



Alkenes & Alkynes - Crash Course Chemistry #41

Crash Course: Chemistry

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Propane, methane, butane, those single-bond carbon chains we talked about last week, they are important, but they're kind of boring. Alkanes are just more of the same, add another carbon to lengthen the chain.

But toss a double bond in here or there, and the situation gets a lot more complicated, and interesting, and delicious. Hydrocarbons can fuel cars and stoves and stuff, but they can also fuel you: dripping off your hamburger, melting into your biscuit or frying up your tater tots. Delicious, marvelous, complicated fats.

Fats have a bunch of jargon associated with them, that the average person uses daily and with abandon, despite having absolutely no idea what it means. But they still jabber on about saturated, or mono- polyunsaturated, omega-3, hydrogenated, or trans. The differences between fats and what makes them better or worse for you is whether or not they have double and triple bonds, and where and how those bonds occur. Seemingly trivial changes in the structure of a carbon chain can completely change the chemistry of the molecule, including the chemistry of what happens when you ingest it. Yes, your body *can* tell the difference between them, and by the time we're done here today, you'll be able to as well.

INTRO

Alkanes, as you'll recall, are saturated hydrocarbons. All of the carbons in a saturated hydrocarbon are bonded to the maximum number of atoms that carbon can accommodate: four. In unsaturated hydrocarbons, some of the carbon atoms are double or triple bonded with each other, so they're only bonded with three or two atoms. And when those double and triple bonds appear, we've got whole new classes of hydrocarbons. If they've got a double bond, we call them alkenes, and those with triple bonds are alkynes.

So three words representing three different groups of organic compounds: alkanes for all single bonds, alkenes if they contain double bonds, and alkynes if they contain one or more triple bonds. How do you remember which is which?

Well, I have a trick that I use. There's only one letter changing here: A in alkanes changes to E for alkenes and then to Y for alkynes. In alphabetical order, A is first, E is second, and Y is third. Not too complicated, I hope.

And it's actually pretty nice that the words are so similar, because it means we can reuse all of those old alkane rules. The prefixes remain the same, but the suffixes change in some fairly easy-to-predict ways. Hydrocarbons that have one or more double bonds end in -ene, while the ones that have triple bonds use the suffix -yne. So a compound with three carbons and one double bond would be propene, three carbons and one triple bond: propyne.

All the other naming rules apply to alkenes and alkynes too. For instance, the main carbon chain, the longest one, is numbered in such a way that the various components, including the double bond, have the lowest numbers possible.

Now, the bonds in alkenes have a few tricks up their sleeves. It's not as simple as you might imagine. Single bonds, also called sigma bonds, are pretty simple, and carbon atoms attached by them can rotate around the bond freely. That may not sound like a big deal at first, but alkenes and alkynes don't have that kind of freedom, and that simple fact has a huge affect on their properties.

Double bonds consist of a sigma bond and a pi bond. That pi bond bridges the sigma bond, locking it in place. So whatever's attached to the other sides of the carbon atoms can't change their orientation with respect to each other. If all of those things attached to those

carbons are the same, it doesn't matter. But if the parts are different, it's possible to have two totally different isomers of the same compound.

Let's build an example for ourselves. 2-butene should suffice. So it starts with but-, so it has to be a four carbon chain. It ends in -ene, so it needs to have a double bond. The 2 tells us that the double bond starts on the second carbon. So we've got our structure! Or do we? With the information we have, this 2-butene could be one of two different isomers: one with the methyl groups on the same side or one with the methyl groups on different sides.

They're not structural isomers like n-butane and i-butane, instead, they're what we call cis-trans isomers. These have the atoms in the same position on the molecule, but the atoms are oriented differently in space. Cis- comes from the Latin word that means on the same side and trans- is Latin based prefix that means across. If the matching groups are on the same side of the double bond like this, we call it cis-2-butene. And if the two components are across from each other, it's called trans-2-butene. Note, by the way, that organic compounds cannot switch from cis- to trans- or the other way around. You would have to break the pi bond, and thus, the entire molecule to rotate between isomers.

The same rules apply no matter what's attached to the double bond. It might be a long hydrocarbon chain or a halogen or an oxygen. All that matters is that the matching components are next to each other or across from each other.

The triple bonds in alkynes, meanwhile, are composed of one sigma bond and two pi bonds for a total of three bonds. The pi bonds prevent the triple bonds from rotating here as well, but triple bonded carbons can only bond to one other atom so even if it could rotate, nothing would change. Thus, no isomers with alkynes. Phew.

Okay I'm done describing for the moment. Let's talk about some actual chemistry. Pi bonds are significantly more unstable than sigma bonds so double and triple bonds are pretty easy to break, opening the doors for some goo chemistry. Certain reactions open up a double or triple bond to insert various atoms, leaving only a single bond between the carbons. These are called addition reactions because atoms are added to the carbons that were previously double bonded.

Probably the simplest addition reaction and one that you've heard of is hydrogenation in which a molecule of hydrogen, H₂, is added across the bond. To do this, a metal catalyst like platinum is usually required to help break the H₂ apart because that bond is very strong. But once that's done, the hydrogen atoms readily attach to the hydrocarbon molecule, converting a double bond to a single bond.

Other molecules can break down a double bond as well. If a halogen, such as bromine, is added in the place of hydrogen, the reaction is called halogenation. Water molecule: hydration. Oxygen gas: oxygenation. You get the idea. The point is that double or triple bonds can be usually opened up fairly easily. Alkenes can be made into alkanes and alkynes can become either alkenes or alkanes depending on how many atoms are added. And those opened bonds can also provide connections for carbon atoms to attach to each other, too, opening the door for polymerization, which we should talk about soon enough.

Now, using all these words we learned today, let's apply some to our society's ubiquitous fat lingo. First, though, what is fat? When three fatty acids, and we will talk about their structures more specifically in a later episode, are bonded to a molecule of glycerol, that is a triglyceride. That's the stuff that we're generally talking



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about when we say "fat." The fatty acid chains, they have long hydrocarbon chains, are what we're mostly concerned with here. They can be alkanes or alkenes, sometimes, even rarely, alkynes.

So, we've heard of saturated fats. What does that mean? It means no double bonds. All of the carbon chains are alkanes and has as many hydrogens as possible. It's saturated. That means that there are no unstable pi bonds, so they tend to have longer shelf lives. They are also able to lay flat against each other, making them more likely to be solid at room temperature. The bad news is that they're kind of hard for your body to do chemistry with since they're so stable, so they often just stick around in your body, clogging stuff up.

Now, what about hydrogenated oils? Vegetable oils are generally poly-unsaturated fats, meaning that they have lots of double bonds, or at least more than one. They're much healthier for us than saturated fats and they're also generally cheaper. Since saturated fats are most likely made from animals, which are notoriously difficult to maintain. But they're also less stable and are usually liquid at room temperature, and thus, harder to spread on your toast. Food chemists use hydrogenation to saturate the unsaturated fat, making it spreadable and also stabilizing it. And, since it's made from vegetable oil instead of animal product, it is much cheaper to create.

Sometimes the oils are fully hydrogenated, creating saturated alkanes. And sometimes, they're just partially hydrogenated, usually leaving just one double bond in the fatty acid chain, creating a mono-unsaturated fat. Now it's not just whether or not there are double bonds, the location of the double bonds also has an effect on what your body can do with the molecules which leads me to omega-3s.

Omega-3 refers to a specific location of the double bond. Three carbons from the end, or omega of the fatty acid chain. Your body is completely incapable of making this sort of fatty acid, and yet, it need them to survive. So, you have to eat them.

A final question: what can you tell me about the dreaded trans fats? Well we know that they're unsaturated alkenes because saturated fats don't have double bonds, and thus, can't have cis- and trans-isomers. But we also know from every advertisement about healthy food that probably isn't that healthy ever, is that trans fats are really bad! So it's an unsaturated fat, but it's really bad for you, that doesn't really jive. What's going on?

Well, almost all natural, unsaturated fats are cis- fats, which our bodies are prepared for and know what to do with. Trans fats are created by partially hydrogenating vegetable oil on a cheap path to tasty fat, without all the saturated fat on the dietary label. However, these trans fats pretty much act exactly like saturated fats, except that since they're naturally very rare, our bodies don't have good systems to break them down into healthy byproducts.

So, as you can see, unsaturated fats went from the best kind of fat to the worst kind of fat with one little isomeric change. Your body can definitely tell the difference. And now, so can you.

Thanks for watching this episode of Crash Course Chemistry. If you payed attention, you learned that hydrocarbons with double bonds are called alkenes and those with triple bonds are called alkynes and that the naming rules are the same as for alkanes. You also learned a little bit about cis-trans isomerism and learned a few important reactions of alkenes and alkynes such as hydrogenation, halogenation, and polymerization. And finally, you learned what all of those names of the different kinds of fats really mean.

This episode was written by Edi Gonzalez and myself. It was edited

by Blake de Pastino and our chemistry consultant was Dr. Heiko Langner. It was filmed, edited, and directed by Nicholas Jenkins. The script supervisor was Michael Aranda who was also our sound designer. And our graphics team is Thought Cafe.