Atomic Hook-Ups - Types of Chemical Bonds: Crash Course Chemistry #22

Crash Course: Chemistry
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Humans, like chemicals, are really all about bonds. Think about all the relationships in your life. You're a casual acquaintance to some people, a colleague or friend to others, and maybe more to that someone special. Maybe you're dating someone casually, or you're in a committed relationship, or you're married. There are all kinds of different combinations of people out there. And sometimes, you know, people fall for a vampire or a werewolf. Who am I to judge? Fact is, each type of relationship requires different things from you and the other person, but if you play your cards right, these relationships allow you to relax and escape the stresses that come with the constant search for affection. Distance is important in relationships too, of course; too much distance makes it hard to stay focused on each other and requires a lot of effort to keep things together, and I may not have to tell you, too little distance can be a problem as well. Everyone needs their space, and when you don't have any, you just end up pushing away from whatever's crowding you. In this way, atoms are a lot like us. We call their relationships bonds, just like we do with our own relationships. And there are many different types. Each kind of atomic relationship requires a different type of energy, but they all do best when they settle into the lowest-stress situation possible. The nature of the bond between atoms is related to the distance between them, and, like people (and vampires and werewolves, I suppose), it also depends on how positive or negative they are. The difference is that, unlike human relationships, we can analyze exactly what makes different kinds of chemical relationships work. And that's what this episode is all about. But, people, please remember that we here at Crash Course do not dispense relationship advice. [intro music]

=====Bonds Minimize Energy (1:38)=====

First things first, why do atoms do this at all? Well, like everything else in the universe, atoms do whatever they can to reduce their overall energy, and they reduce their lowest energy by achieving a balance between attractive and repulsive forces, being neither too clingy nor too aloof. So when two atoms approach each other, the electrons of each are attracted to the protons of the other. This is the electrostatic force. Like charges repel, opposites attract, like in real life, or at least Paula Abdul songs. I know, I'm old. So when one atom is attracted to another, just like Edward Cullen and Bella in chemistry class, to use a slightly more timely reference, it gets stressed out by the attractive force and tries to relieve the stress by getting closer. We've all been there, right? That hot, nerdy vampire girl in your chemistry class? It's just, it's intense. The pull is so strong that the stress level or energy rises when the two are separated, so they stay close. But sometimes, they can get a little too close. When that happens, the nuclei repel each other because of their like charges, and the energy between them rapidly increases and they both back off, just enough to find that perfect little distance between them, and everyone relaxes. This ideal, wonderful distance is the bond length. It's the distance between two nuclei at the point of minimum energy. In other words, where the attractive and repulsive forces cancel each other out. The distance at which these two atoms of chlorine reach their minimum energy, caught between the attraction of the electrons, the nucleus, and the protons repelling the nuclei, is the bond length. That energy minimum, which we know absolutely is â€“239 kilojoules per mole (kJ/mol), occurs when the distance between the atoms is 0.00199 nanometers (nm). That distance is the bond length of Cl_2, chlorine gas. =====Covalent Bonds: Polar Covalent, Non-Polar Covalent (3:19) Now because the electrons are attracted to both nuclei in the molecule, they actually spend the majority of their time in the space between them. This is often described as sharing electrons, and we call this kind of bond a covalent bond. But not all sharing is equal. I should know: I have an older brother. The strength with which an atom holds shared electrons is called its electronegativity. The electronegativities of various elements are all super well known and waiting for you in tables on the Internet. If two atoms in a bond have very different electronegativities, like, say, hydrogen at 2.1 and oxygen at 3.5, the electrons are more attracted to the atom with the higher electronegativity. The difference is so great that the electrons spend most of their time around the stronger atom and much less time around the other one, like how all the neighborhood kids wanted to hang out with John, my older brother, because he was more charismatic. When the electrons hang out closer to one side of the bond, it creates a slight negative charge in that area and a slight positive charge around the other atom. This separation of charges is called polarity, and it's the polarity of the molecule that these atoms form, H_2O, that makes water the most important molecule on Earth. Covalent bonds like this, where electrons are attracted to one atom more than the other, causing a separation of charges, are called polar covalent bonds. But when a covalent bond forms between two identical atoms, like the two chlorine atoms in our graph earlier, the electrons are distributed evenly. We call this a non-polar covalent bond. But you've also gotta consider the middle option, where atoms aren't identical, but have very similar electronegativities, like hydrogen, with an electronegativity of 2.1, and sulfur, at 2.5. The difference here is so tiny that the electrons are pretty much still evenly distributed, and we call that a non-polar covalent bond as well. There's a huge world of important chemicals that have these kinds of bonds. So many, in fact, that we will dedicate a couple of separate episodes to them. Covalent bonds tend to form from non-metals and sometimes metalloids, those elements that have both metallic and non-metallic characteristics. That's because most of them hold their electrons so tightly that they're more likely to share them with another atom than to gain or lose them altogether. Metals, on the other hand, have loosely-held outer electron shells, so they're constantly dropping electrons and becoming positive ions. And when positive ions come across negative ions, like those formed from halogens, for instance, you have to know what's gonna happen. They are attracted to each other, which means energy is required to break them apart, which means they're gonna bond if they can, creating that oh-so-wonderful point of minimum energy.

=====Ionic Bonds (5:37)=====

This type of bond is unsurprisingly called an ionic bond, a bond formed between a positive ion and a negative ion. Because the ions are formed when one atom loses electrons and the other gains them, we often say that an ionic bond is formed by the transfer of electrons from one atom to another. =====Coulomb's Law (5:51)===== And we can calculate the amount of energy that exists in a bond between ions at a given distance using a formula called Coulomb's law. Note that this only works for ionic bonds because the calculation requires the charges of the ions, which covalent bonds don't have. Coulomb's law says that the energy been two ions equals the product of the two charges, which are represented by capital Qs, because why not, divided by the distance, or radius, between the two nuclei, all multiplied by a constant, 2.31 Ã— 10^â€“19^ joules per nanometer (Jâ€¢nm). Of course, the radius also has to be expressed in nanometersâ€”you gotta make the units match. Let's see how it works with something simple: sodium chloride, or table salt. We know that the normal charge on a sodium ion is +1 and the normal charge on chloride is â€“1. These are Q_1 and Q_2. The length of a stable NaCl bond is 0.276 nm, so we put that in for the radius, and finally a quick calculation tells us that the bond contains â€“8.37 Ã— 10^â€“19^ J of energy. Remember, that negative number represents a decrease in the energy of the system due to an attractive force, which certainly makes sense here. Sodium and chloride ions are strongly attracted to each other due to their opposite charges. Of course, you may have noticed that â€“8.37 Ã— 10^â€“19^ J looks like a tiny, tiny number, but keep in mind we're talking about one single pair of ions. The â€“239 kJ that we got for chlorine? That was for a whole mole of molecules. When multiplied by the 10^{17} or so ions in a single grain of table salt and then by the thousands of grains of salt in a mole, the energy becomes much more significant. The NaCl bond is, in fact, quite strong. And because they are formed by a positive ion and a negative ion, two charges completely separated between two different particles, ionic bonds are extremely polar, way more polar than polar covalent bonds. And so those are our three types of bonds: non-polar covalent, formed by the equal or nearly equal sharing of two electrons between non-metal or metalloid atoms; polar covalent, formed by the uneven sharing of electrons between two non-metals or metalloids; and ionic, formed by the transfer of electrons from a metal to a non-metal. It's important to remember, though, that there aren't only three designations for chemical bonds. Just like human relationships, bonds don't always have really well-defined boundaries. Everything is a continuum. Labels are useful, but they can only take us so far. There are, however, certain properties that each kind of bond tends to have that you should know. For instance, ionic compounds are often crystalline in their solid form because of the way the ions act together, like salt is. They're generally soluble in water because the two ions interact separately with the positively and negatively charged areas on a water molecule. And once they're separated or dissolved, the ions allow the solution to conduct electricity. Covalent compounds, on the other hand, tent to be softer solids, liquids, or gases like Cl_2 is at room temperature. They're often not soluble in water, and even when they are, the solutions don't conduct electricity. The differences in these properties stem mostly from the differences in their polarities. So yeah, polarity is crazy important. So important that we'll be doing a whole episode on it soon. =====Ending, Credits (8:50)===== Until then, I want to thank you for the bond that you have to Crash Course Chemistry, whether it's casual observer, faithful viewer, or committed subscriber. Today, if you were paying attention, you learned that chemical bonds form in order to minimize the energy between two atoms or ions. You've also learned that the chemical bonds may be covalent if the atoms share electrons, and that covalent bonds can share those electrons evenly or unevenly. Bonds can also be ionic if the electrons are transferred, and you learned how to calculate the energy transferred in an ionic bond using Coulomb's law. This episode of Crash Course Chemistry was written by Edi GonzÃ¡lez and edited by Blake de Pastino and myself. Our chemistry consultant is Dr. Heiko Langner. It was filmed, edited, and directed by Nicholas Jenkins. Our script supervisor is Michael Aranda. He is also our sound designer, and our graphics team, as always, is Thought CafÃ©.