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Experiment 10 – Stereochemistry & Use of Molecular Models

Discussion and Procedure

This lab will help you discover and learn about stereochemistry and the various terms associated with it. You will be provided with a model kit. Bring your course guide to help you with some of these concepts. Answer the questions below each section at the end of this lab (to be submitted to your instructor).

Construct a model (called structure **A**) in which a carbon atom (represented by a black ball) has four different colored balls attached to it – white, green, red, and blue – representing four different substituents attached to the central carbon. The white ball represents hydrogen, the green ball represents chlorine, the red ball represents bromine, and the blue ball represents iodine. The carbon of structure **A** is called a stereocenter.

Q-1) Using wedges and dashes, draw this molecule in at least four different orientations. In each orientation that you draw, the same two atoms should NOT both be on wedges and dashes. Practice rotating the molecule in your hands and on paper, until you are comfortable with viewing molecules in three dimensions.

*Q-2) Does molecule **A** have a plane of symmetry?*

Replace the red ball with a green one.

Q-3) Does the revised model have a plane of symmetry now? Find an orientation in which it is easy to draw this plane of symmetry, then draw the molecule using wedges and dashes and draw a dotted line representing the plane of symmetry.

Now, rebuild structure **A**.

Put the model on a flat surface so that the white ball points up. Look straight down the model and, starting with the green ball and proceeding clockwise, record the order of the balls. Now, construct a model (structure **B**) which is a mirror image of structure **A**. Place structure **B** on a flat surface adjacent to structure **A** with the white ball of both pointing at the ceiling.

*Q-4) Try superposing (aligning) all five atoms at the same time. Can you superpose structure **B** and structure **A**? How many atoms can you superpose at one time? Try to improve on this number until you think that you cannot get any more atoms to superpose at any one time.*

*Q-5) Are structure **A** and structure **B** identical?*

Q-6) How do the structures differ?

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The two structures **A** and **B** are chiral molecules. A chiral molecule does not have a plane of symmetry and has a non-superposable mirror image. The pair of structures that are non-superposable mirror images are called enantiomers. These two compounds differ only in the way they rotate plane-polarized light. Each enantiomer is said to be optically active.

On both structures **A** and **B**, replace the red ball with a green ball and call the new structures **C** and **D**.

*Q-7) Are structures **C** and **D** still mirror images of each other?*

*Q-8) Do **C** and **D** have internal planes of symmetry?*

*Q-9) Can you superpose structures **C** and **D**? Are these molecules identical or different?*

Structures **C** and **D** represent achiral molecules. Achiral molecules have a superposable mirror image, a plane of symmetry, and do not rotate plane-polarized light. Achiral molecules are optically inactive. (Remember: the prefix a- means the same as non-)

The *R/S* convention is used to designate the configurations at stereocenters. The attached atoms to the stereocenter are arranged in order of increasing atomic number. Thus, higher atomic number means higher priority. If two atoms have the same priority, you move to the next atom out and compare those atoms. Continue this until you break the tie. Look at the molecule from the side opposite the group with the lowest priority. If you count the highest to lowest priority and you go in a clockwise direction, you have the *R* configuration. If you move counterclockwise, the stereocenter is the *S* configuration.

Rebuild structures **A** and **B**. Make sure that **B** is the mirror image of **A**.

In our model kits, the black balls represent carbon atoms, the white balls represent hydrogen, the green balls represent chlorine, the red balls represent bromine, and the blue balls represent iodine.

*Q-10) Using wedges and dashes, draw molecules **A** and **B**.*

Working with structure **A**, interchange any two balls attached to the stereocenter. Call this molecule **E**.

*Q-11) What happened to the configuration at the stereocenter? How does molecule **E** compare to molecule **B**?*

In your molecule **E**, change two *different* balls (not the same ones as you did in the previous step). Call this molecule **F**.

*Q-12) How does molecule **F** compare to molecule **B**? How does it compare to your original molecule **A**?*

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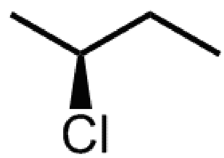
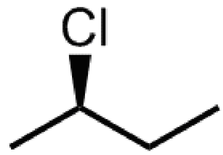
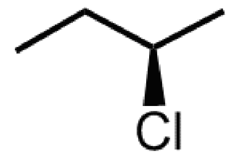
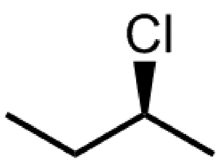
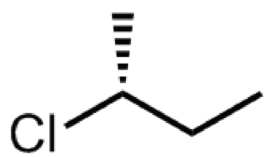
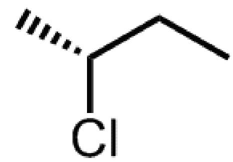
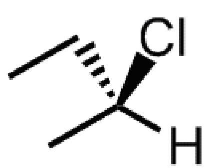
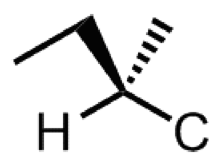
Q-13) Repeat this process by swapping two groups at a time several more times. How many different stereoisomers do you find through this process?

Build a model of *(R)*-2-chlorobutane and a model of *(S)*-2-chlorobutane

Q-14) Using your models, determine which of the structures below have the R configuration and which have the S configuration. To verify your answer, rotate each model to align it with the structure that is drawn below. Label each structure in your Report Form along with the appropriate R or S designations.

Two compounds with the same molecular formula but a different arrangement in space are called stereoisomers. A stereoisomer that has a non-superposable mirror image is called an enantiomer. A stereoisomer with a non-superposable non-mirror image is called a diastereomer. Diastereomers usually have two or more stereocenters.

Now build the following two molecules:

(2R, 3R)-2,3-dichlorobutane = Molecule **G**
(2S, 3S)-2,3-dichlorobutane = Molecule **H**

Label each model with a piece of tape that has the molecule’s letter (**G** or **H**).

Q-15) Determine the relationship between molecules **G** *and* **H**.

Please put your model kit away exactly the way that you found it.

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Data and Questions for Experiment 10

1. Using wedges and dashes, draw this molecule in at least four different orientations. In each orientation that you draw, the same two atoms should NOT both be on wedges and dashes. Practice rotating the molecule in your hands and on paper, until you are comfortable with viewing molecules in three dimensions.

2. Does molecule **A** have a plane of symmetry? Briefly explain.

3. Does the revised model have a plane of symmetry now? Find an orientation in which it is easy to draw this plane of symmetry, then draw the molecule using wedges and dashes and draw a dotted line representing the plane of symmetry.

4. Try superposing (aligning) all five atoms at the same time. Can you superpose structure **B** and structure **A**? How many atoms can you superpose at one time? Try to improve on this number until you think that you cannot get any more atoms to superpose at any one time.

5. Are structure **A** and structure **B** identical? Mark ONE: ☐Yes ☐ No

6. How do the structures differ?

7. Are structures **C** and **D** still mirror images of each other? ☐Yes ☐ No

8. Do **C** and **D** have internal planes of symmetry? ☐Yes ☐ No

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9. Can you superpose structures **C** and **D**? ☐ Yes ☐ No

   Are these molecules identical or different? ☐ Identical ☐ Different

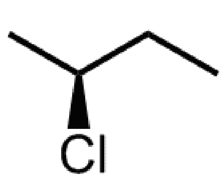
10. Using wedges and dashes, draw molecules **A** and **B**.

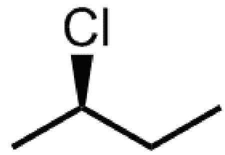
11. What happened to the configuration at the stereocenter? How does molecule **E** compare to molecule **B**?

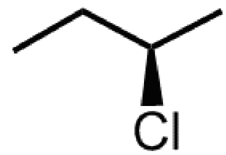
12. How does molecule **F** compare to molecule **B**? How does it compare to your original molecule **A**?

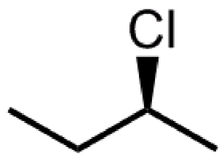
13. Repeat this process by swapping two groups at a time several more times. How many different stereoisomers do you find through this process?

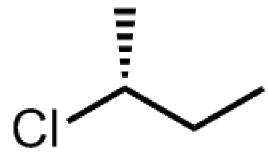
14. Using your models, determine which of the structures below have the *R* configuration and which have the *S* configuration. Label each structure below with the appropriate *R* or *S* designations.

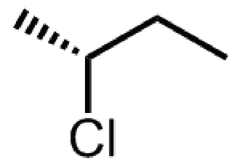


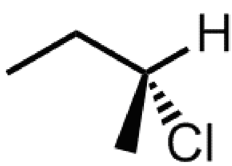


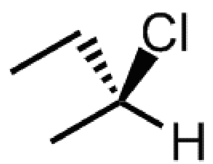


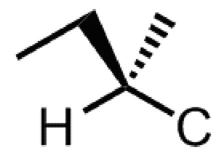












15. Determine the relationship between molecules **G** and **H**.