A TOOLKIT FOR MASTERING ORGANIC NOMENCLATURE IN GENERAL CHEMISTRY

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ABSTRACT

In the second semester of general chemistry, students receive an introduction to organic chemistry. A strong foundation in learning starts with the ability to correctly name organic compounds. Our proposed strategy involves the identification of the parent chain, the recognition of resident functional groups, and the ability to discern/indicate the correct isomer if any, etc. We propose a modular toolbox that facilitates compartmentalization of the nomenclature process of organic compounds and helps the student adequately identify all structural elements present in an organic compound. Accurately naming an organic compound is essential to understanding of its properties; to success in Organic Chemistry 1 and 2; and, for a career as a Chemist in academia, industry or in government agencies. The advantages of our procedure is discussed using examples to illustrate the process. *[African Journal of Chemical Education—AJCE 8(2), July 2018]*

INTRODUCTION

Organic chemistry is the study of compounds that contain chains of carbons with hydrogens attached or hydrocarbons for short [1]. In the second semester of General Chemistry (Gen Chem II), science majors acquire knowledge of the basic procedures of naming organic structures of the aliphatic group and the aromatic group. Herein, they also learn about functional groups which are atoms that are responsible for influencing the carbon chain's chemical behavior in reactions [1].

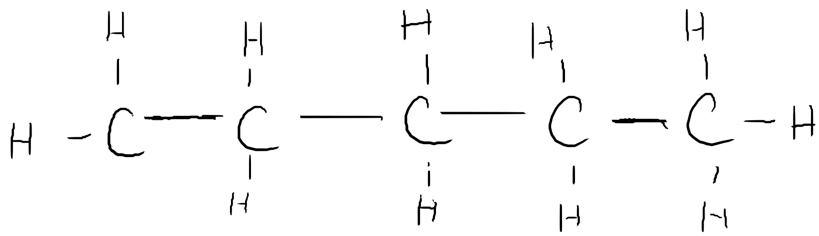
It is common for students not to fully understand the basic naming and reactions or organic compounds. The fundamentals of organic compounds are essential for future chemistry courses. This is a method for guiding peer leaders of the PLTL program in their mission of helping students learn organic chemistry fundamentals. We accomplish this by organizing the naming process into a collection of steps. It helps if students break up a large problem into manageable sub-problems. Learning seems to be achieved when things are broken into steps. Studies have shown that the brain works more efficiently if tasks are done one at a time rather than at the same time [2].

METHODOLOGY

In introductory organic chemistry there are two classes of compounds, the aliphatic and aromatic groups. The rules for their nomenclature are set by the International Union of Pure and Applied Chemistry (IUPAC) [3].

In each group of carbons in a chain (or a ring), there is a name that identifies the chain called parent chain. The parent chain describes what classification the carbon compound is (aliphatic or aromatic) and how long the carbon chain is.

In the first lesson students are taught is that in a chain of carbons, the longest, continuous chain is the parent name. As an example, a chain of five carbons with only single bonds is called pentane, which is an aliphatic member. An image below shows the structure of a pentane:



Pentane is a hydrocarbon; i.e., it is composed of carbons bonded to hydrogens. There are various functional groups that are included in the name, and some of these functional groups have priority in being recognized in the parent name and the student can consult with that in their chemistry book. Examples of functional groups are: alkyls, alkenes, cycloalkanes, alkynes, ketones, esters, ethers, aldehydes. The identity of the functional group, depending on its priority, is emphasized in the parent name based upon IUPAC standards [3].

For educational purposes only the alkyls, alkenes, alkynes and alcohols may be used as examples throughout this article. Some functional groups must be specified by name depending on their location in the chain. The key to learning nomenclature is determining the longest chain of carbons. If after extracting the longest chain and there are leftover chains, or substituents attached, those are to be considered in the name as well [1]. The location of those substituents in the chain are identified in the name. If there are several of the same substituent there must be something in the name to signify its quantity.

A method that relates to the steps in identifying the appropriate name of the carbon chain is analogous to having a family that lives in a street and each familiar member that lives in the street lives in their own house. Their street name will be the longest chain of carbons or the parent name. If there is functional group that has greater priority in the parent name, then it will have significance in the parent name. For example, an alcohol will have an “ol” ending. The street name which is the longest chain of carbons would be the family last name, unless, if there is a functional group of higher priority, the group will hold the last name of the family. Each member that lives in a carbon is their house and their house address can be, for instance, carbon number 2, meaning that family member or substituent or alkyl group is located at carbon 2 in the street of carbons. This method is further explained below:

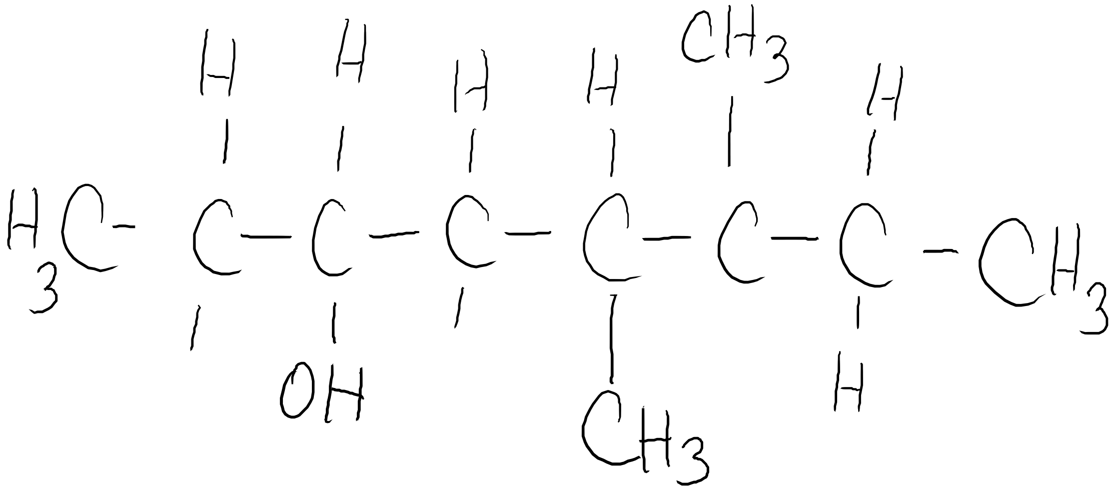
The following structure shows how the name can be broken into parts in a way that helps the student imagine what this structure looks like, and what it contains:

# (CARBON #n ASSIGNED)	NUMBER OF THEM SPECIFIED IF THE ALKYL OR SUBSTITUENT OCCURS MORE THAN ONCE USING A PREFIX (e.g. “di” = 2)	FIRST ALKYL OR SUBSTITUEN T IDENTIFIED IN THE NAME	… (ANY OTHER AKYLS OR SUBSTITUENTS BETWEEN ALONG WITH THEIR LOCATION AND NUMBER OF THEM IF ANY APPEAR MORE THAN ONCE IN THE CHAIN)	LAST ALKYL OR SUBSTITUEN T ATTACHED TO THE PARENT NAME	PARENT NAME OF THE HYDROCARBO N CHAIN (LOCATION SPECIFIED IF NECESSARY)

When given a structure, and the student needs to identify the correct IUPAC name, the first thing the student should do is to count the longest chain of carbons and the functional group responsible for the carbon group. The student must be able to recognize various functional groups and that specific functional group will give a specific ending. An alkane has an “ane” ending and a ketone has an “one” ending. That parent chain goes in the yellow box above. Then, the green boxes are the smaller chains of carbons or the other substituents attached to the chain and the amount can vary. The last alkyl or substituent will be attached to the parent name. Then, the very first green box is where the first alkyl or substituent goes. The blue box is reserved in cases where the number of the same kind of substituents or alkyls appear more than once in the chain and those are denoted with Latin prefixes such as di, tri, etc. The pink box is to specify the location of the substituent or alkyl in the carbon chain.

By IUPAC standards there are rules implemented to keep the naming consistent. That is for the green boxes, the order by which the alkyls or substituents appear in the name is alphabetically such as as chloro, flouro, methyl, etc would be listed alphabetically by the first letter of their name. Thus, for assigning the location of these species attached to the chain, by counting along the chain and assigning a carbon number n, the sum of all n(integers) must the least sum possible. This is achieved by counting the chain starting from the direction that produces the lowest possible number for all the substituents. Once the smallest sum is accounted for, then those are the carbon locations or carbon numbers the substituents or alkyl groups are assigned. The carbon numbers are in the pink boxes above. It is also important to note that species in the green boxes are only named alphabetically not the prefixes in the blue boxes. These are the rules obeyed by the IUPAC society; students can learn these rules from their chemistry books [3].

For the parent names that go in the yellow boxes the location of parent function must be specified if it has priority in being mentioned in the last part of the name of the carbon compound. Consider alcohol. Alcohol has authority in the parent name, which gives the molecule an “ol” ending and gets the first call to the lowest carbon assigned to indicate the location of the hydroxyl group. The rest of the substituents and alkyls will be assigned a number according to the lowest integer for the hydroxyl group. For example:

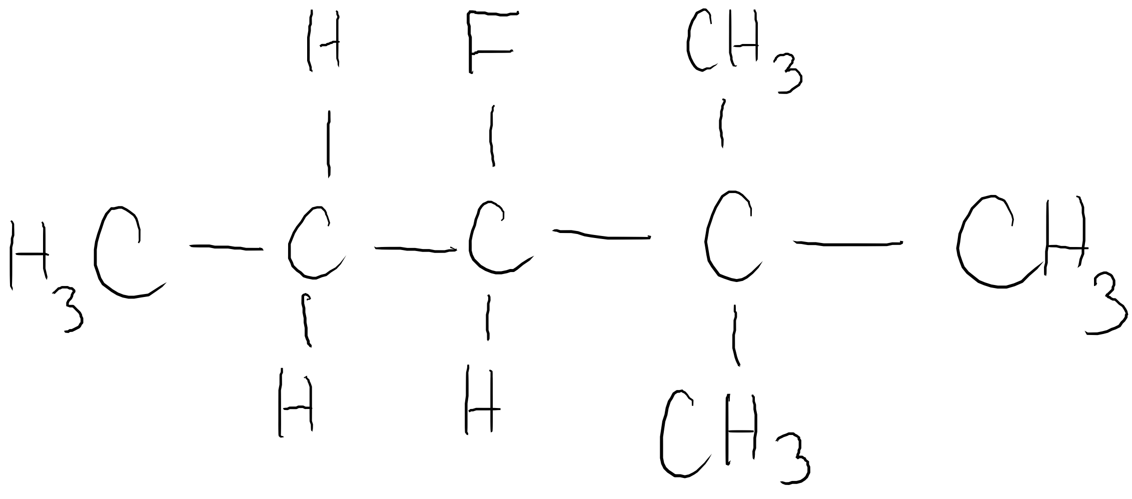


There are two possible answers that a student can come up with - 3,4-dimethylpentan-6-ol and 5,6-dimethylpentan-3-ol. Which name would be the correct name for the structure shown above? Because the hydroxyl functional group has more authority of the name than the alkane functional group, the OH- ion gets the lowest carbon number assigned and the parent name will have an "ol" ending. Thus, the correct name is 5,6-dimethylpentan-3-ol. The remaining substituents or alkyl groups would be assigned carbon numbers according to the hydroxyl group.

This method of learning the basic organic nomenclature can be analogous to having a family. A family with all kinds of relatives, personalities and relationships. This concept can help a student relate to learning this nomenclature. Let's demonstrate to the concept of having a family, see the following name:

3-flouro-2,2-dimethylpentane

The structure of the name is shown:



The longest chain of carbons is the family name, the last name, the last name has authority of the chain. The last name tells you how long the chain is. The last name can tell you, if it is an alkene, alkyne, alcohol, or any other functional group and the location of that functional group.

This structure can be represented as a family of atoms bonded at a specific orientation and to an atom. First, in the name and image the student must identify the longest chain of carbons. The carbons are located at every peak or corner of the chain and end points of the structure. The longest chain is five carbons. Think of the longest chain as a street and each carbon along with the longest chain is a house. The other species attached to the longest chain or remain in the chain are the relatives of the family and live at a specific carbon (at their own house). See the name again:

3-flouro-2,2-dimethylpentane

The last name is also the parent function of the group of atoms. This is highlighted as yellow just like the yellow box above. The last alkyl group or substituent attached to the last name and to the beginning of the name is the first name of the family. The first name of the family tells you all the relatives that live along that street of carbons. The first name is highlighted in green. These species “live” at a specific carbon, so the numbers highlighted in pink are the addresses to the house these species “live” in or the specific carbon they “live” in.

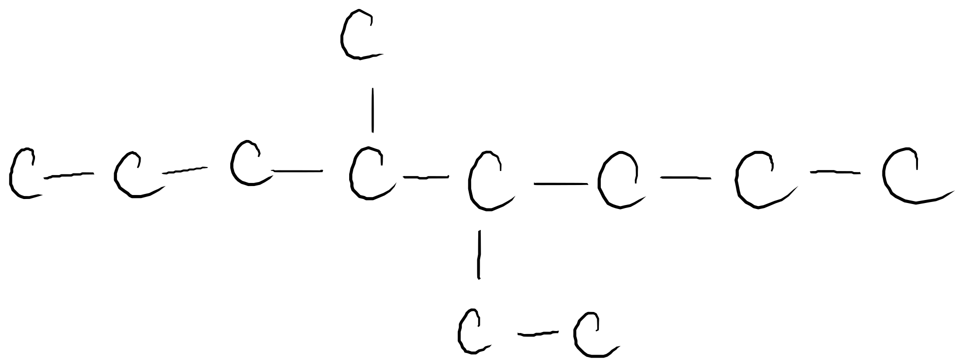
In 3-flouro-2,2-dimethylpentane, there are three relatives that “live” on the street of carbons, a fluorine (Fernando) and two methyls (Marie and Michael). As mentioned before, the three substituents are located at a specific carbon number, Fernando’s address is 3 and Marie and Michael are two cousins that “live” in address 2. The fluorine is located at carbon 3 and the two methyl’s are located at carbon two.

Within the first name, not only does the name tell you what type of substituents or alkyls the molecule possesses but also if there is more than one kind of the same substituent. In the name 3-flouro-2,2-dimethylpentane, the prefix “di” tells that there is 2 methyls at carbon 2, and the location 2 is written twice to indicate that two methyls live at carbon 2. Another example could be 2,3-dinitro-4-nonanol where there are two nitro functional groups located in carbon 2 and 3.

Here are examples this method can be applied (Exploration):

1. 4-methyl-*trans*-2-pentene
2. 3-pentanone
3. 2,3-dinitro-4-nonanol
4. 4-ethyl-2-methyl-hexane

Sometimes the last name of the family can only appear, therefore, only the yellow box would be considered, meaning the family has a street but no relatives live in that street. An example could be as simple as cycloheptane. The last name tells you that the functional group is a cycloalkane and the most number of carbons is 7. Another example is when a structure can have more than one correct name, but there is one that is most preferred for consistency. An example can be shown:



There are technically two correct names for the structure. One is 5-ethyl-4-methyloctane or 4-ethyl-5methyloctane. Again, they are both correct, but the most preferred would be the second one because it is more consistent to have the lowest carbon number assigned to the first alkyl or substituent appear first in the alphabet. There are many examples of this, and the student must be able to identify those situations. This tool can be used in the basic learning or organic nomenclature for students taking the second semester of general chemistry.

CONCLUSION

The goal for the Peer Led Team Learning Program in the Chemistry Department at the University of Texas at El Paso strives to implement ways to make learning more effective for students to succeed in their general chemistry courses. One way is, the peer leaders of the PLTL utilizes a workbook to use in workshops to work out problems for students to gain cooperative skills to work with their peers to learn the material and are encouraged to engage in discussions about the subjects. There is always opportunity to improve on making workshops more effective by coming up with ways students can learn such as memorizing the seven only diatomic molecules that exist at room temperature by the phrase “Have No Fear Of Ice Cold Beer” (PLTL)[4]. Have for hydrogen, no for nitrogen, fear for fluorine, of for oxygen, ice for iodine, cold for chlorine and beer for bromine. Also, the state for ice is solid, so the student can make the connection to iodine being the only diatomic molecule that is solid at room temperature. Same for bromine, beer is a liquid at room temperature so that means the state for bromine is liquid. One of the subjects' students tend to struggle on is the introduction to organic nomenclature and a method has been invented that can help students make connections to stuff they can relate to.

Overall, organizing the problem into steps from image to name or name to image could be used by the household method. Students can use their chemistry books to determine which functional groups have priority. Then determining the first name means what other species remain on the longest chain identified and their location they are at in the chain. This method could help students mentally proceed through a step process and learn the basic organic nomenclature.

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