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TEACHING THE CONCEPT OF ISOMERISM IN ORGANIC CHEMISTRY IN HIGH SCHOOL EDUCATION

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Abstract

Written papers, at least of high school level (textbooks, workbooks etc.), introduce quite unclearly the concepts of isomerism and isomers. Thus, compounds that do not exist are considered to be isomers, or the stereoisomers are presented as a less important category as compared to other types of isomers. At the same time, confusion is also maintained because of the incorrect use of Romanian language grammar and logic in understanding the concept of isomerism and of the types of isomers. This paper presents the author’s personal vision of these aspects based on the logic and grammar of the Romanian language, on the one hand, and on the other hand, on the object of chemistry as the fundamental science of nature, namely “*the study of chemical substances* (which exist) *and the laws of chemistry* (which must be sustained by these substances through their behaviour and attitude in relation to the environment)”. Last but not least, we advance a proposal on teaching the concept of isomerism and the type of isomers in high school chemistry. Also, starting from a number of applications in workbooks, a series of considerations are described regarding the number of isomers corresponding to a molecular formula or to a chemical compound, as well as regarding the number of isomers of a certain type corresponding to a molecular formula or of a particular chemical compound.

Keywords: Isomerism, stereoisomers, enantiomers, molecular configuration, optical activity, mobile/fixed covalentbond.

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1. Introduction

After studying some written materials (high school chemistry textbooks, chemistry workbooks, exam and contest subjects), we found that the issue of isomers is incorrectly put. The error is both of chemical, grammatical and logical nature. Thus, in some texts, this issue is advanced by taking examples of substances that do not exist, and in others some relationships between the isomers are wrongly established. In addition to these strictly chemical errors, mistakes are also made regarding the determination of the number of isomers corresponding to a molecular formula or a chemical compound (corresponding to it) by using a grammatical and logical misstatement.

This erroneous approach has two major inconveniences, both equally important, namely:

- Affecting the prestige of chemistry as a science of nature;
- Misunderstanding by students of the concept of isomerism and isomeric issue.

The first inconvenience is that the use of non-existent substances for explaining chemical phenomena contradicts the subject of chemistry as a science, described in all the basic treatises and writings of chemistry. Below, only two excerpts from two reference treatises that define the subject of chemistry:

The object of study of organic chemistry refers, on the one hand, to the study of methods for the ***construction (synthesis) of molecules*** *with certain structures and, on the other hand, to the study of the chemical and physical methods for* ***establishing the structures of molecules that are synthesized isolated from nature****, as well as the* ***study of their reactivity*** *according to the molecular structure* (Avram, 1983).

Scientific generalizations, called laws, principles, theories, etc. ***have no scientific value*** *except to the extent that they* ***are not contradicted*** *by the experimental facts, the observation of nature and other laws or scientific theories, based on experimental facts or observations* (Nenițescu, 1980).

It is quite clear that the object of study of chemistry is, on the one hand, the characterization of chemical substances (identification of synthesis methods and determination of their physical and chemical characteristics) and, on the other hand, the discovery and enunciation of principles, theories, laws of scientific value for chemistry, based on the findings made during the characterization of these substances. It goes without saying that we deal with substances that EXIST, as we cannot characterize substances that do not exist.

The second inconvenience is only a self-educed conclusion following my didactic activity with students in the X^{th} and XI^{th} grades. The use of some non-existent substances to explain the concept of isomerism, the rejection of a logical argument for establishing the number of isomers and the relationships between them, or the use of this argumentation in only some cases, as well as the careless construction of the sentences are examples of deviations that negatively influence the comprehension of the chemical phenomena, laws, rules and concepts, including those relating to isomerism and isomers, which makes it even more difficult for students to expand and develop analytical, creative and logical thinking, and in many cases even diverts and alters this thinking.

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2. Problem Statement

Here are some examples that support the reasons outlined above.

In the Chemistry Textbook for the Xth grade (Vlădescu, Tărăbăşanu-Mihăilă, & Irinel-Doicin, 2018, p.38) it is stated that:

- "Alkene position isomers differ from each other *in terms of the position of the double bond*. For example, the alkene having the molecular formula C_4H_8 has 2 position isomers:

CH_2=CH–CH_2–CH_3 CH_3–CH=CH–CH_3
1-butylene 2-butylene."

- *"An alkene with different substituent at each of the two carbon atoms participating in the double bond has **geometric isomers**.*

*When the two carbon atoms participating in the double bond have the same pair of two substitutes, different from each other, the alkene has two geometric isomers called **cis** and, respectively, **trans**.*

For example, in the case of 2-butylene, each carbon atom participating in the double bond has two different substitutes: a hydrogen atom and a methyl radical. 2-Butylene is a symmetrically disubstituted alkene and has 2 geometric isomers.

The two isomers are called:

H H CH$_3$ H
\ / \ /
C=C C=C
/ \ / \
H$_3$C CH$_3$ H CH$_3$
cis-2-butylena trans-2-butylena."

By analysing these textbook statements, one understands:

- that there is an (un-nominated) alkene, a sort of "parent alkene", having the molecular formula C_4H_8 which has two position isomers: 1-butylene and 2-butylene;
- that, in its turn, 2-butylene, which also has the role of "parent alkene", has two geometric isomers: cis-2-butylene and trans-2-butylene;
- that when there are two geometric isomers an alkene must also exist (a "parent alkene" as well) to which they belong;

At the same time, it can be understood that among the alkenes having the molecular formula C_4H_8 there are at least five, namely: 1-butylene, 2-butylene, cis-2-butylene, trans-2-butylene and the un-nominated "parent alkene" having the two position isomers.

The reality, however, shows that alkenes having the molecular formula C_4H_8 are four, namely:

H H CH$_3$ H
\ / \ /
A) CH_2=CH-CH_2-CH_3 B) C=C C) C=C D) CH_2=C-CH_3
1-butylene / \ / \ |
H$_3$C CH$_3$ H CH$_3$CH$_3$
cis-2-butylene trans-2-butylene isobutylene

By facing the statements in the textbook with the reality we find:

- that it is not possible to identify among the four C_4H_8 molecular formula alkenes a "parent alkene" **having** 1-butylene and 2-butylene as position isomers.
- that among the four C_4H_8 molecular formula alkenes there is no 2-butylene, so that the two geometric isomers, cis-2-butylene and trans-2-butylene, can not belong to it because it does not exist.

It should also be noted:

- that there is no basic chemical substance (a "parent substance") that has (to generate) isomers no matter what type they are;
- that *cis* and *trans* denominations are assigned to the geometric isomers only in two situations: when the pair of substituents different from one atom is also present at the other atom involved in the occurrence of geometric isomerism and, respectively, when each substituent pair has a hydrogen atom, the other two substituents being different, in any other case the geometric isomers being denominated *Z* and *E*.

In the collection titled "Organic Chemistry (2018)- Admission Tests in Medical Higher Education, 2018" end "Organic Chemistry (2016) - Admission Tests in Medical Higher Education, 2016", published at "Carol Davila" University Publishing House, Bucharest, there are several problems in which the issues of isomers and isomerism are wrongly approached, of which we have selected the following:

- Problem no. 141 (Vlădescu, Tărăbăşanu-Mihăilă, & Irinel-Doicin, 2018, p. 125):

Out of 235.5 g of alkyl chloride, 144 g of alcohol are obtained with a conversion level of 80%. The number of alcohol isomers is:

A) *1; B) 2; C) 3; D) 4; E) 5.*

Solving this problem leads to the following molecular formula of the alcohol: C_3H_8O which corresponds to the following three isomers: *1-propanol, 2-propanol* and *ethyl methyl ether*, with the first two being alcohols and the latter, ether. By asking for the "number of isomers of alcohol" it is logical that alcohol can only be one of the two listed above and its isomers the other two, so that the number of isomers of alcohol can only be *2*. Contrary to this conclusion, the authors of this workbook consider the number of alcohol isomers is *3*, indicating that, in their view, the alcohol is an isomer with itself. It is obvious that in this case the grammatical and logical meaning of the problem was ignored, confusing the number of alcohol isomers of with the number of isomers corresponding to the molecular formula of the alcohol.

- Problem no. 426 (Vlădescu, Tărăbăşanu-Mihăilă, & Irinel-Doicin, 2018, p. 162):

The number of isomeric amines containing 65.75%C; 15.07%H; 19.18%N and which presents optical activity is:

A) 1; B) 2; C) 3; D) 4; E) 5.

Solving this problem leads to the $C_4H_{11}N$ molecular formula which corresponds to the following 9 amines: *1-butylamine, (+)-2-butylamine, (-)-2butylamine, isobutylamine, tert-butylamine, N-methylpropanamine, N-methylisopropylamine, diethylamine and N,N-dimethylethanamine*. From this enumeration it is clear that there are two amines (*(+)-2-butylamine and (-)-2-butanamine*) which exhibit optical activity which is contrary to the opinion of the authors who consider that only one amine exhibits optical activity. This problem is one example among many such where stereoisomers are replaced by "parent substance", in this case it is 2-butylamine, a substance that does not really exist.

- Problem no. 256 (Vlădescu, Tărăbăşanu-Mihăilă, & Irinel-Doicin, 2018, p. 140):

How many alkenes having the formula $C_{3n}H_{4n+4}$ exhibit Z-E isomerism?

A. 1; B. 2; C. 3; D. 4; E. 5.

Solving this problem leads to the C_6H_{12} molecular formula, the authors pointing the D choice as the correct variant, which means that four alkenes with this molecular formula exhibit Z-E isomerism.

There are two aspects that make this answer wrong.

First of all, isomerism is not a property (an attribute) that chemical substances can have (develop) or not have (not develop) chemicals. For this reason, the problem requirement is incorrectly formulated, and the correct formulation can be (a variant): *How many alkenes with the formula $C_{3n}H_{4n+4}$ are Z-E isomers?*

Secondly, the number of alkenes which are Z-E isomers is 8 (and not four), namely *Z-2-hexene, E-2-hexene, Z-3-hexene, E-3-hexene, Z-3-methil-2-pentene, E-3-methyl-2-pentene, Z-4-methyl-2-pentene* and *E-4-methyl-2-pentene*.

This time as well we can speculate that the authors considered only the 4 “parent alkenes” that would have Z-E isomerism, namely: *2-hexene, 3-hexene, 3-methyl-2-pentene* and *4-methyl-pentene*, logic that can not be taken into account because these alkenes do not exist.

- Problem no. 235 (Vlădescu, Tărăbăşanu-Mihăilă, & Irinel-Doicin, 2018, p. 137):

How many isomers (excluding stereoisomers) correspond to the molecular formula $C_4H_{11}N$ and how many of them do not react with benzoyl chloride?

A. 4 and 4; B. 5 and 4; C. 8 and 7; D. 9 and 8; E. 8 and 1.

3. Research Questions

The authors of the problem indicated E choice as the correct variant, which means that, excluding the steric isomers, only 8 amines are left corresponding to the molecular formula $C_4H_{11}N$, out of which only one does not react with benzoyl chloride because it is tertiary (tertiary amines, unlike the primary and secondary ones, do not give the acylation reaction to the functional group).

Or, as mentioned above (see Vlădescu, Tărăbăşanu-Mihăilă, & Irinel-Doicin, 2018**,** problem No. 426), 9 amines correspond to this molecular formula, out of which one is indeed tertiary (*N,N-dimethylethanamine*) and 2 are optically active (*(+)-2-butylamine and (-)-2-butylamine*), which gives them the status of steric isomers. If these two stereoisomers are excluded, as the problem requires, there are 7 amines left, so the correct answer is: *7 and 1* and not *8 and 1* as the authors have indicated.

Trying to read their logic and identify the eighth amine, there are only two options, namely: taking into account an optically active amine of the two or taking into account *2-butylamine* as an amine. However, either of these two variants is incorrect because, in the first variant, the amine, being optically active, is a steric isomer, and the requirement of the problem excludes them, and in the second variant, the *2-butylamine* is not found among the 9 isomers corresponding to the mentioned molecular formula.

This problem is another case in which logic and grammar have been ignored, but this time in determining the number of isomers that fulfil a certain condition.

4. Purpose of the Study

These aspects illustrated above could be clarified, first of all, by establishing a general procedure for the presentation of the types of isomers, a procedure that is appropriately adapted to each class of organic compounds and in correlation with students' level of comprehension. A variant of this procedure is described below.

Secondly, it is important for everyone to understand, and especially for the chemists, that chemistry deals with the study of substances that EXIST and that the comprehension, assimilation and correct application of laws, principles, theories, and phenomena specific to chemistry can only be fulfilled by means of the correct use of grammar rules, of vocabulary and logic and argumentation.

The general procedure for the description of isomeric types comprises:

- the preparatory stage - in which the specific terms are presented, among which, mandatorily:

- *isomers* – chemical compounds having the same molecular formula;
- *isomerism* – a concept that includes the types of isomers;
- *carbon chain* – the chain formed solely of carbon atoms bonded through simple σ bonds; this chain is obtained from the flat structural formula by eliminating all atoms other than carbon and all the π bonds, leaving only the carbon atoms and the σ bonds between them;
- *functional group* – the atom other than carbon and hydrogen, or the group of atoms containing at least one atom other than C and H, existing in the composition of an organic molecule;
- *substitute* – the atom or group of atoms that binds through a covalent bond of one atom;
- *asymmetric (chiral) carbon atom* – the carbon atom which has four different substitutes attached thereto;
- *mobile covalent bond* – covalent bond allowing the rotation of an atom around it (σ bond);
- *fixed (rigid) covalent bond* – bond that does not allow the rotation of an atom around it (π bond);
- *the structure (constitution, forming) of the molecule* – the existing functional groups, the type of carbonate chain, the type of the bonds between atoms, the position of the functional groups or of the multiple bonds of the carbon atoms within the carbonate chain (all of which are constituent elements, forming elements of the molecule);
- *molecular configuration* – the spatial (steric) orientation of the substitutes around a centre which may be an atom or a plane of a π bond or of several bonds (which form a cyclic chain, for example) etc.

optical activity – the rotation of the plane of polarization of linearly polarized light with a certain number of degrees clockwise, the isomer being called *dextrorotatory* and noted by *(+)*, or anticlockwise, the isomer being called *laevorotatory* and noted by *(-)*; this property is caused, inter alia, by the asymmetric carbon atom;

- Presentation of types of isomers, in the following order:

<u>*- structural (constitutional) isomers:*</u>

- functional isomers - differ by the functional group they bear;
- chain isomers - differ in carbonate form (they do not have the same chain), only if they have the same functional group and the carbon chain has the same number of carbon atoms;
- position isomers - differ by the position occupied by the multiple bond or the same functional group, only if they have the same carbon chain;
- compensation isomers - differ by the number of carbon atoms forming each of the two or more carbon chains that bind to an atom part of a functional group;

<u>*- configuration isomers (steric isomers, stereoisomers):*</u>

- diastereoisomers:

- *geometric isomers:* differ in the spatial orientation of the two different substitutes that bind to each of the two carbon atoms of a double bond or to each of the two carbon atoms of a cyclic chain only if they have the same chain and the same position of double bond;

- *optical isomers:* they may differ either in terms of the direction of rotation of the linearly polarized light and the value of the angle of rotation, or only in terms of the value of the angle of rotation of the linearly polarized light, the direction being the same, only if they have the same chain and the same positions of the multiple bonds and of the same functional groups, if these constitutive elements are present; in the case of diastereoisomers, two specific situations were included in the class of saccharides: the *anomers* - differ in terms of the position of the glycosidic hydroxyl as opposed to that of the hydroxyl in the positions 2 or 4 and the *epimers* - differ in terms of the configuration of a single asymmetric carbon atom, the other asymmetric carbon atoms having same configuration within the acyclic formulas.

- *enantiomers:* differ only in terms of the direction of rotation of the linearly polarized light, the value of the rotating angle being the same only if they have the same chain and the same positions of the multiple bonds and of the same functional groups, if these constitutive elements are present; as they rotate the linearly polarized light (thus having optical activity), the enantiomers are *optical isomers*;

NOTE: To see if two carbon chains are different, we proceed to overlapping them by translating one another over the other (only linearly). If it is found that they do not coincide, then the translated chain is rotated from top to bottom (or from bottom to top) and from right to left (or from left to right) performing the overlap operation after each rotation. If after none of the overlaps the chains do not coincide then they are different, as they represent one and the same chain if they coincide after any of the overlaps.

Presentation of the types of isomers encountered in classes of organic compounds.

The issue of isomerism is more difficult for students to comprehend because, up to the Xth grade, they were accustomed that a single substance corresponds to a molecular formula. For this reason, and in order for this issue to be correctly understood, when it comes to the first classes of organic compounds (alkanes and alkenes), in the Xth grade there is a need for a very clear procedure to describe the types of isomers to be, at the same time, accessible to the students' level of knowledge.

We describe below only the procedures for teaching the types of isomers found in alkanes and alkenes; the procedures for teaching the types of isomer to other hydrocarbon classes (alkynes, dienes, arene) may be adaptations to those of the alkenes.

- Alkane isomers

In the first part, the notions of *isomers, isomerism and structure (constitution)* will be introduced and explained, with some simple examples: the isomers for the molecular formulas C_4H_{10} and C_5H_{12}.

In the second part, the classification of the isomers encountered in alkanes: *chain isomers* (part of the structural isomers) and *optical isomers* (which are part of the steric isomer category) that can be: *enantiomers* and *diastereoisomers*.

Because the understanding of the enantiomeric and diastereoisomeric relationship, respectively, requires notions such as: configuration, chirality (asymmetry), optical activity etc., which in the Xth grade are harder to comprehend, these types of isomers will not be presented in detail, leaving this only for chain isomers. In order for this type of chain isomers to be correctly understood, the procedure should be presented to determine whether two chains are different, taking care that the examples are chosen so as to avoid situations where to a molecular formula correspond also optical isomers. More exactly, molecular formulas having at least 7 carbon atoms should be avoided. If such a formula were to be used, situations would arise where a non-existent compound would be considered as a chain isomer of another one that exists.

For example, for the C_7H_{16} molecular formula, it is wrong to consider that 3-methylhexane is the n-heptane chain isomer since the first one does not exist while the second one exists, as the chemical compounds. In this example, the chain isomers are: *(+)-3-methylhexane* with *n-heptane* and, respectively, *(-)-3-methylhexane,* with *n-heptane,* which, for a Xth grade student, is difficult to be comprehended as he has no knowledge of optical isomerism.

- Alkene isomers

In the first part we shall make a presentation of the covalent bonds σ and π insisting on the differences between them, in particular, on the rigidity of the π bond as compared to the mobility of the σ bond and its role in the existence of the geometric isomers, and the notions of configuration and substituent shall be defined.

In the second part we shall present the classification of the isomers found in alkenes: structural (functional, chain, position) isomers and steric isomers (enantiomers and diastereoisomers where geometric isomers are also included). Afterwards, the following isomers are described: functional, chain, position and geometric, the other types being omitted because of the difficulty of comprehension of their particularities by Xth grade students. For this reason it is necessary that the examples chosen, when taught, as well as the applications, when consolidating or verifying knowledge takes place, contain only isomers of the types described.

It is preferable that the order in which these types of isomers are described is this because it facilitates the understanding of the characteristics of each type of isomer. For this approach, it is necessary to specify that a certain type of isomerism is to be established only if the conditions of the former type are not met any more, statement otherwise valid in any class of organic compounds.

- Isomerisation of hydrocarbon derivatives

Given that the main classes of hydrocarbon derivatives are studied in the XIth grade, we believe that, before introducing the specific issues of each of these classes, it is advisable to introduce a first chapter with the following two sections: describing the main functional groups and the hydrocarbon derivatives generated by them (indicating also their names) and describing the whole issue of isomerism in accordance with the procedure set out in point 3.1. The introduction of this chapter would greatly facilitate the proper understanding of the types of isomers encountered at each of the hydrocarbon derivatives classes to be taught in the next chapters throughout the XIth grade. This creates the possibility that for each organic function the types of isomers to be described by the students themselves.

Determining the number of isomers

This requirement may be set with the aim of:

- establishing the number of isomers corresponding to a molecular formula;
- establishing the number of corresponding isomers (of) to a chemical compound;

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- establishing the number of isomers of a certain type corresponding to a molecular formula or a chemical compound.

5. Research Methods

In order to achieve these goals, obviously, account must be taken of the conditions enforced and, at the same time, the procedure set out in point 3.1 must be observed. Thus, if the number of isomers corresponding to a molecular formula is required, without enforcing any condition, ALL isomers must be identified, according to the mentioned procedure, WITHOUT ANY OMISSION. If at least one is omitted, for various reasons, it’s obvious that the number set is wrong. The same, if at least one is taken into account two or more times. In the case where the isomers of a chemical compound are required without any specification of their type, it is logical that their number is smaller by 1 than the total number of isomers corresponding to the respective molecular formula; this number, in any case, cannot be equal to the total number of isomers, since the respective compound is also part of this number, and it cannot be an isomer with itself.

This problem of establishing the number of isomers is complicated when requiring isomers of a certain type, corresponding to a molecular formula or chemical compound.

In order to understand the complexity of this problem, let’s start from a quite accessible example, namely from the C_7H_{14} molecular formula to which corresponds a total of 11 isomers, out of which 7 (*n-heptane, 2-methylhexane, 2,2-dimethylpentane, 2,4 -dimetilpentanul, 3,3-dimethylpentane, 3-ethylpentane* and *2,2,3-trimethylbutane*) have no optical activity and 4 (*(+)-3-methylhexane, (-)-3-methylhexane, (+)-2,3-dimethylpentane, (-)-2,3-dimethylpentane*) are optical isomers. The questions that might be asked for this example could be:

- How many isomers correspond to the molecular formula C_7H_{14} (excluding stereoisomers)?
- How many stereoisomers correspond to the molecular formula C_7H_{14}?
- How many isomers have (correspond to) any of the 7 isomers lacking optical activity and how many of them are chain isomers?
- How many isomers have any of the 4 optical isomers and how many of them are chain isomers?
- How many chain isomers correspond to the molecular formula C_7H_{14} and what are they?

5.2. Given the total number of isomers corresponding to the C_7H_{14} molecular formula, and taking into account the restrictions enforced, the logical responses to these questions are (in the same order):

- **7 isomers,** i.e. those **which are not optical isomers** that are stereoisomers;
- **4 isomers,** i.e. those that **are optical isomers**;
- **10 isomers** (the other 10 excluding the one in question), **all of which are chain isomers** because each of them has a different chain from the one in question;
- **10 isomers** (the other 10 excluding the one in question), out of which **9 are chain isomers** (excluding the one in question and its enantiomer) because they alone have chains different from the one in question and its enantiomer, the two enantiomers having the same chain;
- Everyone would respond that *9 chain isomers* correspond to the molecular formula C_7H_{14}, especially that this statement is in Table 2.2 on page 19 of the Xth grade chemistry textbook referred to in point 2.1. Complications occur when it is necessary to specify which are the 2 isomers, out of the 11 ones,

to be removed because they would not be chain isomers with the other 9. If you remove any 2 isomers from the 7 non-optically active, it would be wrong, because we saw that each one of them is a chain isomer with the other 10 having a chain different from theirs. If we remove one of the enantiomers from each of the two pairs, we consider that it would be wrong again, because the two enantiomers in each pair are equal in terms of the relation of chain isomerism with the other 9. Taking into account these reasons we consider it is impossible to determine the number of chain isomers of this molecular formula. Note that a net distinction should be made between the number of carbon chains corresponding to these isomers, which indeed is equal to 9, and the number of isomers having these chains and which is, as we have seen, equal to 11.

6. Findings

Working with other examples we found that:

- Not always the number of isomers corresponding to a molecular formula is equal to the number of carbonate chains corresponding to the respective molecular formula. For this reason a clear distinction must be made between isomers, which are chemical compounds, and carbonate chains which are a structural element of these compounds, so that when it comes to a category of these two, the other is not taken into account;
- There is only one isomeric relation between two isomers, irrespective of its type. Also, an isomeric relationship of whatever type can only be established between at least two compounds, a chemical compound not being an isomer with itself;
- It is not always possible to determine the number of isomers of a certain type corresponding to a molecular formula. Thus, if the number of optical, geometric, compensatory or functional isomers (in the sense of isomers of the same organic function) corresponding to a molecular formula can be determined, the number of chain and position isomers, corresponding to the same molecular formula, cannot be set because for the same chain and, respectively, for the same position within the same chain of the multiple link or functional group, there are several configurations corresponding to as many isomers. The number of chain and position isomers of a molecular formula can only be established if, among its corresponding isomers, there are no optical, geometric, functional and compensation isomers.

7. Conclusion

Synthesizing what we have introduced in this paper, it can be said that:

In the field of chemistry, in the theoretical activity (teaching, learning, solving exercises and problems), as in the practical one (experimental and production activity), it must be worked only with existing substances. In this context, formulations such as “a substance that has x isomers...” are chemically incorrect, which is why they should be avoided;

Isomerism is not a property of chemical compounds, but a concept on which the chapter of organic chemistry with the same name has been developed. For this reason, expressions such as “substance or substances having or having isomers...” are chemically incorrect and should no longer be used;

The existence of any type of isomers is not conditioned by the existence of a “parent substance” to generate them, to which it belongs, because this parent substance does not exist as a chemical substance;

When determining the number of isomers corresponding to a molecular formula, all isomers, of whatever type, are to be taken into account, as for the determination of the number of isomers corresponding to a chemical compound, all isomers corresponding to the respective molecular formula are to be taken into account except for the one in question, as it cannot be an isomer with itself;

An isomeric relationship can exist only between at least two chemical compounds, and between two such compounds there can be only one isomeric relationship, and they cannot be isomers of several types at the same time;

The determination of the number of chain and position isomers corresponding to a chemical molecular formula can only be established if, among the isomers corresponding to the respective molecular formula, compensatory, function, optical or geometric isomers are not found;

For the correct comprehension of the isomeric issue it is necessary, on the one hand, to establish a general procedure for presenting the types of isomers, and, on the other hand, to adapt and correlate it with both the particularities of the classes of organic compounds and with the possibilities of comprehension of the students;

Last but not least, in the entire theoretical and practical activity, both the grammatical rules and the vocabulary of the Romanian language, as well as the logic and the argumentation must be used correctly.

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