How To Speak Chemistrian: Crash Course Chemistry #11

Crash Course: Chemistry
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=====Introduction (0:00)=====

Imagine you wake up one morning, and you're under a tree, and you don't recognize anything. You're surrounded by low, grassy hills. It's raining a bit and smells like waffles and potatoes. As you rub the sleep from your eyes, you notice a woman, and she's like "Qu'est-ce que tu fais dans la pluie?" and you're like "What? Where am I? Was that French? Did I fall asleep in my house and wake up in France?"

Then another guy walks up, and he's got a mustache that, frankly, not a lot of other guys could pull off, and he's like "Wa zijde gij hier nu feitelijk aant doen in die regen?" And that was clearly not French.

And then a little kid comes up with an umbrella, and says "Wat doe je hier buiten in de regen?" Okay...

Do you know where you are? Give up? Belgium. And you know what's an awful lot like unexpectedly waking up in Belgium with a bunch of people speaking several different languages you don't understand? Chemistry.

(Intro)

Maybe more than any other scientific discipline, chemistry has its own language. Not jargon, though it has that too, but a whole system of speaking and writing that's unique to the study of chemicals, a way of translating symbols and numbers of chemical formulas into words that can be spoken. Chemistrian, if you want to call it that (and I do), can be tough to learn at first, but it can be done, once you know the rules. And of course, as with all languages, fluency really only comes with lots of use, so I don't expect you to walk out of this video spouting off about three-keto-two-carboxy-arabinitol, but I do want to get you off on the right foot.

So, talking about chemistry can sometimes be like describing a rainy day in Belgium. I mean, all three of those people in the beginning of the video, they were saying the same thing. They just used different sets of rules to describe it. The woman using French, the kid, Dutch, and the guy with the 'stache, a Dutch dialect called Flemish.

So the trick is knowing which rules to apply where, and fortunately for Chemistrian, there's a kind of phrasebook, the Periodic Table. Just as there are parts of Belgium where different dialects are spoken, the rules for describing an element can change depending on where in the table it is. This is especially the case with the things that we're going to be talking about today: ions and acids. These rules apply not only to their formulas, that is, the chemical symbols that we use in equations, but also to their names, how we write and say them.

=====Determining Formulas and Names of Mono-atomic Ions (2:20)=====
Let's start off with ions. Atoms become ions by gaining or losing electrons, giving them a positive or negative charge. Atoms that have lost electrons, and therefore take on a positive charge, are cations, whereas ones that gain electrons to become negative are anions. Notice, despite the rules of English, that these are pronounced "cat-ions" and "ann-ions", not "cayshuns" and "aniuns"

The most basic ions, called monatomic ions, are formed from single atoms. To write one as a formula, you just use the chemical symbol of its base element and then add the charge as a superscript. That's it. If the charge is just of a single electron lost or gained, you don't need to write the one, but any charge greater than that requires a number. So the sodium ion is written like this, while the ion of chlorine looks like this.

But the names of these ions change somewhat depending on whether they are cations or anions. Cations, for some reason, the name is just the element followed by the word "ion". So, in this case, it's just a "sodium ion". But with anions, you use a special suffix, "ide". So, the anion of chlorine is chloride, and is written so.

Now, when we name ionic compounds, we just say the cation first, and the anion second. You've done this. You just maybe didn't know you were doing it. "Sodium chloride", "hydrogen sulfide", easy peasy.

=====Finding Cation and Anion Forming Elements on the Periodic Table (3:32)=====

Now in order to figure out what's what, we have to rely on our handy phrasebook, the Periodic Table.

The first two columns on the left are your alkali metals, and your alkaline earth metals. They all form ions readily when they react with non-metals, and when they do, they always lose electrons, forming cations.

On the other side of the table, you'll find most of the common anion-forming elements grouped together, particularly your halogens, along with oxygen, sulfur, and nitrogen. These elements gain electrons to form those negative ions ending with "ide". And you've no doubt heard of most of them.

=====Writing Formulas and Naming Transition Metals (4:03)=====

But here's a wrinkle. Many elements can form more than one kind of ion. Iron, for example, in the middle there, forms cations, but they can have a charge of either two or three. This is the case for many of the transition metals in these middle columns of the table. They're grouped together precisely they have these properties in common. Everything's where it is for a reason people, that's the beauty of it.

But it's in this middle region of your language map where really unique dialects start to crop up, changing how ions are named and written.

The formulas for ions here are, thankfully, as easy as anywhere else, with the size and polarity of the ion's charge written as a superscript.

But when naming these ions, we introduce a whole new naming convention, and by new, I mean really, really old. Roman numerals. Yeah, Roman numerals still have a practical application beyond telling you which Star Wars movie you're watching. In this case, when saying or writing the name of a transition metal ion, you use Roman numerals to denote the size of the ion's charge, like Iron II or Iron III, and you write it this way whether the ion's in a compound or by itself. Just be sure to put the numerals in parentheses with no space between the cation and the first parenthesis, because trust me, teachers will mark off for that.

Okay, so I know what you're probably thinking right now: Why, in the name of Pliny the Elder, do we have to use Roman numerals like a bunch of Romans? Well, check it out. Arabic numerals are already being used to denote how many atoms of an element there are in a molecule, the molecule's charge, its oxidation state, the number of molecules reacting in an equation. We didn't need more Arabic numerals! So the chemistrians decided to trundle out the

Romans.

=====Naming Acids and their Anions (5:35)=====

Now, acids are ionic compounds just like any other, but when they ionize, their hydrogen ions, just lone protons, become the cation, and any negatively charged leftover is the anion. So all acids are made up of one or more hydrogen cations bound to an anion.

Writing the formula of an acid is easy if you know what the anion is. Because ClO_3 is negative one charge, you can tell that it will bond with just one hydrogen ion to form $HClO_3$. Simple.

Now, when we name these acids and anions, we have to kind of watch our mouths, because in the realm of chemistria, there's a whole system of prefixes and suffixes that you have to keep track of to make sure you're addressing everyone by the proper title. Y'know, you don't want to offend anyone.

Once you've acquired an ear for it, though, you can tell just from the name of an acid or it's anion what its composition is, because these prefixes and suffixes practically give you the formula. Specifically, they tell you how many oxygen atoms it has. That's right, even though an acid is defined by its ability to give up hydrogen ions, it is identified by it's oxygen content. Eh, when in chemistria.

Let's go back to that ClO_3 minus. You might know that as the chlorate ion. That's chlorate, with an "-ate". Not a number 8. A-T-E. Like we said, chlorate bonds with a hydrogen ion to form $HClO_3$ which is called chloric acid. That's chloric with an I-C. As a rule, all anions that end in "-ate" form acids that end with "-ic". Phosphate ion has a three charge, so it bonds with three hydrogen ions to form phosphoric acid. Similarly, the sulfate ion needs just two hydrogen ions to form sulfuric acid. You get the idea.

These compounds, the "-ic" acids and their "-ate" anions, are really common and familiar, so much so that they form kind of a baseline for the language of acids. Chlorine, hydrogen, and oxygen can combine to make chloric acid, but they can form way more other similar acids. And all these variations are named using a special, super-explicit set of prefixes and suffixes that tell you whether they have more oxygen atoms or less oxygen atoms than the baseline compounds. And by how many.

Take $HClO_2$. Because we know that the cation is H plus, we can immediately see that the anion is ClO_2 minus, which we know as the chlorite ion. In addition, we can see that $HClO_2$ has one less oxygen atom than $HClO_3$. The "-ous" suffix means "less than" and thus gives us our name, chlorous acid for $HClO_2$. So the chlorite ion forms chlorous (with an "-ous") acid. And indeed, all atoms that end in "-ite" form acids that end in "-ous". O-U-S.

But what if it has two fewer oxygen atoms than it's "-ic" counterpart? For both the acid and its anion, you simply use the suffixes I just mentioned, "-ous" and "-ite", but then additionally, you add a prefix. It's from the Greek for "less than" or "under": "hypo-". So, HClO is hypochlorous acid, and likewise, it's anion, ClO minus, is hypochlorite.

But there are still a couple of scenarios that we haven't considered yet. Like, what if an acid has one more oxygen than the "-ic" version? In that case, you use a different prefix, using "per-", Latin for "very" or "thoroughly". Sounds like it'd be fun to find some uses for that "per-". Let's do it. There's perplexed, like very plexed. Pervaded, thoroughly invaded. Perfect, very... fect. I had to look it up. It's from the Latin for "to complete". So "perfect" is to complete something thoroughly. I like it.

So the "per-" prefix is just a way of saying "thoroughly oxygenated", completely, in fact. If you see the "per-" prefix, that's the highest number of oxygens that can get on there. So $HClO_4$ is perchloric acid and it dissociates into an anion called perchlorate.

And what if, brace yourself, the acid doesn't contain any oxygen at all? Remember, hydrogen is the key player in acids, so even though oxygen is common, it's by no means required. When a hydrogen bonds with chlorine to form an acid, since there's no oxygen it's just called hydrochloric acid, and it's anion follows the same rules for anions we talked about at the very beginning, ending in "-ide", in this case, chloride.

Now, considering what just happened to you here, there's a 99% chance that you're now more confused than you would be if you woke up in a drizzly Belgian meadow. So, if that's the case, get a pencil and get ready to pause the video. Now, copy this table down. It's all you need to know. Be familiar with the "-ate" ions and the "-ic" acids and simply cobble on the appropriate prefixes and suffixes based on the number of oxygen atoms present.

=====Conclusion (9:57)=====

It might not be as fanciful as waking up in a Belgian meadow, but it is enlightening. Just look at all the stuff we learned, like how to determine the formulas and names of mono-atomic ions, how to find cation and anion forming elements on the Periodic Table, how to write the formulas and name transition metals, and how to name acids and their anions.

Thank you for watching this episode of Crash Course Chemistry, which was written by Blake de Pastino. The script was edited by me, and our chemistry consultant was Edi Gonzalez. This episode was filmed and edited and directed by Nicholas Jenkins. Our script supervisor and sound designer was Michael Aranda and our graphics team is Thought Café.