

Organic Chemistry—An Introduction

I am not the best person to be giving a lecture on organic chemistry—the world is filled with two kinds of people, the ones who despise organic, and the ones who love it. During the year I took organic in college, I was also plastering the words from sad songs all over my dorm room walls—looking back I realize there was a cause and effect relationship between organic and typing up those songs. Honestly, I always thought the lunch each Tuesday afternoon before organic lab felt pretty much like a person going before a firing squad, only it happened over and over and over for an entire year.

With that off my chest, a nice lecture that surveys the important foundational concepts for what to expect in organic chemistry. Mostly you will get a feel for the fact that organic is a lot of nomenclature and a lot of systematic rules. For those who like languages and lists, and for those who can close their eyes and imagine a three-dimensional world of molecular structures, organic is quite easy. For those, like me, who would rather reduce the subject to a couple of simple mathematical formulas, it is quite difficult. I mean, what kind of science course doesn't need a calculator.

But enough rant.

Organic Chemistry Nomenclature.

Why does it take a year to do organic—the study of a single atom, carbon? The reason is that pesky carbon atom is remarkably adept at forming different kinds of molecules. For example, if I were to draw all the legal ways to put together 12 C atoms and 26 H atoms (to satisfy the Nobel gas configuration) there are 355 correct structures, each with its own unique properties. And then if we let the C react with all the compounds that form covalent bonds, like N, O, Cl, P, S, etc., the possibilities explode exponentially. And organic chemists want you to be able to draw and name everyone of those compounds and then explain why one of them evaporates just a little faster, or reacts just a little slower, than another.

So I guess they can have their year. But it is still just stuff you learned in my class.

Alkanes: The basic organic compound is an alkane—it has only C and H bonds, and every one of those bonds is a sigma bond. Alkanes are not very exciting because they don't do much reacting. But they are a great place to start learning nomenclature.

To begin, every organic molecule has three parts defined by a VERY systematic set of rules:

a prefix

a parent

a suffix

- The parent is the length of the longest carbon chain—like **methane** for one carbon, **ethane** for two carbons, **heptane** for seven carbons
- The prefix contains any substituents on the molecule besides the parent C chain—like an extra methyl or hydroxyl group
- The suffix is the family in which the compound falls based upon the functional group attached to the parent chain—for example, the suffix **-ol** indicates that **ethanol** is an alcohol.

For the first molecules we are studying, the **alkane** family has a suffix **-ane** to indicate that nothing more exciting than a bunch of hydrocarbon sigma bonds are found in the molecule.

So whether you have

Pentane or decane or 2-methylpropane or 2,4 dimethylheptane

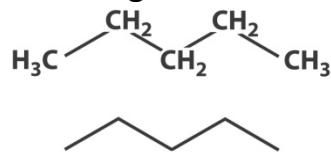
The **ane** suffix indicates you have an alkane.

So what are all the possible parent names? Not surprisingly, they kind of make sense if you know your Greek, and are so consistent that you pick them up quickly even if you don't speak the language.

TABLE 18.1 Alkane Nomenclature

Number of carbon atoms	Formula	Name of alkane	Name of alkyl group	Formula
1	CH_4	methane	methyl	CH_3-
2	CH_3CH_3	ethane	ethyl	CH_3CH_2-
3	$\text{CH}_3\text{CH}_2\text{CH}_3$	propane	propyl	$\text{CH}_3\text{CH}_2\text{CH}_2-$
4	$\text{CH}_3(\text{CH}_2)_2\text{CH}_3$	butane	butyl	$\text{CH}_3(\text{CH}_2)_2\text{CH}_2-$
5	$\text{CH}_3(\text{CH}_2)_3\text{CH}_3$	pentane	pentyl	$\text{CH}_3(\text{CH}_2)_3\text{CH}_2-$
6	$\text{CH}_3(\text{CH}_2)_4\text{CH}_3$	hexane	hexyl	$\text{CH}_3(\text{CH}_2)_4\text{CH}_2-$
7	$\text{CH}_3(\text{CH}_2)_5\text{CH}_3$	heptane	heptyl	$\text{CH}_3(\text{CH}_2)_5\text{CH}_2-$
8	$\text{CH}_3(\text{CH}_2)_6\text{CH}_3$	octane	octyl	$\text{CH}_3(\text{CH}_2)_6\text{CH}_2-$
9	$\text{CH}_3(\text{CH}_2)_7\text{CH}_3$	nonane	nonyl	$\text{CH}_3(\text{CH}_2)_7\text{CH}_2-$
10	$\text{CH}_3(\text{CH}_2)_8\text{CH}_3$	decane	decyl	$\text{CH}_3(\text{CH}_2)_8\text{CH}_2-$
11	$\text{CH}_3(\text{CH}_2)_9\text{CH}_3$	undecane	undecyl	$\text{CH}_3(\text{CH}_2)_9\text{CH}_2-$
12	$\text{CH}_3(\text{CH}_2)_{10}\text{CH}_3$	dodecane	dodecyl	$\text{CH}_3(\text{CH}_2)_{10}\text{CH}_2-$

Drawing an organic molecule in two-dimensions. So a simple five carbon alkane is called pentane and has the following structure:

**2 Pentane, C_5H_{12}**

Note that in trying to tell people about the molecule, you can give the compound a formal name, like pentane, or you can draw a simple structure in which the bonds between the carbons are shown adjacent to the CH_2 and CH_3 groups, or, if you are a real organic chemist, you don't waste your time ever drawing C and H, since that is 99% of what you have in your molecules anyway, and instead you just draw the bonds (so zig-zag sticks above), and let everyone else make a mental note that at the vertices are carbons and that every carbon is fitted out with enough hydrogens to satisfy the octet rule.

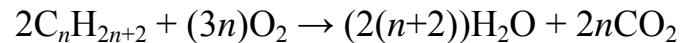
By the way, if you wanted, you could turn pentane into a nice three dimensional picture just like the ethanol above, that is, if you wanted to, and after awhile, you just automatically imagine that 3-dimensional picture in your head and don't bother with any more than squiggly lines.

Structural Isomers. Recall that I told you that there were 355 ways you could write forms of $C_{12}H_{26}$? Well now you see how this can be done. A structural isomer is a compound which has the same molecular formula, but a different structure. And while smaller chain hydrocarbons don't have many structural isomers (for example, butane with four carbons has just two structural isomers), by the time you reach the C_{32} alkanes, there are about 3×10^7 structural isomers (trust me on this.)

As we near the end of the section on alkanes, a question, can you state a general formula for hydrocarbons of length n? This is as close as we get to math:

Answer: C_nH_{2n+2} take a look at the table and you will see it is so.

Now some chemistry of alkanes. Basically, alkanes burn, and cleanly, I might add, following the combustion equation below:



In the table below is a who's who of fuels which are basically hydrocarbons, mostly alkanes, all of them fractional cuts of petroleum, separated by boiling point range as the number of carbons increases. And as you can see, even though alkanes are the most boring of organic molecules, they are the only ones over which people fight wars.

TABLE 18.2 Hydrocarbon Constituents of Petroleum

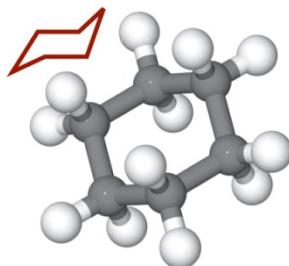
Hydrocarbons	Boiling range (°C)	Fraction
C_1 to C_4	-160 to 0	natural gas and propane
C_5 to C_{11}	30 to 200	gasoline
C_{10} to C_{16}	180 to 400	kerosene, fuel oil
C_{17} to C_{22}	350 and above	lubricants
C_{23} to C_{34}	low-melting-point solids	paraffin wax
C_{35} upward	soft solids	asphalt

Let's get cyclic.

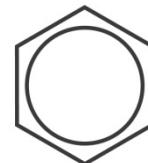
A bit more nomenclature involving hydrocarbons. It is possible for a molecule to form a loop on itself. These are two kinds of cyclic compounds.

Cyclic hydrocarbons are known as cyclic compounds, and we designate them with the prefix, cyclo—

Benzene and its aromatic friends. The really important cyclic species are aromatic compounds—those based on the ring structure shown below:

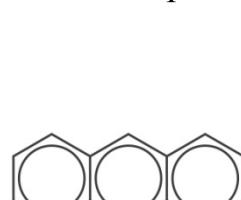


16 Cyclohexane, C₆H₁₂

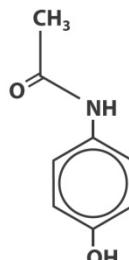


31 Benzene, C₆H₆

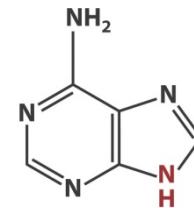
As we learned while discussing molecular orbital theory in CH301, aromatic compounds are hexagonal ring structures formed from the overlap of C_{sp²}-C_{sp²} that form σ bonds. What makes aromatic compounds is the leftover 6 electrons that form a sea of delocalized π electrons positioned above and below the ring. It is this p-bonding structure that creates a unique stability and reactivity for aromatic species. While we won't spend any more time on these structures, it is enough to know that aromatic species are ubiquitous in nature, whether in petrochemicals like anthracene or drugs like Tylenol or biological-active molecules



33 Anthracene, C₁₄H₁₀



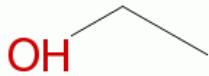
14 Tylenol **22 Adenine**



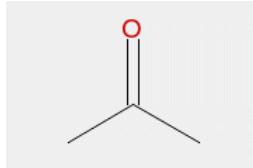
like adenine.

Other functional groups in organic molecules. If all of our compounds had only hydrogens and carbons, organic chemistry would be easy and life would be boring. So there are hundreds of functional groups that can be added. I want you to know just four of them because they pop up all the time

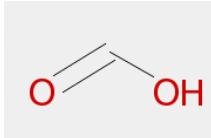
- Alcohols: Ethane plus –ol (an alcohol) make ethanol, a 2 carbon alcohol



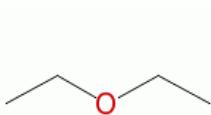
- Ketones: Ethane plus –one (a ketone) make acetone, a 2 carbon ketone



- Carboxylic acids: Methane plus –oic acid (a carboxylic acid) makes metanoic acid or formic acid, a 1 carbon acid that is the stuff in ant bites

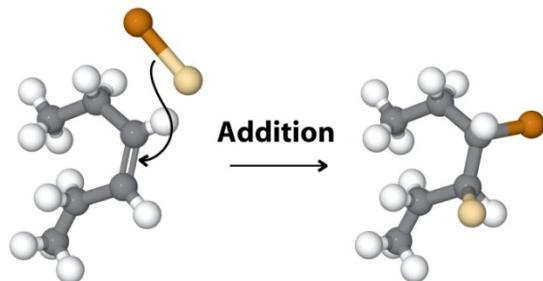
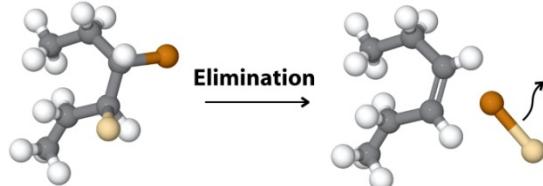
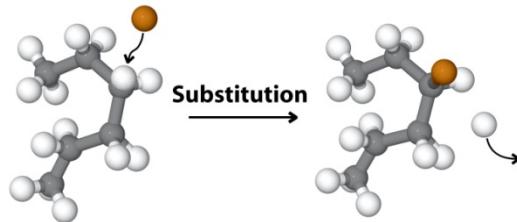


- Ethers: an ethane plus an ethane with an O in the middle is an ether, specifically diethyl ether, the stuff bad guys put in handkerchiefs to kidnap you.



Organic Chemistry Reactivity. What makes organic such a challenge isn't simply being able to assign names to compounds, it is being able to predict the reactions that this incredibly broad array of compounds undergo. To say an understanding of organic reactivity is beyond the scope of this course, is about as understated a comment as one can make. To understand organic reactivity is to understand the chemistry of not just these relatively small molecules, but also the fields of polymer chemistry and biochemistry—you know, pretty much everything.

But we can create three classes of general reaction mechanisms. They are listed below in some nice pictures from the text that suggest why the names are given to these reactions.



And that is more than enough to know about organic.