Name ______________________________

Lesson 4: Stereochemistry

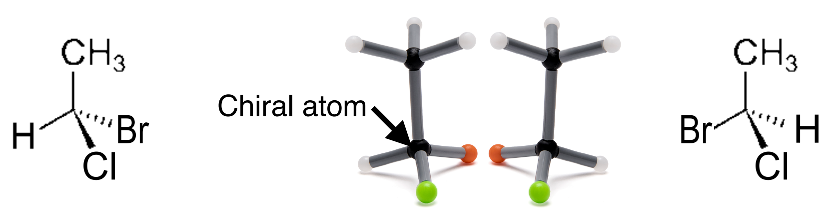
Lesson four will delve into the fascinating world of stereochemistry, exploring the properties and relationships of chiral molecules. By visiting the provided link to Khan Academy's organic chemistry videos on chirality, you will gain a comprehensive understanding of enantiomers, the R,S naming system, and various stereoisomeric relationships. Through hands-on activities and molecular manipulation, you will grasp the intricate concepts surrounding chirality and its applications in organic chemistry. So let's embark on this journey of discovery and expand our knowledge of stereochemistry.

THINK! Distinguish between a chiral molecule and enantiomers?

A chiral molecule possess a chiral center, typically an sp^3 hybridized atom that features four distinct groups bonded to it in a way that its mirror image cannot be superimposed onto it. Enantiomers are a pair of chiral molecules that are non-superimposable mirror images of each other. Enantiomers have the same connectivity of atoms and bonds, but their three-dimensional spatial arrangement differs.

Go to https://www.khanacademy.org/science/organic-chemistry
Watch the videos on Chirality.

1. Build and rotate the two molecules shown below to determine if they are mirror images and nonsuperimposable. Are the two molecules enantiomers? Defend your answer.



Chirality is crucial in biology because many biological processes and interactions rely on the specific three-dimensional arrangement of molecules. In living organisms, cells are composed mostly of chiral molecules, such as amino acids and sugars. In biological molecules, chirality influences their biological activity, including enzymatic reactions, receptor binding, and drug interactions. For example, enantiomers, which are mirror images of each other, can exhibit vastly different effects in the human body, where one enantiomer may be therapeutically beneficial while the other can be inactive or even harmful. Therefore, understanding chirality is essential in fields like pharmacology, biochemistry, and drug development to ensure safe and effective treatments.

THINK! What is the R,S naming system used for, and how does it designate enantiomers?

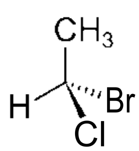
The R,S naming system provides a systematic way to assign labels (R or S) to chiral centers based on the spatial arrangement of substituent groups around them. To determine the R or S designation using the Cahn-Ingold-Prelog (CIP) rules.

Go to https://www.khanacademy.org/science/organic-chemistry
Watch the videos on Enantiomers.

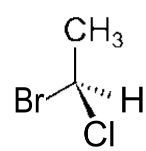
Cahn-Ingold-Prelog (CIP) rules:

- Assign priority: Assign a priority to each substituent bonded to the chiral center based on the atomic number of the atoms directly attached to the chiral center. The higher the atomic number, the higher the priority.
- Orient the molecule: Orient the molecule so that the lowest priority group is directed away from you (into the page) while looking at the chiral center.
- Trace a path: Trace a path from the highest priority group (1) to the second highest priority group (2) to the third highest priority group (3). This path can be either clockwise or counterclockwise.
- Determine the configuration: If the path is clockwise (R), the configuration of the chiral center is designated as R. If the path is counterclockwise (S), the configuration is designated as S.

2. The R,S (Cahn, Ingold, Prolog) naming system is used to designate between the enantiomers. Name each enantiomer.

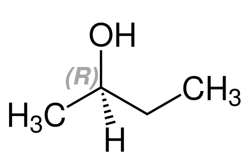


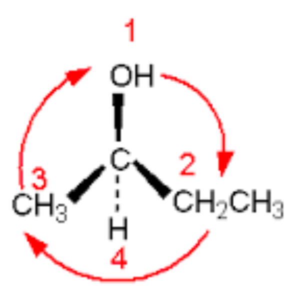
(   )-1-bromo-1-chloroethane



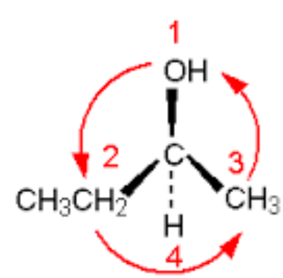
(   )-1-bromo-1-chloroethane

3. There are not many “tricks” to doing well in organic chemistry, but the Single Swap Rule may be helpful. Here’s how it works. Take a molecule with a chiral atom, also called a stereocenter, like (R)-2-butanol. Switching ANY TWO substituents will give you (S)-2-butanol. Build a molecule of (R)-2-butanol. Switch any two substituents and verify that the resulting molecule is (S)-2-butanol.



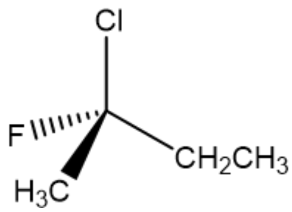


(R)-2-butanol



(S)-2-butanol

4. Disassemble the molecules and build 2-chloro-2-fluorobutane. Order the substituents. Put the 4th ranked substituent in the back and then determine whether the 1st, 2nd, and 3rd ranked substituents trace a clockwise (R) or counterclockwise (S) path.



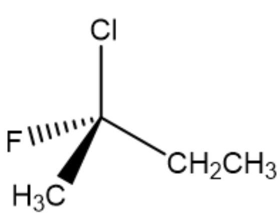
What is the name of this enantiomer?

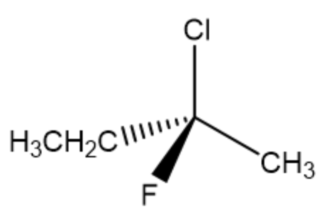
THINK! What are diastereomers, and how do they differ from enantiomers?

Diastereomers are stereoisomers with different configurations at some, but not all, chiral centers in a molecule. They have distinct physical and chemical properties and may or may not exhibit optical activity. Enantiomers have opposite configurations at all chiral centers and always display optical activity.

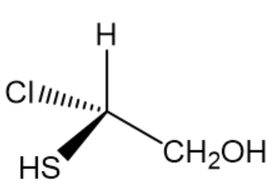
Go to https://www.khanacademy.org/science/organic-chemistry
Watch the videos on Stereoisomeric relationships.

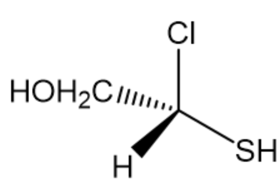
5. A pair of stereoisomers can be enantiomers, diastereomers, or the same molecule (called a meso compound). Diastereomers are stereoisomers that are not mirror images of each other and non-superimposable. What is the relationship between the two molecules? It may be helpful to build the molecules. Defend your answer.



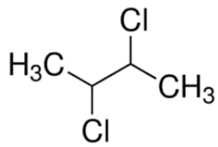


6. What is the relationship (meso compounds, enantiomers, or diastereomers) between the following two molecules? It may be helpful to build the molecules. Defend your answer.





7. How many chiral centers do you see in this molecule? Draw the 3D structures of (R,R)-, (S,S)- and (R,S)- 2,3 dichlorobutane.



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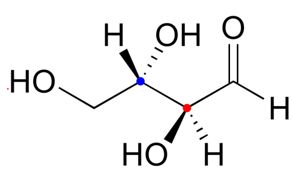
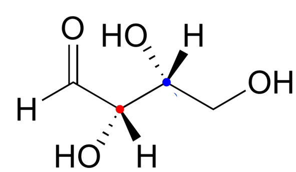
Stereoisomer Shortcut:

- If both of the chiral centers are of opposite configuration, such as (RR and SS) or (RS and SR), they are enantiomers.
- If at least one, but not all of the chiral centers are opposite, such as (RR and RS), they are diastereomers.
- This shortcut does not take into consideration the possibility of additional stereoisomers due to alkene groups. We will go there later.

8. What is the relationship (meso compounds, enantiomers, or diastereomers) between the following two molecules? It may be helpful to build the molecules. Defend your answer.

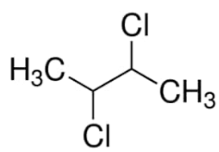


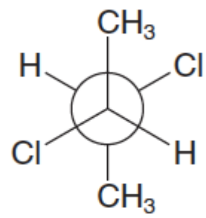


Just to make things clear, a meso compound is a molecule that has chiral centers but also has an internal plane of symmetry. This renders the molecule achiral (not chiral). A meso compound does not have an enantiomer and it does not rotate plane polarized light.

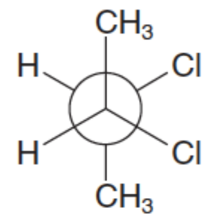
The Meso Trap is a common feature on exams and tests to make sure that you understand the concept of chirality and that you are paying attention.

9. Let's look at the Newman projects for the compound from question #7. Build each molecule and look for the plane of symmetry. Which molecule (A, B, or C) is meso?

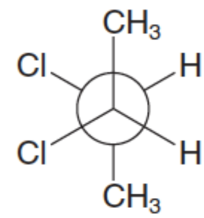




A

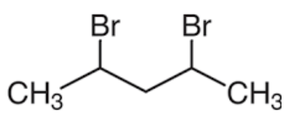


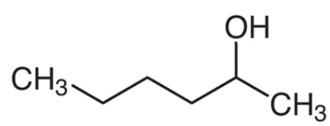
B

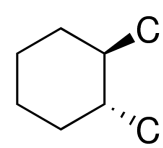


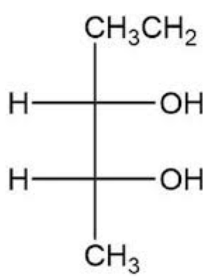
C

10. Identifying a meso compound means being able to identify a plane of symmetry in a molecule. It's important to realize that the plane of symmetry can cut either through a bond or through an atom. Circle the meso compounds below.

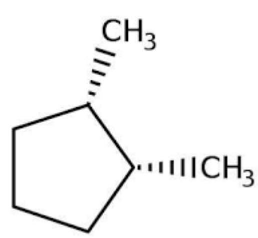


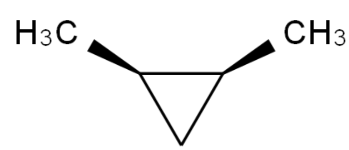






(Fisher projection)





In summary, lesson four explored the properties and relationships of chiral molecules. The R,S naming system, which designates the configuration of chiral centers and differentiates enantiomers, was introduced. Meso compounds and diastereomers were also explained, highlighting their differences from enantiomers. Overall, lesson four provided a comprehensive overview of stereochemistry and and its applications in the biological and chemical sciences.