Hydrocarbon Derivatives - Crash Course Chemistry #43

Crash Course: Chemistry
https://youtube.com/watch?v=hlXc_eEtBHA
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===== Introduction =====

The smell of cinnamon and rotting cadavers... Compounds that can remove nail polish, power a car, knock you unconscious, or make your headache go away... All of these things can be accomplished by simple organic compounds with different functional groups sticking off of them!

Yes, I said functional groups! We will be talking about them a lot today.

Now, when chemists started studying this stuff, they didn't always know what really made one chemical different from another. Only that certain compounds, though different, often behave similarly.

Some smelled like fish, some had relatively high boiling points, some reacted in similar ways with the same compounds [rainbow shimmering].

Now, however, we know better! We know what they are, where they come from, and why they act the way they do. We are DEEP in the knowledge of organic chemistry's most powerful tools!

It feels good in here, so dive in, join me in this solution of ethers and esters and aldehydes and amines and alcohols... but, like, not literally because that would be super gross and you would probably die.

[(00:52) Crash Course opening & theme]
===== Intro: Functional Groups (01:01) =====
[Title card: Sec 43-0 HYDROCARBON DERIVATIVES]

Thus far, we have only discussed organic compounds involving carbon and hydrogen and nothing else. And yes, carbon and hydrogen are the backbone of organic chemistry. In fact, one-, two-, and three-dimensional combinations of carbon atoms are the backbone of most organic compounds.

But today we're going to throw a couple of newcomers into the mix: two of my very favorites, oxygen and nitrogen. Using these two extra elements, we're going to talk about seven exciting and different functional groups.

But first, what is a functional group? Sounds super boring. Well organic chemistry is the architecture of chemistry. With it, we don't just study chemicals, we build them. And we know that certain groups of bonded atoms function in very specific ways. Since we know how these functional groups function, we (and by we I mean the human race) can add to or modify or remove and join them together in predictable ways.

And thus, we can build the compounds we need, whether it be the simple stuff, like acetylsalicylic acid, aspirin [structure (01:53)], or something more complicated, like alpha-(5,6-dimethylbenzimidazolyl)cobamidcyanide, better known as vitamin B12 [structure (01:58)]. Neat, right?

===== Intro: Structural Shorthand (02:03) =====

When we talk about functional groups, we get so focused on those small areas of the molecule, that the rest of the molecule doesn't actually matter that much. So we use "R" to represent the rest.

R just represents any fragment of organic molecule that we're not super concerned with at the moment. We also sometimes call the area of unconcern the "R group" as opposed to the "functional group" where the business is getting done.

So now that I've been talking at you for like, three minutes, let's actually look at what kind of trouble nitrogen and oxygen can get up to in an organic compound.

===== Alcohols (02:32) =====

The first and most familiar oxygen-based functional group is the alcohol, a terminal "-OH". Not terminal in that it will kill you, though ethanol can kill you and other alcohols like methanol absolutely WILL kill you, but terminal in that it ends a carbon chain.

===== Aldehydes (02:47) =====

Now, what happens when you dehydrogenate an alcohol? Not when an alcohol dehydrates you -- that would be a hangover - but we dehydrogenate it. In a chemical reaction, removing the hydrogen from the oxygen and creating a double bond to the carbon.

That dehydrogenated alcohol is an aldehyde, literally from "alcohol dehydrogenated". Alcohols and aldehydes have a lot of similar properties because of the electronegativity of the oxygen. Hydrocarbons on their own are actually pretty dang boring.

===== Polarity of Alcohols & Aldehydes (03:13) =====
Checking out our electronegativity chart, you can see that the difference in electronegativity between C and H is only 0.35, so there's no real regions of negative or positive charges in the molecules. Therefore, these simple hydrocarbons are pretty nonpolar and their electrons are distributed evenly over the molecule, which is why, you know, oil and water don't mix.

Adding those oxygens mixes stuff up. Electrons start clumping, the oxygen-hydrogen bond of an alcohol is fairly polar, with a difference in electronegativity between "O" and "H" of 1.22, so the oxygen gets a delta minus (?-) and the hydrogen gets a delta plus (?+).

Not only does this make alcohols and aldehydes more likely to be soluble in water, but it completely changes the kind of chemistry you can do with them.

Impending confusion alert!

===== Hydroxyl Groups (03:51) =====

There can be functional groups inside of functional groups. We've already seen two of them. If an OH is part of a larger functional group, we'll refer to it as a Hydroxyl, and if a carbon double bonded to an oxygen it's part of a larger group, we call that a carbonyl. For example if we have a carbonyl bonded to a Hydroxyl, that, my friends, is a Carboxylic Acid, (hopefully you're getting the hang of the lingo).

===== Carboxylic Acid (04:06) =====

Just looking at this Carboxylic Acid thing, if you think about the electronegativity of those two oxygens, you can imagine that that hydrogen there is gonna be pretty weakly held, and so it can dissociate in solution, making it an acid. Carboxylic Acids are the acid part of amino acids, which make up proteins, which make up, you, so they're pretty important.

The simplest carboxylic acid, commonly known as Formic acid, is what makes fire ant bites burn, and just one more carbon and you get Acetic acid, or vinegar, which, even in a diluted solution you have in your cupboard, is not something you want to get in your eyes.

===== Acetone is a Ketone (04:43) =====

Now, Acetic acid is also interesting because one upon a time, a clever chemist called Leopold Gmelin did some chemistry and knocked off the OH group and joined the carbonyl with another carbon. The result was a non-terminal, or internal, carbonyl. He named that stuff 'acetone', meaning basically 'derived from Acetic acid'.

Now, acetone is just a name of that one chemical, not the functional group itself. To get that, we knock the 'A' off and harden that 'C' into a 'K' and get a 'Ketone'. So yeah, when we have a carbonyl in the middle of a carbon chain, that is a ketone functional group. Acetone has a ketone group and it's called 'acetone' because it was derived from acetic acid, which is vinegar, the most common carboxylic acid in your kitchen. I swear, if you watch this episode twice, you will understand.

Acetone, with that big hunk and double bond is nice and polar so it's water soluble- great for cleaning stuff; the hydrogen bonds between that oxygen and those outer hydrogens are enough to keep the molecules bound together so it's not gaseous at room temperature. It's also stable enough that it isn't very toxic, in fact, there's a little bit of acetone in your blood right now, which is why it's safe enough to use as nail polish remover. It is, however, unstable enough that you don't want to get it near any open flames.

===== Esters and Esters (05:49) =====

Now we only have two more oxygen-based functional groups that we're gonna talk about- these are groups that have internal oxygens bonded directly to carbons. When you see it now in the middle of the chain like this it's either an ether or an ester, either ester or ether, ether or ester, either one, one or the other, either ether or ester.

Ethers have just one oxygen all alone in the middle of that carbon chain. Esters, on the other hand, I focus on that 'S' noise, making me think it must be plural, because they have two oxygens: one in the middle of the chain and one as part of a carbonyl. Esters are just like a ketone mixed with an ether. In fact, if you look at all these oxygen based functional groups
you'll see that they're all very closely related. Aldehydes are just dehydrogenated alcohols, ketones are just aldehydes bonded to R-groups on both sides (instead of a hydrogen on one side), while carboxylic acids are ketones bonded to an OH group instead of an R group, and ethers are just alcohols bonded to an R-group instead of a hydrogen.

===== Amines (06:39) =====

Now I did promise you some nitrogen at the beginning and I apologize to all of you die-hard nitrogen fans for having given you none so far. Let's just say that the amine is ever so simple, just a terminal NH2 group. Remember, ammonia is NH3, so that "m"th ammonia gets stuck onto that amine group. Amines are super stinky: two of my favorites are putrescine and cadaverine. And yes, they are found in abundance in rotting carcasses of animals and yes, they smell super terrible.

===== Recap (07:05) =====

And those are the seven functional groups that we're going to talk about. It was super fun for me anyway but I am, I admit, kind of a huge dork. Organic compounds that include these functional groups have various wonderful names: wood alcohol, cinnamaldehyde, and cadaverine. It's lovely, right? Well chemists want more out of their names than wit and charm. Which is why, next week we'll be talking about how to figure out how to name these compounds, and if we have the name, how to figure out what the compounds are.

Thanks for watching this week's episode of Crash Course Chemistry. If you were paying attention, you learned that alcohols are organic compounds with hydroxyl groups, if you dehydrogenate them, the hydroxyl converts to a carbonyl and they become dehydrogenated alcohols or aldehydes. If a carbonyl bonds to a hydroxyl, the functional group becomes acidic and it becomes a carboxylic acid, the most common of which is acetic acid, which if you switch the hydroxyl out for a methyl group, becomes acetone and if that 'C' were a 'K' noise, it'd be a ketone, which is what acetone is. Finally, a carbon chain with an internal oxygen is either an ether or an ester, and it's only an ester if it's bonded to a carbonyl. And of course, anything with an NH2 group is an amine.

This episode of Crash Course Chemistry is written by me, Hank Green, 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 Michael Aranda, who is also our sound designer. And our graphics team is Thought Cafe.