Nomenclature - Crash Course Chemistry #44

Crash Course: Chemistry
https://youtube.com/watch?v=U7wavimfNFE
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=====IUPAC (0:00)=====

There are some of you out there, taking chemistry and feeling a little bit like there's an international body whose job is simply to make your life more difficult, to force you to cram tons of information into your head, to suck all the wonder and excitement out of learning about how the world works at this beautiful, fundamental level of chemicals. You are not actually imagining this. That organization actually exists.

It's called the International Union of Pure and Applied Chemists or IUPAC and really, they're looking out for your best interests, in just the same way that my mom was looking out for my best interests when she said that I couldn't go to the "Violent Femmes" concert with Megan Cross. And yeah, I hated my mom for, like, a full year after that but she was right, that girl was trouble.

So yes, you are allowed to hate IUPAC for changing the name of 'cinnamaldehyde', the aldehyde that makes cinnamon smell like cinnamon to 'trans-3-phenylprop-2-enal'. Yes, they're sucking all the fun out of the world, but trust me when I say, they're doing it for your own good.
(intro music)

=====Every Organic Compound Has Only One Name (1:02)=====

'Cinnamaldehyde' is a lovely name for a lovely aldehyde, just like 'cadaverine' is a creative name for a rancid-smelling amine. 'Citronellol', 'angelic acid', 'vanillin', they're beautiful names but there are tens of thousands of regularly used organic compounds and we can't come up with pretty names for all of them.

More important than that, though, there's no way to translate those names into chemical formulas and IUPAC hates that. They're like, "Cinnamaldehyde, yeah, sure, gives cinnamon its lovely smell but we think 'trans-3-phenylprop-2-enal' is way better of a name!" And it actually is, because if I say 'trans-3-phenylprop-2-enal' to somebody properly educated they can just write down the chemical structure without even thinking about it. And that's, like, almost a kind of magic, where words go from relating to reality as we experience it (this chemical comes from cinnamon so name it after cinnamon) to relating to the actual physical reality of the universe, and that's a magic worth knowing.

IUPAC created a language that could be understood by everyone with minimal even zero misinterpretation and that's no easy feat. That's why, as we've discussed organic chemistry, when we start counting carbons, we make sure that the first thing named on the molecule is the lowest possible carbon, not because there's something special about lower numbers but because they had to make a rule, otherwise one chemical could be named two different ways.

=====Prefixes (2:16)=====

Let's go through the process of naming a chemical, it's a multi-step process. Step 1: how long is the carbon chain? Five carbons will have 'pent-', seven 'sept-', three 'prop-', one 'meth-', don't feel weird if you have to look these up. I, for example, had no idea that a twenty-three carbon atom chain had the prefix 'tricosa-', until I looked it up just now.

The only tricky thing here is to make sure you find the longest carbon chain. Sometimes, a hexane can look like a pentane with an ethane sticking off of it. So now that you know your longest carbon chain, you've got your prefix, time to figure out the suffix.

=====Suffixes (2:47)=====

If there's nothing but hydrogen and carbon, your suffix just depends on whether you have any double bonds or triple bonds; you know these, propane, propene, propyne. Then there are a ton of other groups that can change the suffix, like last week we talked about alcohols and aldehydes and ketones, but we didn't talk about how they affect nomenclature and boy do they.

When working with functional groups, each one adds a particular suffix to the end of the name of a compound. Usually, these are pretty easy to remember because they come straight off the name of the functional group.

Alcohols add an '-ol', so for methane you drop the 'e' and you get methanol; ethane, you get ethanol. Aldehydes, instead of '-ol' you add '-al', so from ethane you get ethanal. Ketones, add '-one', so a ketone of a hexane would be hexanone, and amines, you just add '-amine' to the end so methenamine or propanamine, super easy. For caboxylic acids, you have to identify it's an acid, so you end in acid, that's obvious, but instead of adding '-ylic' you add '-oic'.As far as I can tell, this is just because ethanoic acid is much more fun to say than ethanylic acid.

Going over that again: alcohol, on an ethane, is ethanol, aldehydes add '-al' giving ethanal, ketones add '-one' pronounced 'eth/an/own', amines, add amine for ethanamine, and carboxylic acid, on an ethane, is ethanoic acid.

And of course, there are literally dozens of other named functional groups that will change the suffix. It's terrible, that's why they're on Wikipedia. So if you got a functional group, there's a name that defines the suffix of the molecule and that is called the parent functional group. Now it is perfectly possible that a molecule will have two different functional groups, so how do we know which one is the parent? Which one defines the suffix?

=====Ranking Functional Groups (4:18)=====

Well, different groups have different precedence, the most weighted of all is the carboxylic acid functional group, so no matter what else is on a six carbon chain, if there's a carboxylic acid, then it's a hexanoic acid. That precedence is decided by a list that was, you guessed it, created by IUPAC to minimize confusion by creating yet more rules. The list is linked in the description.

Okay, so now we have created our base name for the molecule, it's time to start looking at what else is attached to it. Any side chains or functional groups sticking off the side have to be identified and named. If it's a six carbon chain with a carboxylic acid on it and an alcohol on one of the other carbons, our name has to do two things: identify that the hydroxyl group is there and identify where it is. If it's got a double bond, we likewise have to identify that it is there and where it is, all with our words. Use your words! Also, use your numbers.

Counting out carbons can be a little confusing but try it both ways, in both directions, to make sure that you get the lowest possible number on the group that defines your suffix. Alright, enough of the talking, let's try to do some actual examples here. I mentioned earlier angelic acid. It's not actually particularly angelic, it was just

named after a flower it was derived from, but it's actually found all over the place in nature, so 'angelic acid' tells us pretty much nothing about the molecule, except that it's acidic.

So in order to figure out the structure I have to look it up. That's no fun, but here it is. Let's figure out a better name for it. Count up the carbons, 1-2-3 if you count that chain, 1-2-3-4 if you count this one so it's a butane derivative. Actually it's a butene derivative because it has that double bond. It's also got the carboxylic acid though, so let's go ahead and call it butenoic acid, except that there's a methyl group sticking off so it's methylbutanoic acid.

=====Lowest Possible Numbers for Carbon Chains (5:54) =====

Of course, with that name, without any numbers, no one has any idea where anything is on the chain, so, time to number. From this direction, 1-2-3-4 we get 3-methylbut-2-en-4-oic acid, which is obviously wrong, mostly because that parent functional group, the one that defines the suffix, is supposed to be as low as possible and in fact it is as high as possible, so that can't be right. Also it just sounds terrible.

Numbering the other way, 1-2-3-4, the carboxylic acid is on carbon 1 (that's pretty ideal). The double bond and the methyl group are both on the second carbon, much better, and thus it is named 2-methylbut-2-enoic acid. Two important notes here, if the parent functional group is on carbon one we just leave the number off.

=====Cis or Trans for Double Bonds (6:35)=====

And two, there's a double bond in this molecule and we haven't identified whether it's cis or trans and we can't do that so we haven't actually completely named it. We should stick a cis in front of the name because the carbon chain continues on the same side, not the opposite side as it would be in the trans form.

Of course, it works both ways, that's the beauty of it, you can build a name from a molecule and a molecule from a name. Earlier, I told you that cinnamaldehyde was trans 3-phenylprop-2-enal. Can you build it? Well, start with the three carbon chain, because of that prop, and count out the carbons, 1-2-3. We know, because it's prop-2-enal with that 'e' there's a double bond from the second to third carbon and we know it's trans. We also know that there's a phenyl group on the third carbon. The word ends in a non-numbered '-al', so finally we can stick an aldehyde on carbon number one, and yeah, that was actually pretty easy!

Now look, IUPAC does it's best but past a certain point of complexity no one expects anyone to know all this by heart unless you work for them and name compounds for a living. That's why we have the internet and textbooks and libraries to go look things up. Because I'm a dork, I actually find these things to be kinda delightful puzzles and they're often super fun for me, but taken one or two steps beyond the level of complexity we have here my personal viewpoint is that you're better off looking it up than memorizing the novel-sized list of functional groups, names, precedence lists, prefixes and suffixes.

As long as you can recognize why trans 3-phenylprop-2-enal is in fact a superior name to cinnamaldehyde and no, I am not going to do the cinnamon challenge. Ever.

=====Conclusion (8:03)=====

Thank you for watching this episode of Crash Course Chemistry, if you were paying attention you learned that IUPAC is the international organization responsible for your unhappiness, and that their goal is to create a system where every organic compound has one and only one name to prevent confusion.

They do this by giving prefixes to compounds for the number of carbons in a chain, suffixes based on parent functional groups, and ranking functional groups somewhat arbitrarily for precedence. You also learned that you have to number your carbon chains so that your parent functional group has the lowest possible number and that double bonds require you to label the molecule as either cis or trans and hopefully, you learned that this is a kind of word magic worth learning.

This episode was written by me, Hank Green, and edited by Blake de Pastino. Our Chemistry consultant is Dr Heiko Langner, it was filmed, edited, and directed by Nicholas Jenkins. Our script supervisor was Caitlin Hofmeister, our sound designer is Michael Aranda, and our graphics team was thought cafe.