

A New and Simple Method for the Specification of Absolute Configuration of Allenes, Spiranes, Alkylidenecycloalkanes, Helicenes and Other Organic Complex Systems

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Abstract: Specification and prediction of the absolute configuration of some of organic chiral molecules without stereogenic center described by new easy method specially the molecules that their stereochemistry are difficult and troublesome. The specification of absolute configuration of allenes, spiranes, alkylidenecycloalkanes, biphenyl derivatives, helicenes, *trans*-cyclooctenes and other organic systems specified by means of this method. It is sufficient that to be regard two “planar” and “out of plane” parts in the molecule and then to be assume as an hypothetical tetrahedral form for the molecule. In this method, we always regard the highest and lowest-ranked substituents in the “out of plane” part of the molecule. The highest-ranked substituent to be nearer toward an observer in this part of the molecule then ranked them in order of decreasing preference in this two parts and then specified absolute configuration according to the Cohn-Ingold-Prelog notational system.

1. Introduction

The precise of substituents at a chiral centre is its absolute configuration. Neither the sign nor magnitude for the rotation by itself provides any information concerning the

absolute configuration of a substance. While no absolute configuration was known for any substance before 1951, organic chemist had experimentally determined the configuration of thousands of compounds relative to one another (their relative configurations) through chemical interconversion [1].

Historically the Cahn-Ingold-Prelog rules were first formulated to deal with the problem of the absolute configuration at the stereogenic center, and this their major application. This method is called the “sequence rule” by it’s developers, is used to specify the absolute configuration at the stereogenic center [1,2]. Stereoisomers are described by specifying their topology and the nature of their relationship to other stereoisomers of the same constitution [3]. Stereoisomers differ in configuration and in order to distinguish between stereoisomeric compounds it is necessary to specify the configuration [4-6].

The specifying of absolute configuration of molecules possessing axial symmetry, i.e., those which are dissymmetric but not asymmetric carbon which might serve as the basis for configurational correlations [7]. Molecule of C_2 symmetry such as, allenes, spiranes, hindered biphenyls, hexahelicenes and *trans*-cyclooctenes are of particular interest, and ingenious solutions have been provide for this cases by both chemical [8] and crystallographic [9-11] methods. Chiral molecules with C_2 symmetry are of interest because of their chiroptical properties (i.e., rotation of the sodium D line, ORD and CD). Using the nature of this properties several examples of absolute configuration assignment to molecules of the chiral allene and spiran type possessing that symmetry has been described in recent years [12]. Lowe [13] pointed out that allenes (including those with C_2 symmetry) with the absolute configuration (Figure 1) are dextrorotatory at the sodium D-line when A is more polarizable than B and X is more polarizable than Y. This rule has been useful in predicting the absolute configuration of a large number of chiral synthetic and natural allenes [12,13]. Application of Lowe’s rule to (S)- and (R)-

Spiro [2,3]-1,5-diene is shown in Figure 2 with a screw pattern of right-handed helicity [13].



Figure 1

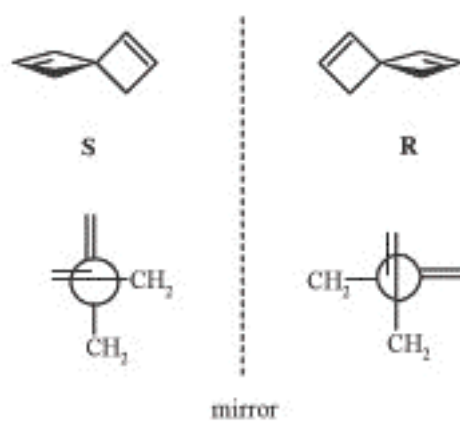


Figure 2

For example, some molecules have chiral axis the structure is regarded as an elongated tetrahedron and viewed along the axis, it is immaterial from which end it is viewed. The nearer pair of ligands receives the first two positions in the order of preference as shown in Figure 3 [4].

In this work, we have proposed a new and easy method for specification of organic chiral molecules without stereogenic center.

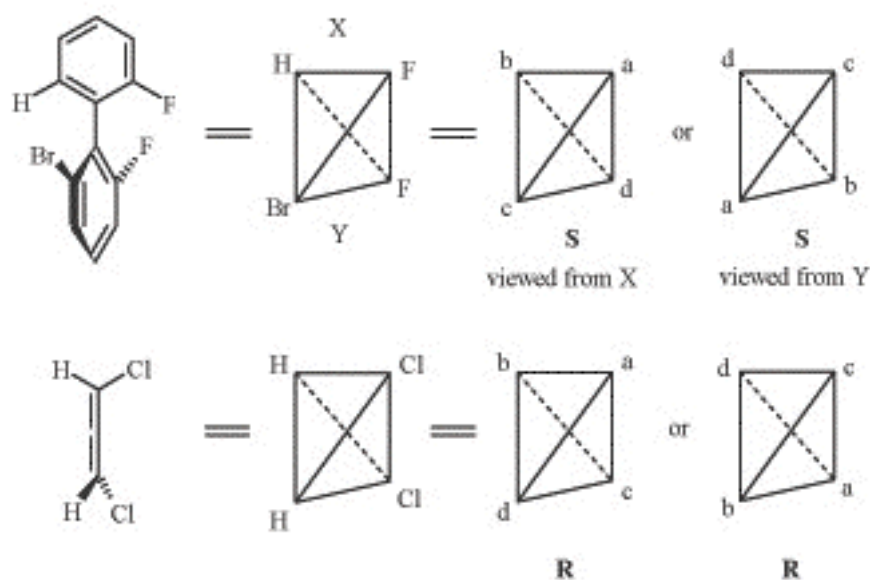


Figure 3

2. Results and Discussion

In this new presented method, we proposed an easy and logical route for specifying absolute configuration of some organic chiral molecules with lacking stereogenic center and compared with other common and known methods in references. For example, all of atropisomers, cumulenes (with even double bonds), spiranes, alkylidenecycloalkanes, helicenes and *trans*-cyclooctenes are in this category. We also used an hypothetical tetrahedral form for the molecules of *trans*-cyclooctenes (Figures 23-37) and all of results are compared with other common and known methods.

In our method, it is regard two *out of plane* (*out of plane*) and *plane* parts assigned in the molecule are shown in violaceous ellipsoid lines in all Figures. It is sufficient that the molecule to be rotate in a way that always the highest and lowest-ranked substituents to be took place in front and back of the paper sheet toward an observer in out of plane part respectively! (Figure 4). If the highest-ranked substituent to be nearer toward an observer in out of plane part, the molecule's rotation of 90° is not necessary. Therefore, always the highest and lowest-ranked substituents are considered in the out of plane part

assigned in the molecule in all Figures. Then it is identify all of four substituents in the both parts assigned in the molecule as an hypothetical tetrahedral form with hypothetical stereogenic center, ranked them and specified the absolute configuration according to the Cahn-Ingold-Prelog R-S notational system as a chiral molecule with one stereogenic center. All ranked ligands designed with numbers in the small circles in all Figures. All of mentioned kinds of molecules are discussed in Figures 4-37. The specification of absolute configuration of the sections **a**, **b**, **c**, **d** and **e** are similar.

2a. Allene systems

2a-1. If ligands $a = a'$ is highest-ranked than $b = b'$ and the highest-ranked ligand to be located in the back of the paper sheet toward an observer in out of plane part, the molecule's 90° rotation is necessary (Figure 4).

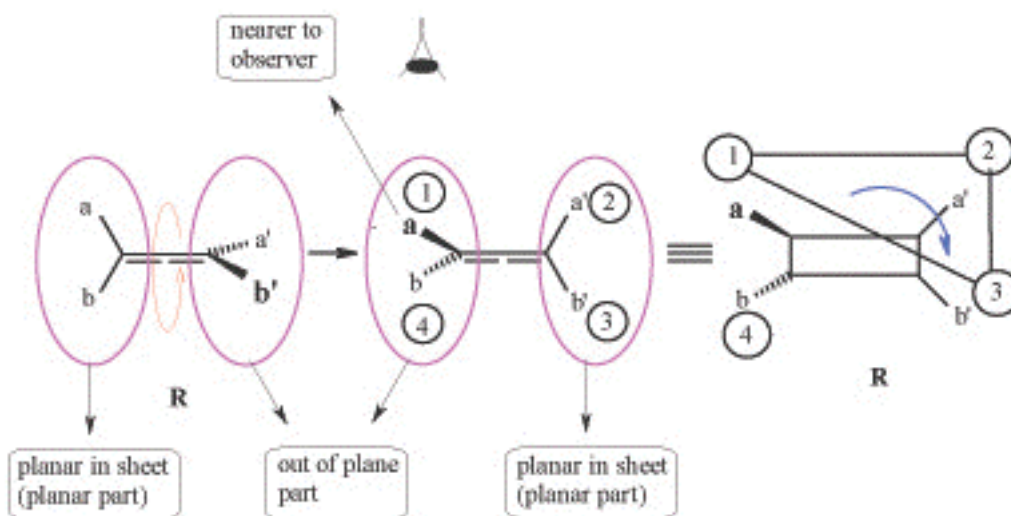


Figure 4

Example 1: $a = a' = \text{CH}_3$, $b = b' = \text{H}$;

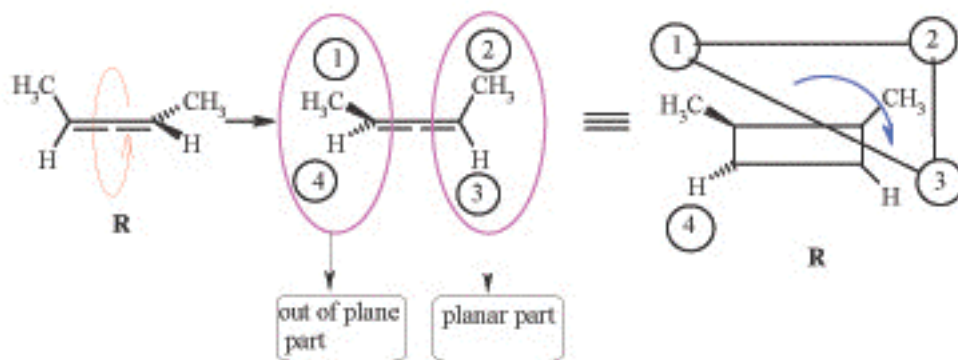


Figure 5

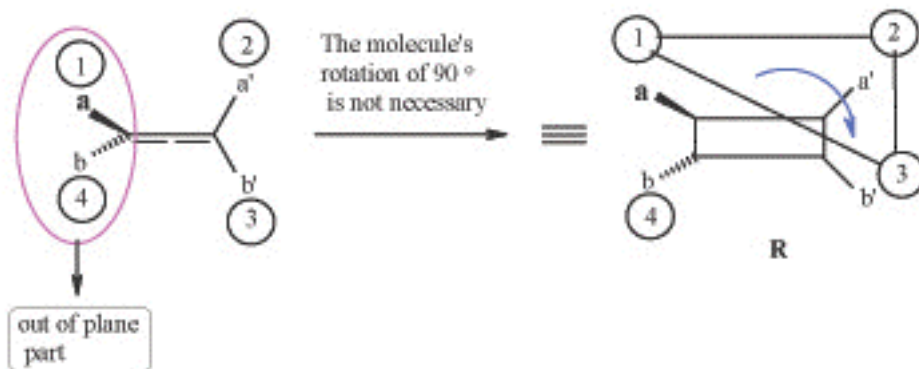


Figure 6

2a-2. If $a \neq a'$ is highest-ranked than $b \neq b'$, it is starting from a or a' as highest-ranked substituents for the specifying of absolute configuration and with section **a-1** is the same.

Example 2: $a = \text{Cl}$, $a' = \text{Br}$, $b = \text{H}$ and $b' = \text{CH}_3$;

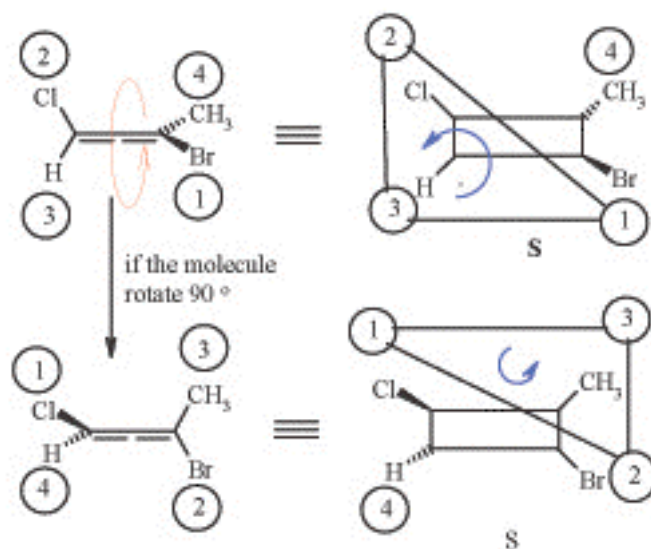


Figure 7

2b. Alkylidenecycloalkane systems

2b-1. If $a = a'$ is highest-ranked than $b = b'$;

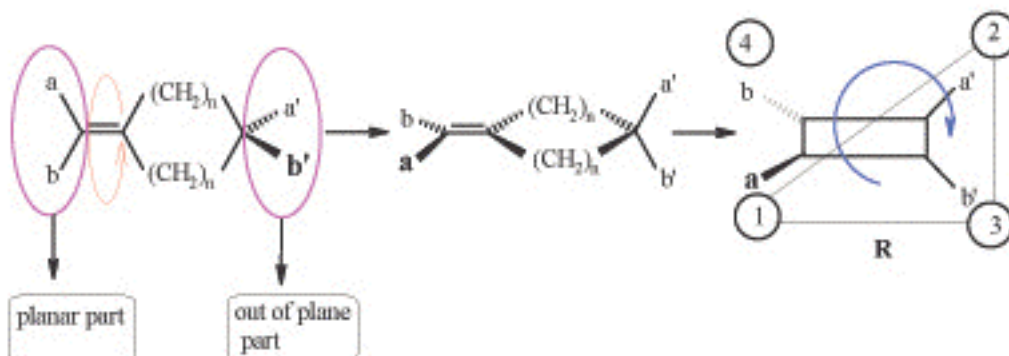


Figure 8

Example 3: $a = a' = \text{CH}_3$, $b = b' = \text{H}$ and $n = 2$;

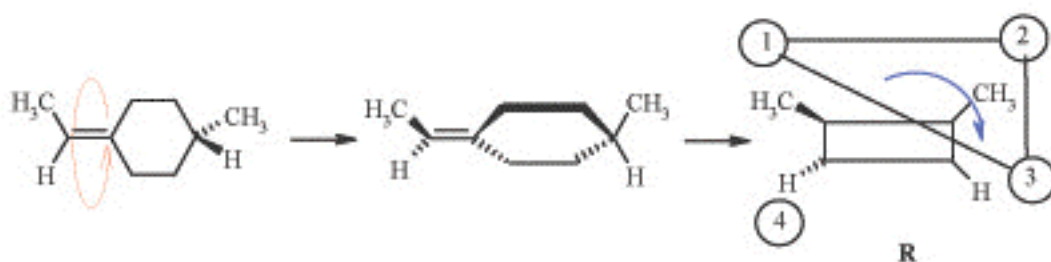


Figure 9

2b-2. If $a \neq a'$ is highest-ranked than $b \neq b'$;

Example 4: $a = \text{CH}_3$, $a' = \text{Cl}$, $b = \text{H}$, $b' = \text{Et}$ and $n = 2$;

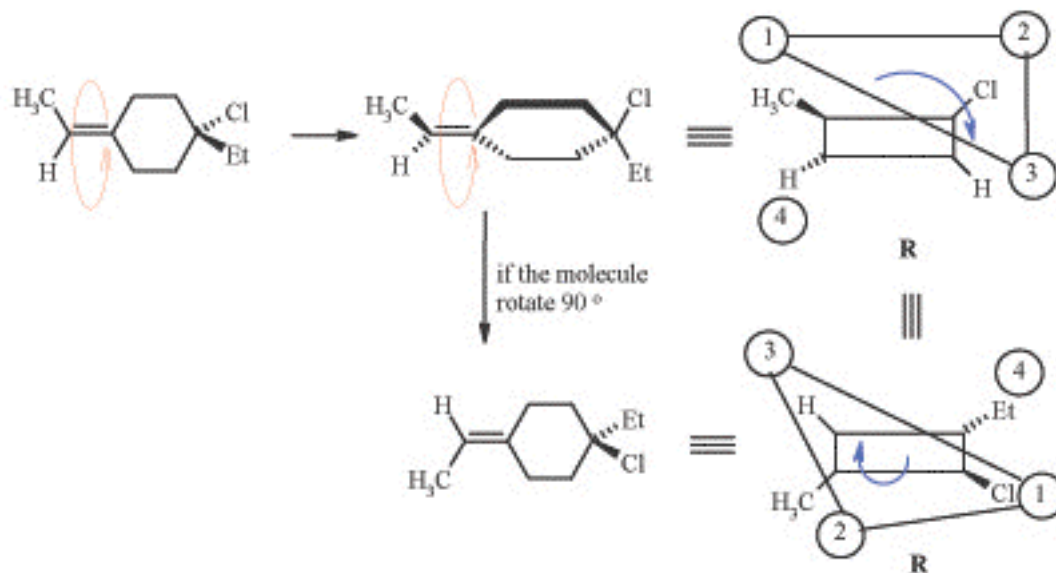


Figure 10

2c. Spirane systems

2c-1. If $a = a'$ is highest-ranked than $b = b'$;

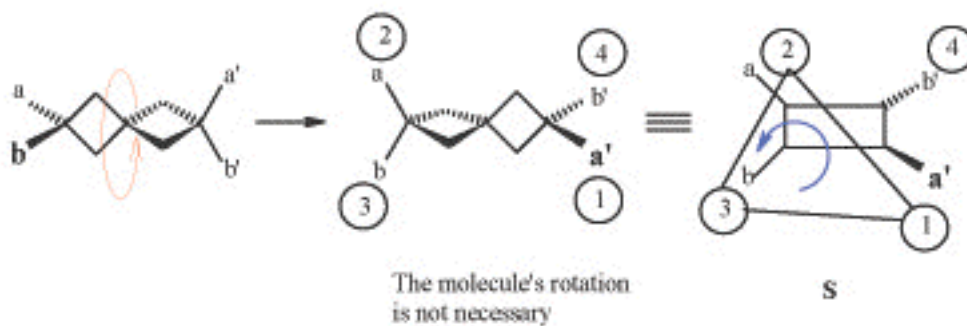


Figure 11

Example 5: $a = a' = \text{CH}_3$ and $b = b' = \text{H}$;

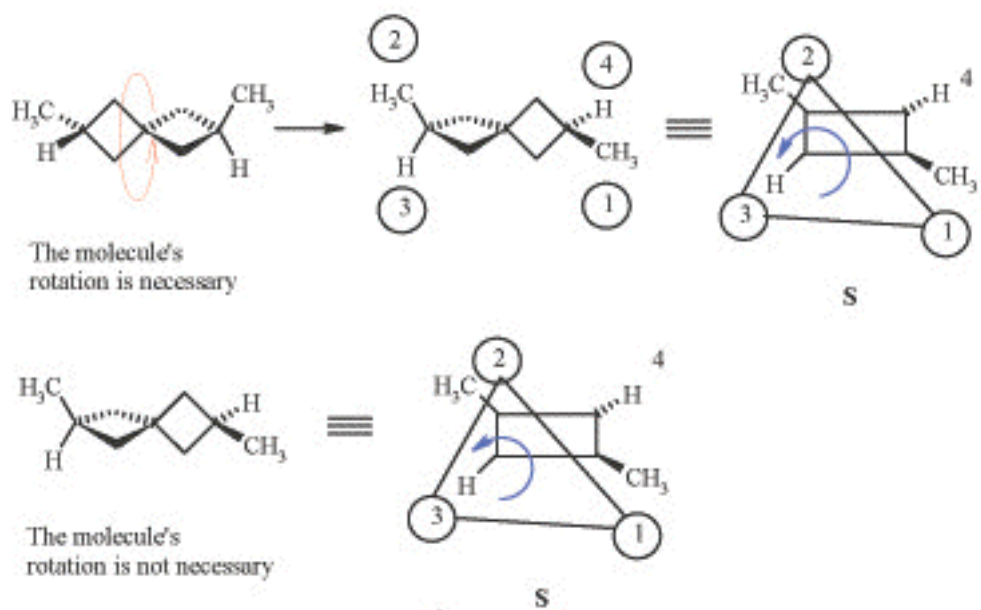


Figure 12

Example 6: $a = a' = -\text{CH}=\text{}$ and $b = b' = -\text{CH}_2-$;

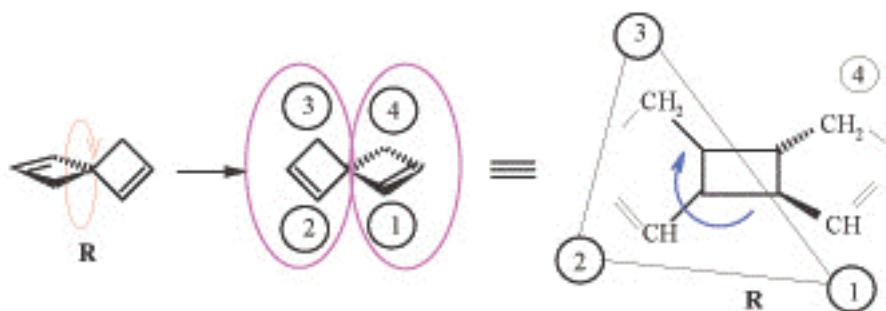


Figure 13

2c-2. If $a \neq a'$ is highest-ranked than $b \neq b'$;

Example 7: $a = \text{CH}_3$, $a' = \text{Cl}$, $b = \text{H}$ and $b' = \text{Et}$;

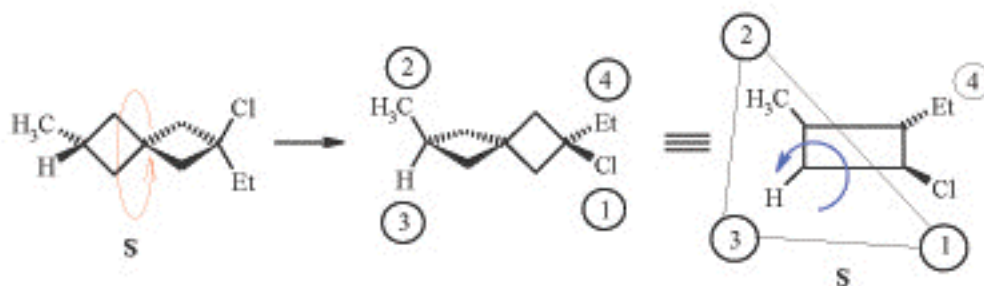


Figure 14

2d. Biphenyl derivative systems

2d-1. If $a = a'$, $b = b'$ and a is highest-ranked than b , the method is the same with previous sections.

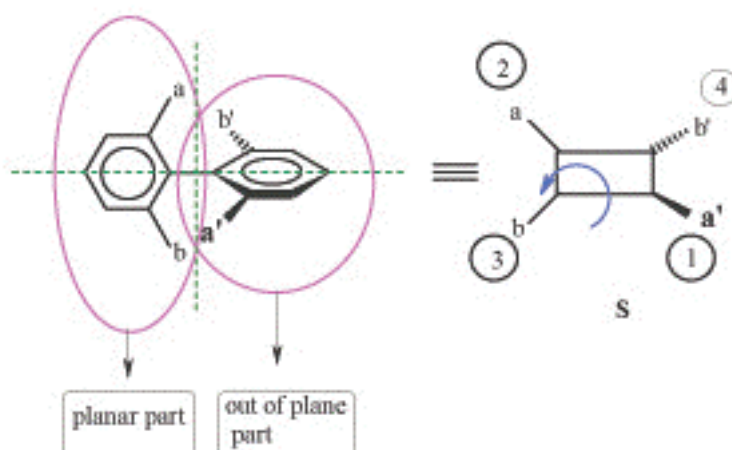


Figure 15

Example 8: $a = a' = \text{CH}_3$ and $b = b' = \text{H}$;

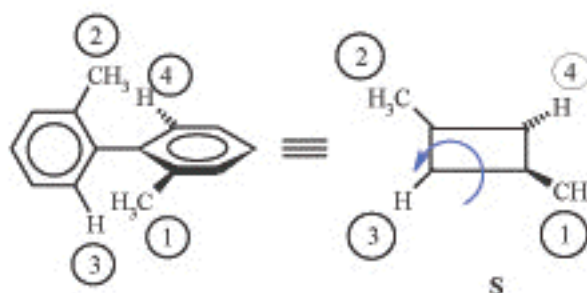


Figure 16

Example 9:

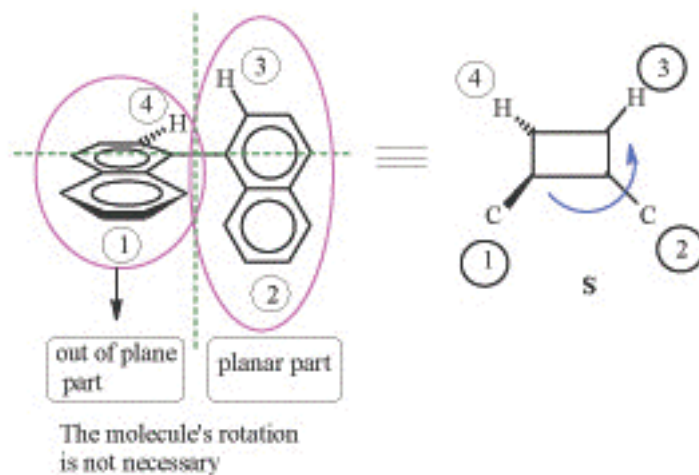


Figure 17

Example 10:

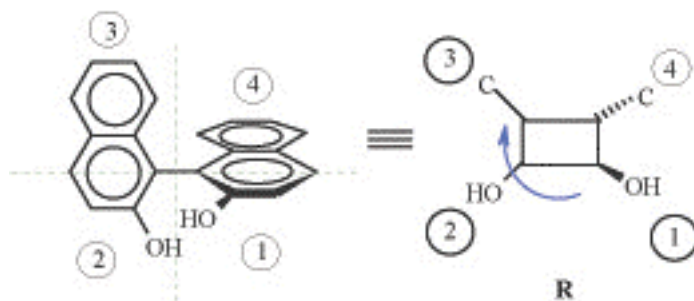


Figure 18

2d-2. If $a \neq a'$, $b \neq b'$, a and/or a' is highest-ranked than b and/or b' ;

Example 11: $a = \text{CH}_3$, $a' = \text{Cl}$, $b = \text{H}$ and $b' = \text{Et}$;

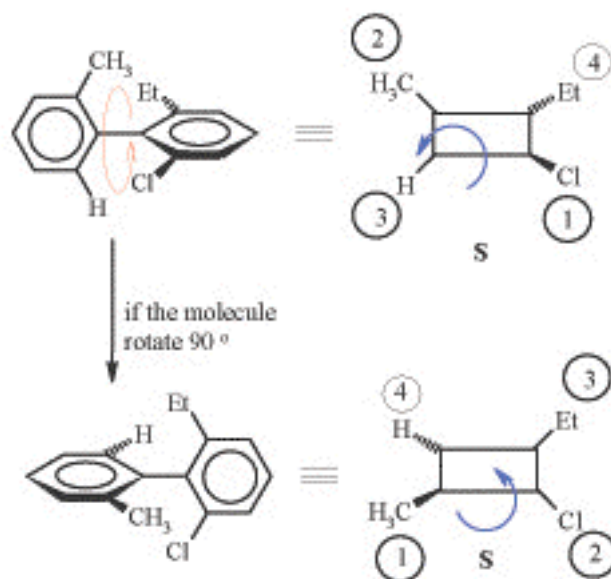


Figure 19

Example 12: $a = \text{CH}_3$, $a' = \text{Et}$, $b = \text{H}$ and $b' = \text{Et}$;

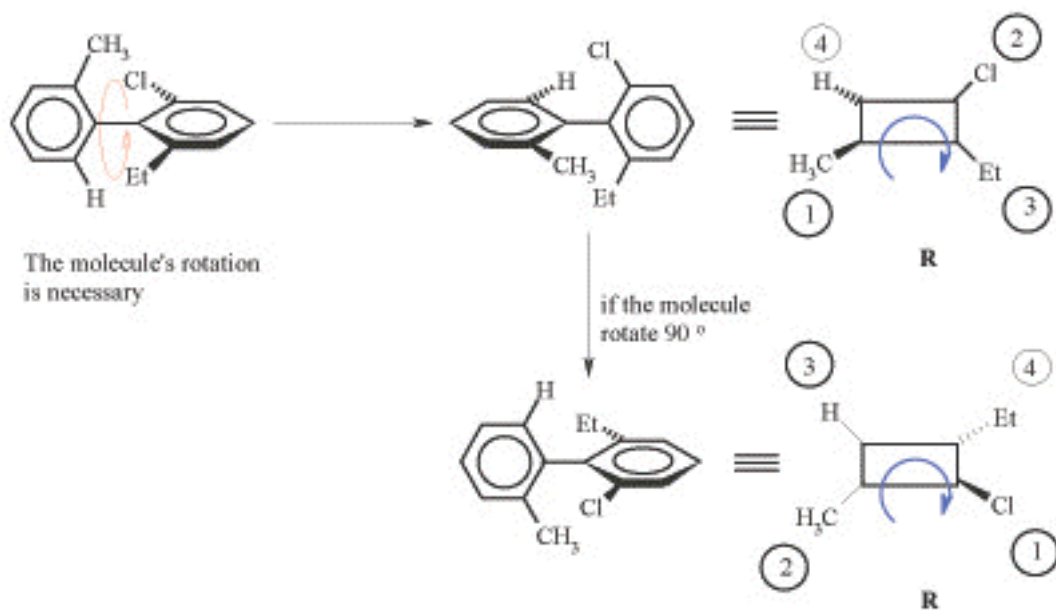


Figure 20

2e. Hexahelicene systems

Example 13:

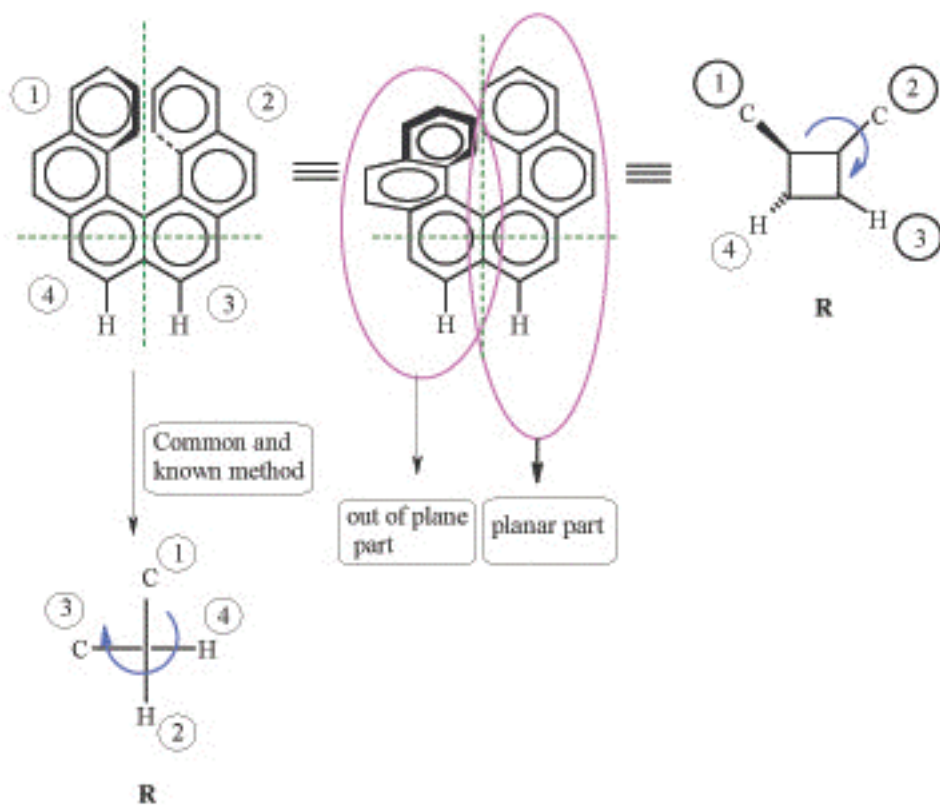
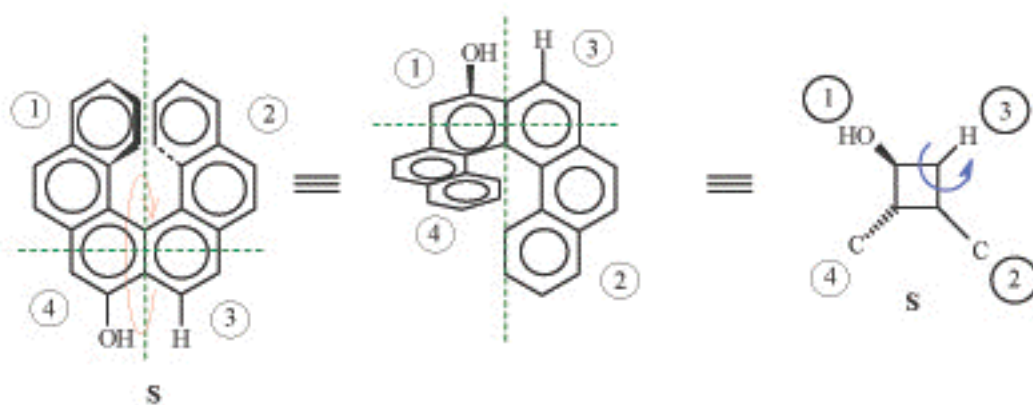


Figure 21

Example 14:



The molecule's rotation of 90° is necessary

Figure 22

2f. *trans*-Cyclooctene systems

For the specification of absolute configuration of *trans*-cyclooctenes, we have proposed an assumed molecules **A** and/or **A'** that; 1- If an observer look at the molecule from top of the sheet of paper, the molecules **A** and/or **A'** can be shown in two cases **B** and **C** and/or **B'** and **C'** (Figures 23 and 25 respectively). 2- We have also proposed an hypothetical tetrahedral form that the highest and lowest-ranked ligands to be considered in the out of plane part of the tetrahedral forms **D**, **E** and/or **D'** and **E'** (Figures 23 and 25). If the highest-ranked ligand is not nearer to observer in the out of plane part, it is necessary to rotate 90° that the highest-ranked ligand to be nearer to an observer. Then we can specify the absolute configuration similar with previous sections. The forms **B** with **C** and hypothetical forms **D** with **E** in Figure 23 and **F** with **G** are equals in Figure 24. The forms **B'** with **C'**, hypothetical forms **D'** with **E'** are equals in Figure 25 and **F'** with **G'** also are equals in Figure 26.

2f-1. A form: If a or a' is highest-ranked than b or b', n = 2 (Figure 23);

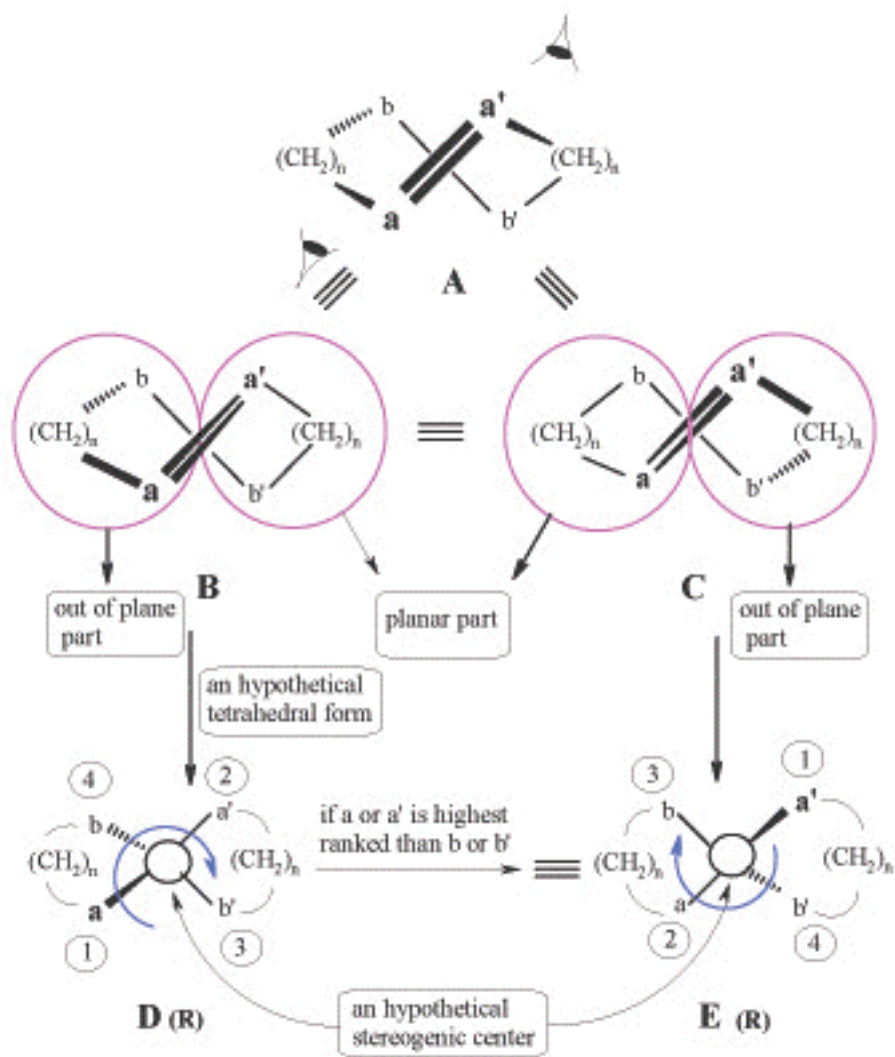


Figure 23

If b or b' is highest-ranked than a or a' in the Figure 23, the molecule's rotation of 90° is necessary for making b or b' nearer to observer in the out of plane part (F and G in Figure 24).

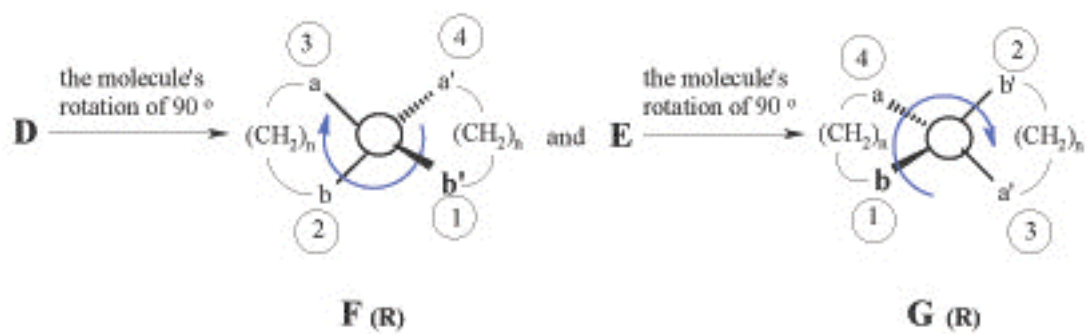


Figure 24

2f-2. A' form: If a or a' is highest-ranked than b or b' , $n = 2$;

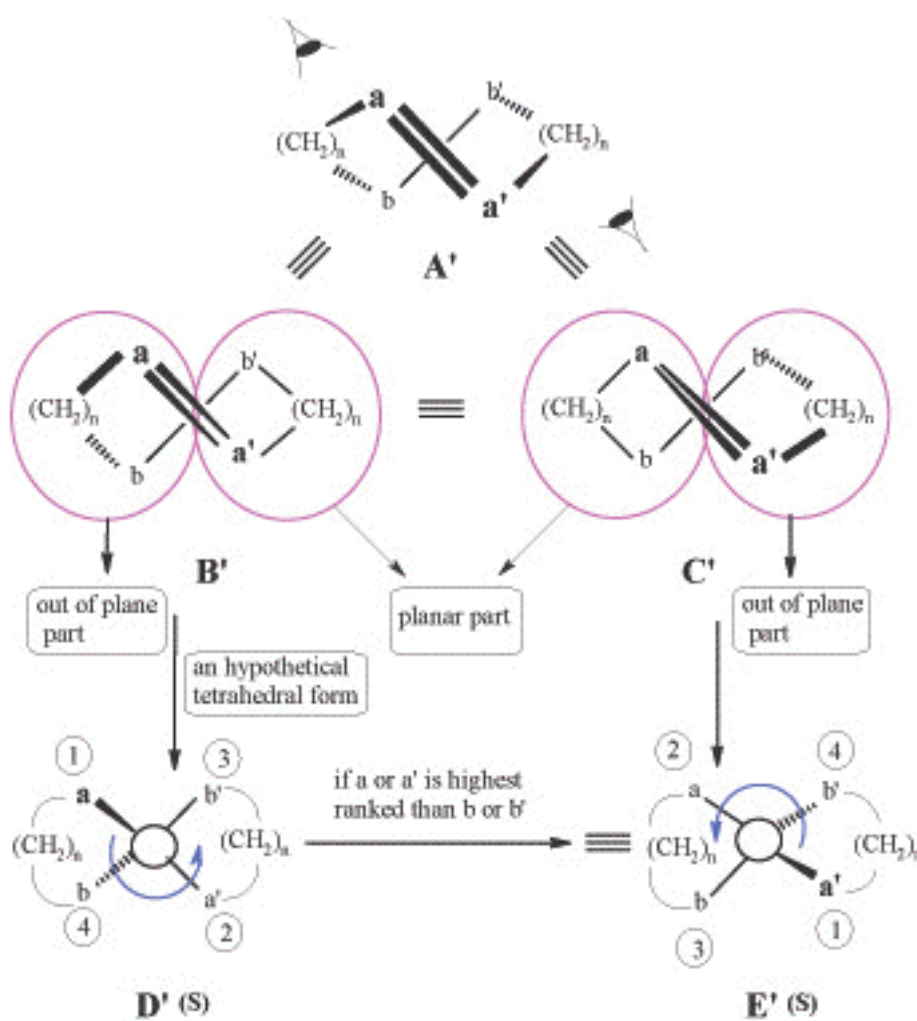


Figure 25

If b or b' is highest-ranked than a or a' in the Figure 25, the molecule's rotation of 90° is necessary for making b or b' nearer to observer in the out of plane part (F' and G' in Figure 26).

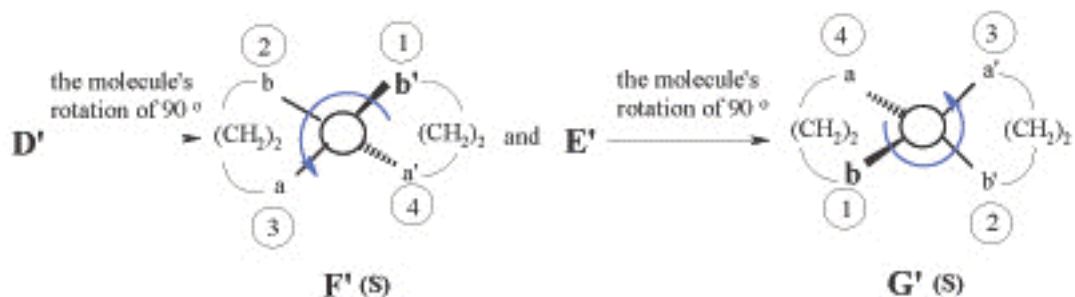


Figure 26

All shapes of *trans*-cyclooctenes with different substituents in violaceous line circles are described as highest or lowest-ranked substituents and is shown in Figure 27. For example; all different types of the shape **a** are shown in Figures 28-35 respectively and specified according to Figure 23. We can also use these eight types for the other shapes of **b**, **d** and **f** in Figure 27. Examples are included in below in Figures 28-35 respectively.

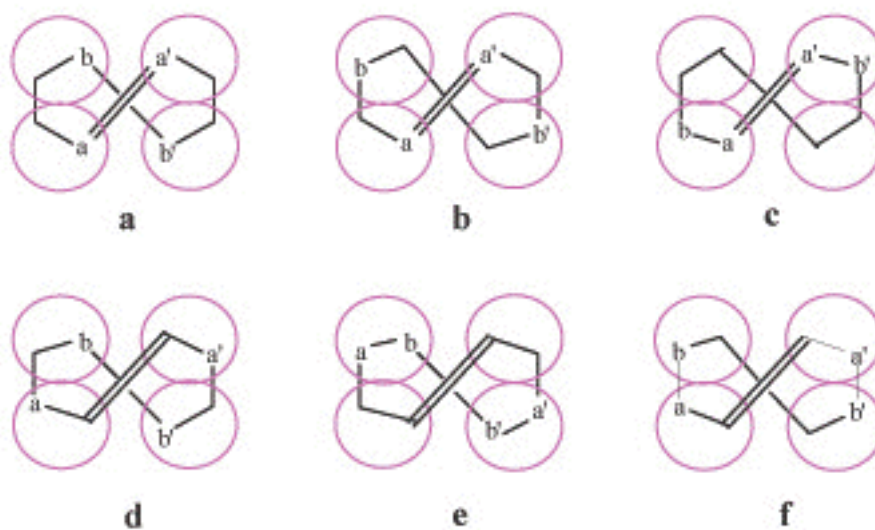


Figure 27

1) If $a = a'$ is highest-ranked than $b = b'$ ($a = a' = -CH=$ and $b = b' = -CH_2-$ (Figure 28);

Example 15:

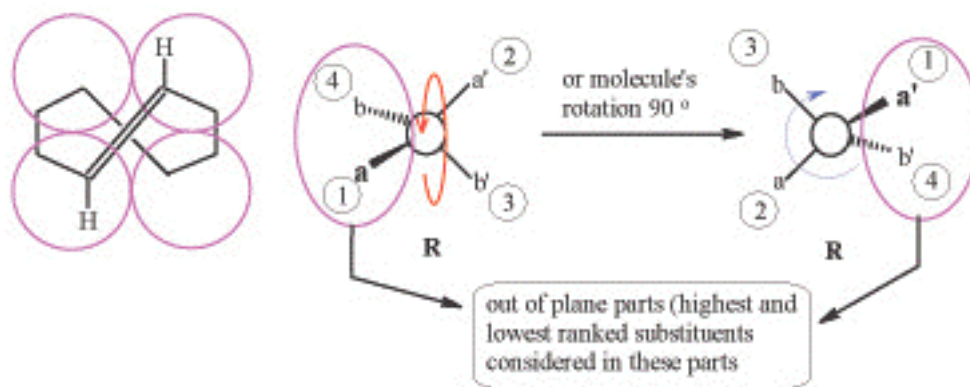


Figure 28

2- If $a = a'$ is lowest-ranked than $b = b'$ ($a = a' = -CH=$ and $b = b' = -CHCl-$);

Example 16:

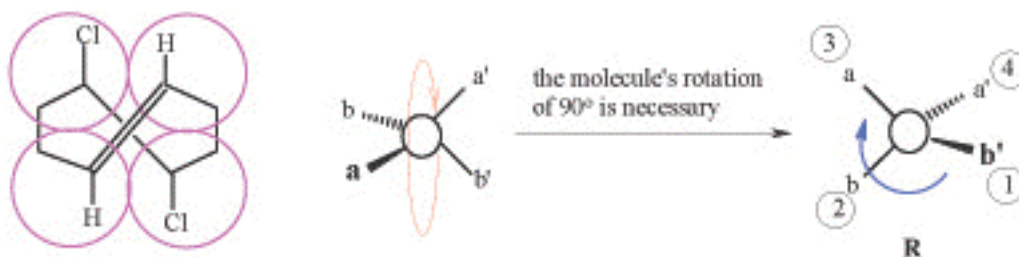


Figure 29

3- If $a = a'$ is highest-ranked than $b \neq b'$, ($a = a' = -CH=$, $b = -CH(CH_3)-$ and $b' = -CH_2-$);

Example 17:

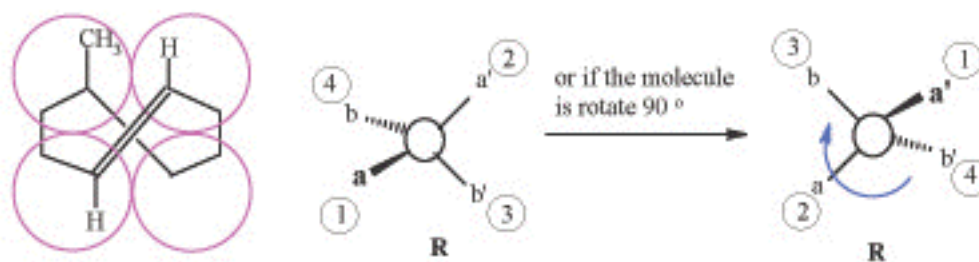


Figure 30

4- If $a = a'$ is lowest-ranked than $b \neq b'$, ($a = a' = -CH=$, $b = -CHBr-$ and $b' = -CHCl-$);

Example 18:

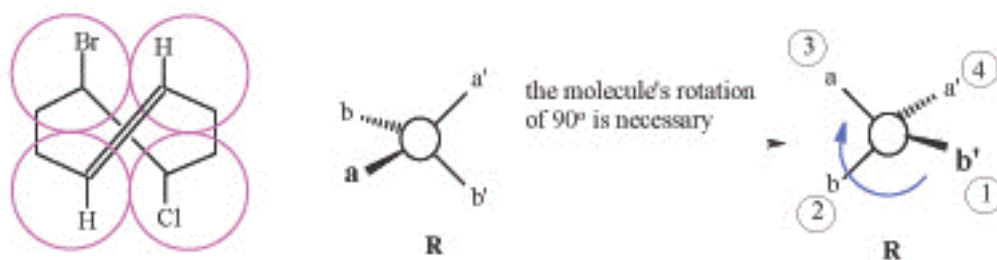


Figure 31

5- If $a \neq a'$ is lowest-ranked than $b = b'$, ($a = -CH=$, $a' = -C(CH_3)=$ and $b = b' = -CHCl-$);

Example 19:

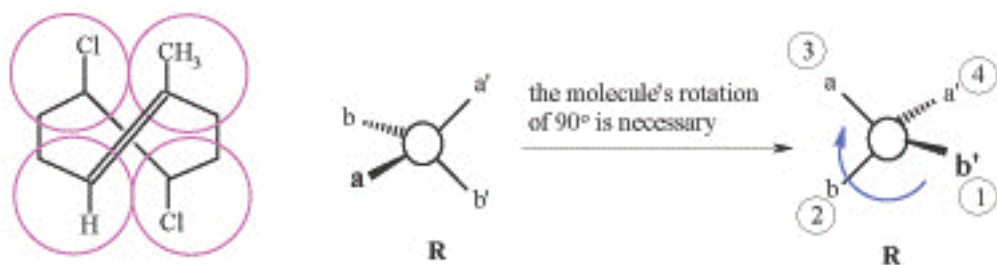


Figure 32

6- If $a \neq a'$ is highest-ranked than $b = b'$ ($a = -CH=$, $a' = -C(CH_3)=$ and $b = b' = -CH(CH_3)-$);

Example 20:

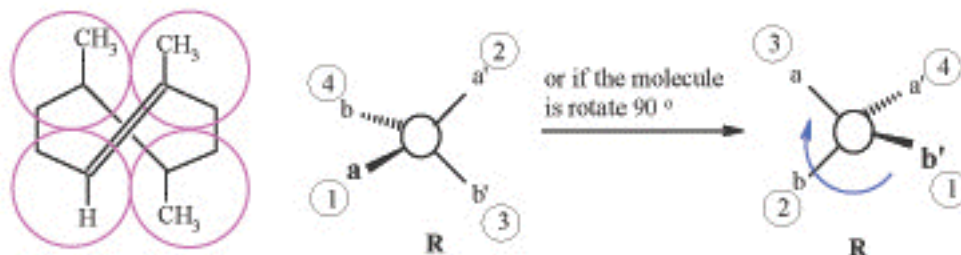


Figure 33

7- If $a \neq a'$ is highest-ranked than $b \neq b'$ ($a = -CH=$, $a' = -C(CH_3)=$, $b = -CH_2-$ and $b' = -CH(CH_3)-$);

Example 21:

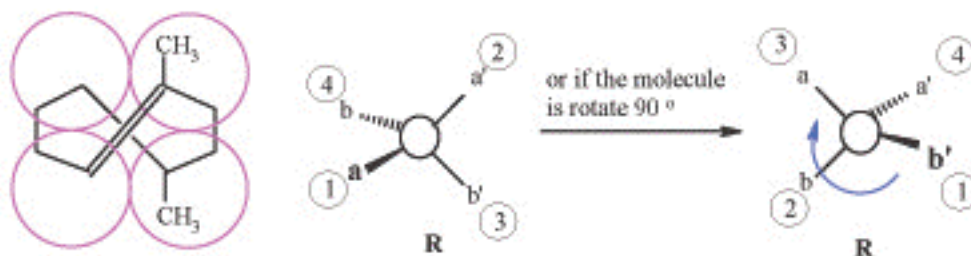


Figure 34

8- If $a \neq a'$ is lowest-ranked than $b \neq b'$ ($a = -CH=$, $a' = -C(CH_3)=$, $b = -CHBr-$ and $b' = -CHCl-$);

Example 22:

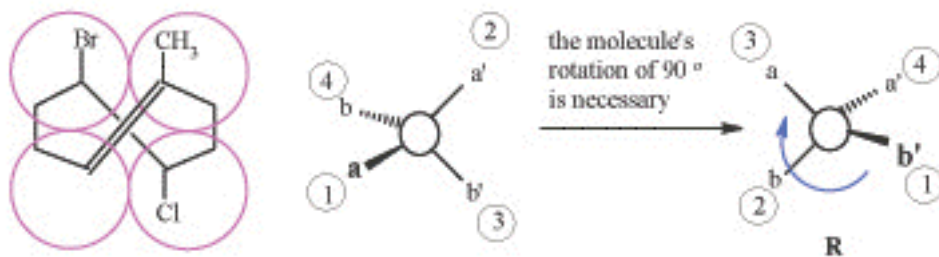


Figure 35

The specification of absolute configuration of the types of 1, 3, 6 and 7 are similar and the types of 2, 4, 5 and 8 are similar too. If the carbon-carbon double bond is located in back side of the single bond, (**H** and/or **H'**) in Figures 36 and 37, it is not difference from the previous cases. We can also use the all of eight types to the **H**, and/or **H'**. The forms **I** with **J**, hypothetical forms **K** with **L** and **M** with **N** are equals in Figure 36 and **I'** with **J'**, hypothetical forms **K'** with **L'** also are equals in Figure 37.

1) If $a = a'$ is highest-ranked than $b = b'$ ($n = 2$);

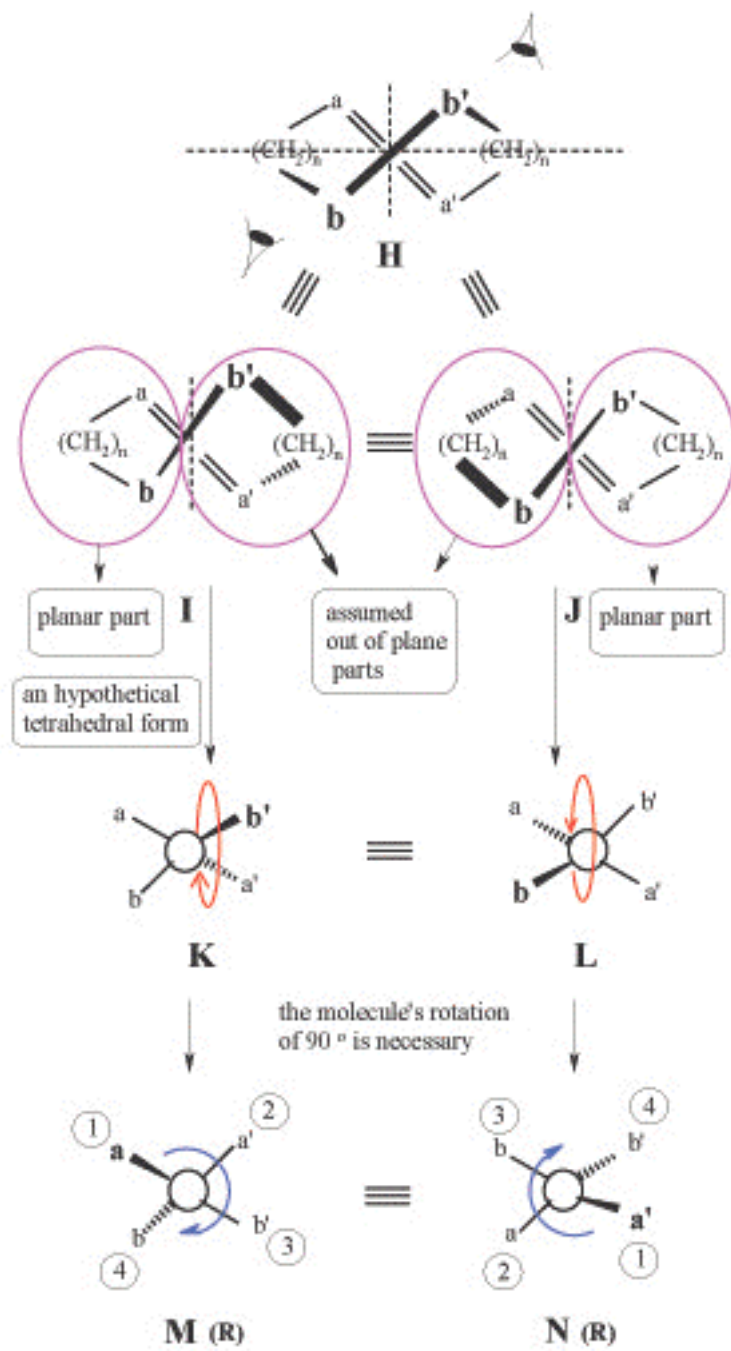


Figure 36

2) If $a = a'$ is lowest-ranked than $b = b'$;

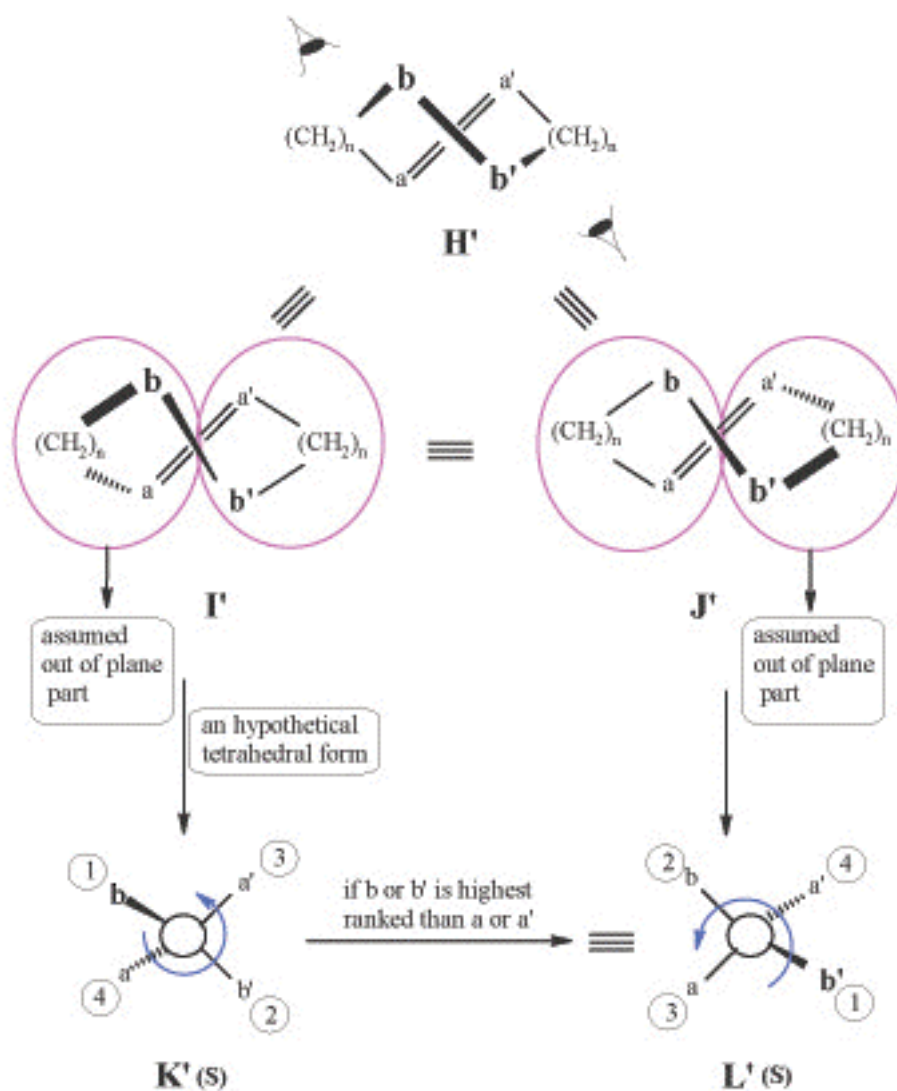


Figure 37

3. Conclusion

In conclusion, in this new method, we used an hypothetical tetrahedral form with hypothetical stereogenic center for the molecule. It can be used for many of chiral organic molecules without of stereogenic center, such as; allenes, spiranes, alkylidenecycloalkanes, biphenyls, hexahelicenes, *trans*-cyclooctenes and etc. On the other hand, this method is very easy, useful and simple for specification of absolute configuration of the molecules that their incarnation are difficult and troublesome. Therefore we can use an hypothetical tetrahedral model for specifying of absolute

configuration according to the Cahn-Ingold-Prelog notational system similar with an asymmetric molecule with stereogenic center. In this method, it is sufficient that the highest and lowest-ranked substituents to be near and far from an observer in out of plane part respectively. Therefore always the highest and lowest-ranked ligands are regarded in the out of plane part of the molecule. If the highest-ranked ligand is located far from an observer in this part, it is sufficient the molecule to be rotate 90° in a manner that highest-ranked ligand to be nearer toward an observer in the out of plane part, then ranked all of ligands precedence in out of plane and planar parts of the molecule and then identify according to the Cahn-Ingold-Prelog method. This facile and new method is useful in chemistry as an educational method.

4. References

1. F. A. Carey, *Organic Chemistry*, 2ed ed., McGraw-Hill: New York (1992).
2. E. L. Eliel, S. H. Wilen and L. N. Mander, *Stereochemistry of Organic Compounds*, John Wiley & Sons: New York (1993).
3. F. A. Carey and R. J. Sundberg, *Advanced Organic Chemistry, Part A*, 3rd ed., Plenum Press: New York (1990).
4. The IUPAC rules and definitions for fundamental stereochemistry are given with examples in *J. Org. Chem.*, vol. 35, 2849-2867 (1970).
5. N. L. Allinger and E. L. Eliel, *Top. Stereochem.*, vol. 1, 1nd ed., John Wiley & Sons: New York (1967).
6. J. K. O'Loane, *Chem. Rev.*, vol. 80, 41-61 (1980).
7. R. K. Hill and D. A. Collison, *J. Am. Chem. Soc.*, vol. 95, 1229-1239 (1973).
8. G. Krow, *Top. Stereochem.*, vol. 5, N. L. Allinger and E. L. Eliel, Eds., 2nd ed., John Wiley & Sons: New York (1970).

9. D. A. Lightner, D. T. Hefelfinger, T. W. Powers, G. W. Frank and K. N. Trueblood, *J. Am. Chem. Soc.*, vol. 94, 3492-3497 (1972).
10. P. C. Manor, D. P. Shoemaker and A. S. Parkes, *J. Am. Chem. Soc.*, vol. 92, 5260-5262 (1970).
11. L. A. Hulshof, A. Vos and H. Wynberg, *J. Org. Chem.*, vol. 37, 1767-1770 (1972).
12. L. A. Hulshof, M. A. Mckerverey and H. Wynberg, *J. Am. Chem. Soc.*, vol. 96, 3906-3912 (1974).
13. G. Lowe, *Chem. Commun.(London)*, vol. 17, 411-413 (1965).

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