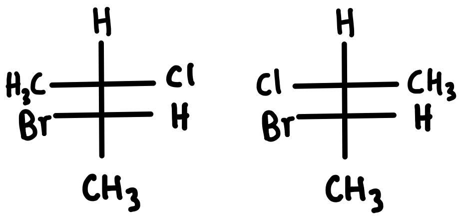
Diastereoisomers:

- Are stereoisomers but not mirror image to each other.
- They can't be superimposable since they are not miror.
- They have different physical properties and can be separated using physical methods such as distillation.

Summary of relationships

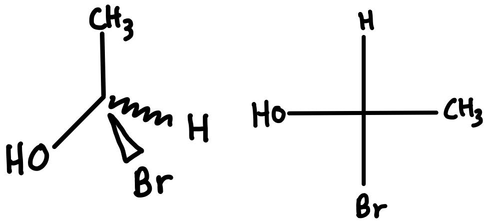
- **Isomers**
  - Constitutional isomers
  - Stereoisomers
    - Conformers
    - Configurational
      - Diastereoisomers
        - Cis-trans: In alkenes and or 2-subs in cycloalkenes
        - E -Z: In alkenes
        - When some configurations are inverted and others are kept
      - Enantiomers: All configurations are inverted.

What is the relationship between the following compounds?

1) 

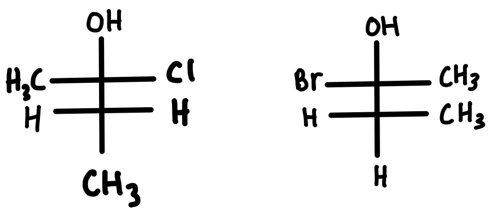
→ Carbon 1: R ⟶ S
Carbon 2: S ⟶ S

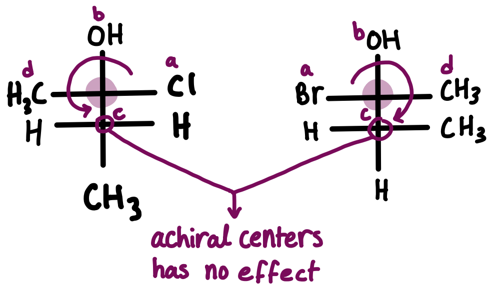
Diastereoisomers

2) 

→ Both are R configuration

Identical

3) 



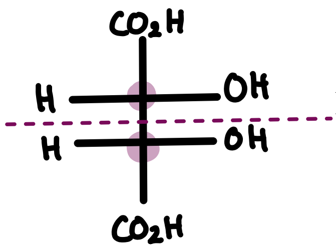
Do not forget to invert the configurations in both compounds since d is on the horizontal line.

R-configuration ⟶ S-configuration

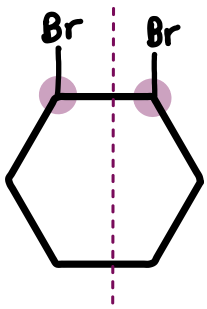
Enantiomers

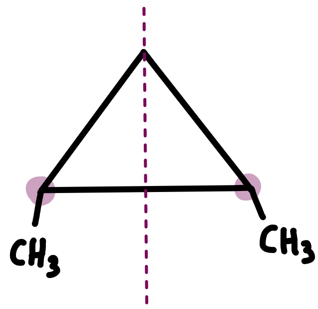
5.9 : Meso compounds

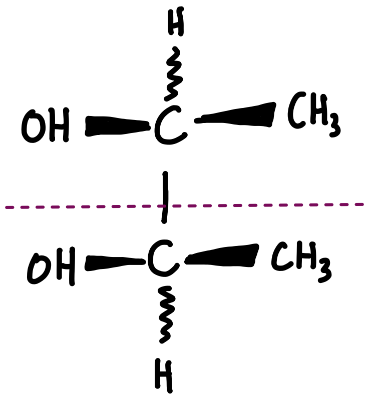
Are compounds the have at least two chiral centers and a plane of symmetry



Plane of symmetry

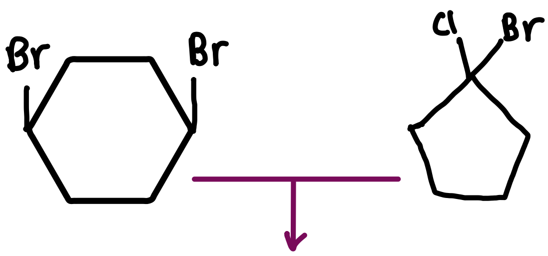




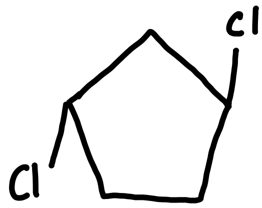


Note:no miso molecule has inly one chiral center

Important ex: the following compounds are not meso compounds



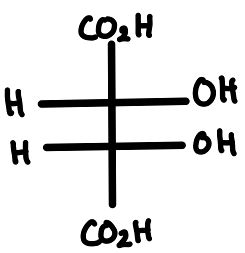
No chiral center



There is chiral center but there is no plane of symmetry.

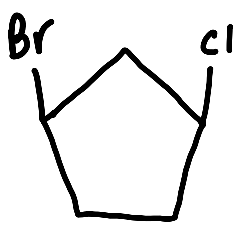
*** Although meso compounds have chiral centers, they are Achiral molecules ***

Question: in which of the following α =zero, and optically inactive?



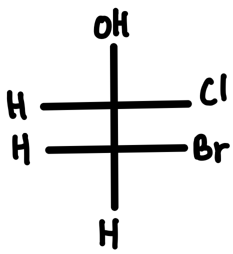
Meso compound
Achiral

$\alpha = 0$ ✓



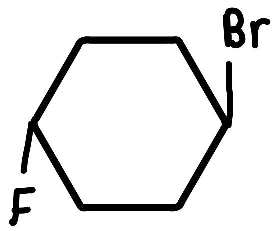
Chiral molecule

$\alpha \neq 0$



Chiral molecule

$\alpha \neq 0$

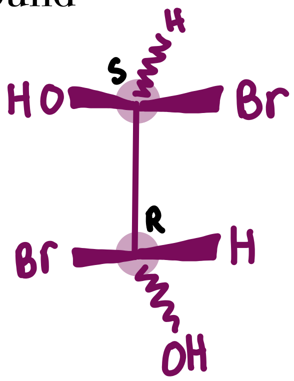


Achiral molecule

$\alpha = 0$ ✓

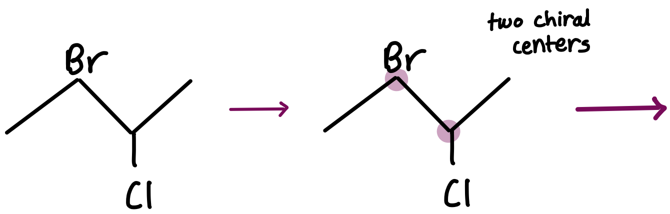
Any molecule that has identical atoms of two chiral centers and one chiral center has S configuration and other chiral center has Rconfiguration this is a meso compound

Ex



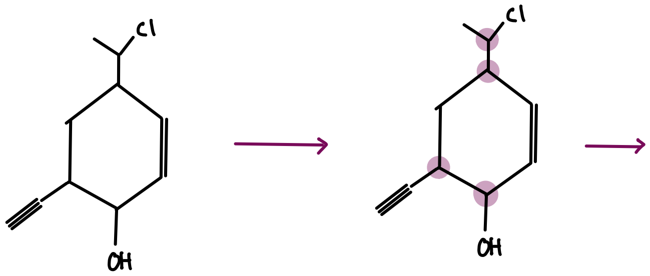
To calculate the maximum possible number of stereoisomers use a formula 2^n where n=(number of chiral centers)+(number of double bonds).

↳ Not always used



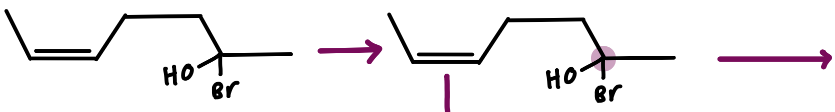
n = 2

Number of stereoisomers = $2^2 = 4$



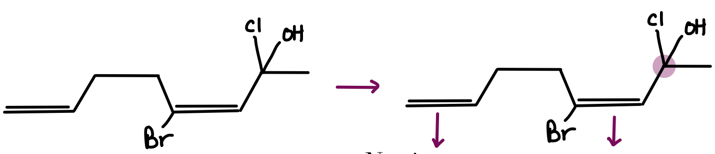
n = 4

Number of stereoisomers = $2^4 = 16$



Number of stereoisomers = $2^2 = 4$

This alkene is cis in this drawing, but it can also be drawn as trans, it acts as a chiral center



No cis or trans so it does not act as chiral center.

Acts as chiral center

Number of stereoisomers = $2^2 = 4$

5.10 :Some definitions in stereochemistry

- Conformers: interconvertible by rotation about single bond
- Configurational isomers: not interconvertible by rotation, only by breaking and making bonds
- Chiral molecules: mirror image, not superimpossable on itself
- Achral molecules: molecules and mirror image are identical
- Enantiomers: mirrored image, have opposite configurations at all stereogenic centers.
- Diastereoisomers: they are stereoisomers but not mirror images, have same configuration at one or more chiral center, but differ at the remaining stereogenic centers.

5.11: Stereo chemistry and chemical reactions

Two concepts:

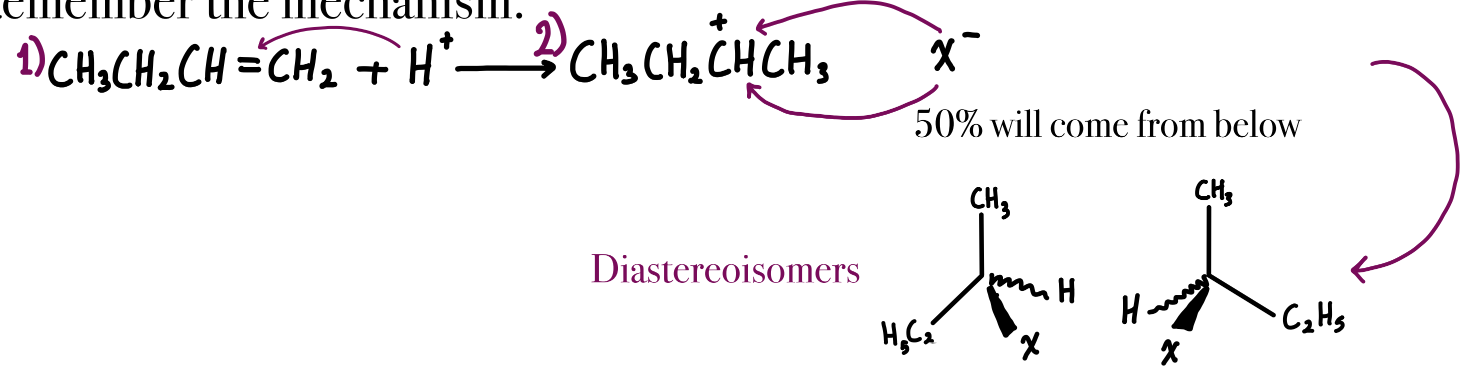
A)Reactants has no chiral center:

We should include stereochemistry in the product since it contains a chiral center

$$CH_3CH_2CH=CH_2 + HX \longrightarrow CH_3CH_2\underset{X}{\underset{|}{C}}HCH_3$$

No ciral center — One chiral center

Remember the mechanism:

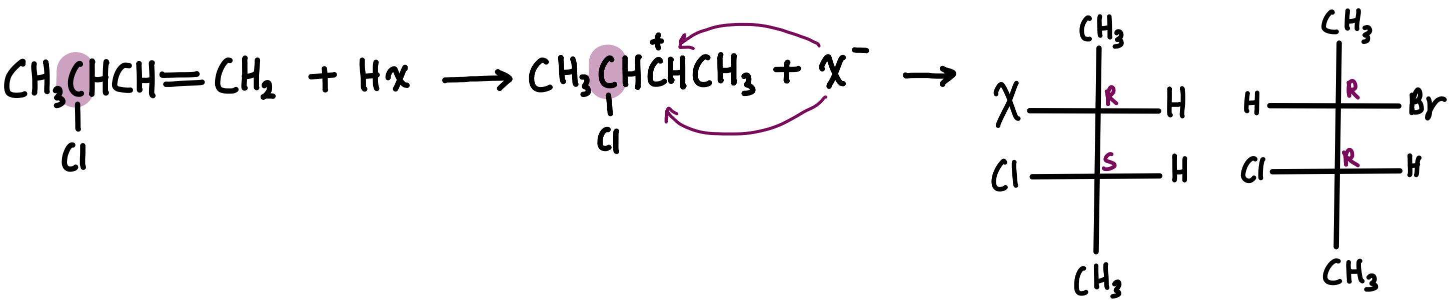


50 : 50

Racemic mixture obtained

B)Reactants has chiral center:

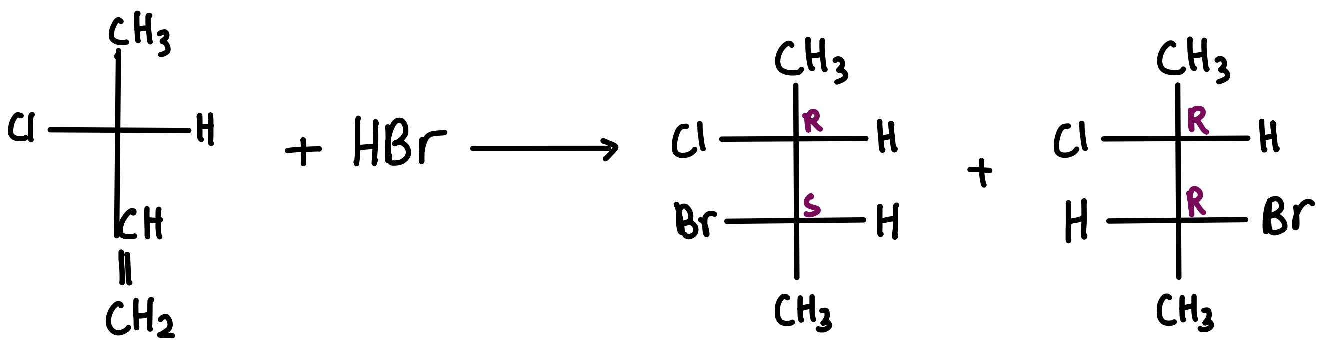
The chiral center in the reactants has no role in this reaction now include stereochemistry and the



Diastereoisomers 50 : 50

Specific examples

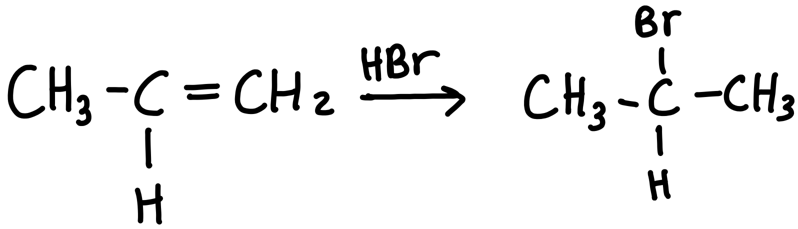
★



50:50 diastereoisomers

Not Racemic mixture

★



No chiral center is produced,no need for 3 dimensional drawing