Big Picture Podcast – Episode 12

Covalent Bonding (Chapter 6C)

A detailed review of the covalent bond, one-on-one with your textbook author featuring you as our special co-host. Topics include: covalent bond formation, molecules, multiple bonds, VSEPR, substituents, molecular shape, polar bonds, and molecular polarity. The duration is relatively long because the pace is slow but methodical and guaranteed to improve your understanding and appreciation of this foundational chemistry. Duration: 1:08:13.

John: Welcome to the Big Picture podcast for today's episode. We'll be looking at the amazing covalent bond, not the ionic bond, not the metallic bond, but the covalent bond itself for the yeah. Of an entire episode. Now with us today is no one but me and you, the listener. Tracy is on the road.

John: J.W. has returned back home. So I was thinking perhaps you, the listener, might want to jump in as our virtual closed. Great. OK, then, might you please introduce yourself?

John: Welcome. Welcome. And together, we are going to pass out the main details of that covalent bond. Let's begin.

John: Ok, so what resources do we have here? Well, we've got the book, we're going to be going through pages of the book and I have my pen and paper, four notes. Perhaps you have that too. Or perhaps you just driving along and ready to get a basic overview of the stuff we've got myself.

John: And we also have you all these resources together. You know, it's gonna happen. So the covalent bond to dig into the covalent bond, gosh, we're going to need to back up a little bit to review the ionic bond recall. What happens there is you have an element that tends to lose an electron. And that's usually a metal atom. And it will lose that electron to another atom, which tends to be a non-metallic atom. And as that metal atom loses, an electron it forms is a positively charged iron. And as the non-metal atom gains an electron, it becomes a negatively charged iron. And what do you know about two oppositely charged ions? How do they feel about each other?

John: That's right. They like each other very much and they're going to come together because opposites, science attract and those two oppositely charged ions are held together by that electrical force and we call that electrical force the ionic bond. It's the force of attraction, the electric force of attraction between two obviously charged ions. Yeah. So what about a covalent bond? What happens there?

John: Imagine you got two kids sharing toys. What is it that holds those two kids together? Yeah. Yeah, they might be friends and all. But, you know, think of it this way. The kids love the toys. And so if you have two kids, each kid with one toy, they get together. You have a situation where each kid now has access to both toys. Now, wouldn't you rather have two toys and just one toy? And that can happen when the two kids are sharing their toys. So same thing with Adam's. You'll have one Adam that likes its electron. It's not going to lose its electron. And then you have another atom that also likes its electron. It's not gonna lose that electron. And of course, these tend to be non-middle atoms. Those to the upper right side of the periodic table. If you could bring those two non-middle atoms together, those atoms could then share their electrons so that each atom has not access to one electron, but two electrons, its own electron, plus the electron of its neighbor. Let's look at this from the point of view of a hydrogen atom. Kate? What what what is a hydrogen atom? This is where you go ahead and describe the hydrogen atom. Yeah, yeah. You've got a proton in the nucleus and an electron whizzing about it. Right.

John: And we talked about the shell model where the electron is safe.

John: The hydrogen atom, it's in the first shell and it's whizzing around that nucleus much like a bunch of bees. Mate was around. A very sweet flower. Yeah. And when we talked about the Shell model, recall that there is a capacity for electrons for each of the different shells in the first shell has the capacity for two electrons.

John: So the hydrogen atom. Think you've got a proton and a single electron whizzing around that proton within the first shell? You with me? But that first Shell has the capacity for two electrons. Mm hmm. Might it be possible to have two electrons whizzing around that nucleus? Now the nucleus, it's just one proton. We're talking about the hydrogen atom and it's just one proton. Is it possible to have two electrons whizzing around that one proton, two electrons around one proton? Yeah, actually, it is. How so? Because that first shell has the capacity for two electrons. Well, what are you going to have there? You're going to have a hydrogen atom with one proton and two electrons. Wait a second.

John: We're talking about that when you have an atom that has a different number of protons versus electrons. What do you call that?

John: Very good. Everyone together. An eye on you have an eye on this iron is going to be. Is that going to be positively charged iron ore? Negatively charged iron? It's negatively charged because it has two electrons and one proton and electrons. A negatively charged me get two of them. You get one proton, which is positively charged. The net charge there is going to be minus one. We've just described the negatively charged hydrogen ion sometimes called the hydride ion. The main thing for you to understand is that there can be two electrons around that one proton, just as there can be two B's hovering around a sweet flower. I know you might think that. Well, here's one electron and here's one proton and the two are going to neutralize each other out. So the net charges zero. No, no, no. Don't think like that. Think about the flower. The flower has the sweet aroma that's spreading out into space. And if there's room around that flower for a bee. A B is going to go there. Why? Because the B is attracted to that sent to the sweet flower. Likewise, if you have a positively charged proton just hanging out in space, you bring in one electron. Yeah, yeah. The two add up to being neutral, but the electrons say is on one side of the proton. There's still the other side of the proton that can still attract another electron. So the positive charges don't disappear. They are there. And when the second electron comes in close enough, it will be there much like a second B around that sweet flower. Belaboring the point because it's real important that you understand. You can have two electrons around that one proton.

John: In fact.

John: It likes to have two electrons around that one proton. So let's think about now of two independent hydrogen atoms. Each hydrogen atom, not ion each hydrogen atom, has a proton and any electron, right.

John: They're just hovering around in space then.

John: Then one day the two atoms meandered close to each of their. And the electron of one hydrogen atom looked over and saw the proton of the other hydrogen atom and said. Meanwhile, the electron of the other hydrogen atom looked to the one hydrogen atom and saw that proton in the center, and it said. You with me?

John: There is an attraction, an electric attraction between negative and positive charges. And so these two hydrogen atoms, they came together with the two electrons situated in between those two protons.

John: And what has happened here is the shell of the first atom is now overlapping with the shell of the second atom.

John: And in that region of where the shells overlap resides, those two electrons. What do you suppose those two electrons are spinning in opposite directions? Absolutely, they're spinning in opposite directions. Right. If the electrons are to be close to each other in the same vicinity, within the same seat on the school bus analogy we have from the last episode. Yeah, they're going to be spinning in opposite directions. But there they are, two electrons situated between two protons, very much like two kids sharing two toys. Each kid puts the toy in between the other and suddenly each kid has access to not one but two toys. That is a favorable situation, just as when you have two protons with two electrons in between them. That, too, is a favorable situation. Now let's check out what's happening here. Those two protons in between them are sandwiched, those two electrons. Now, are those two protons just going to go away? No. They're attracted to those two electrons is to say those nuclei are held together by the electrons that are in between.

John: They're stuck. They're held. By any electric force.

John: What we call that electric force here where electrons are being shared. We call that a covalent bond code, meaning sharing Vaillant, meaning valence electrons. These are valence electrons that are being shared. Remember, the valence electrons are those that are found in the outermost shell.

John: So when a covalent bond, you've got the sharing of valence electrons, bam. Any questions?

John: Ok. Can you explain that? What we just did.

John: Go ahead and hit the pause and use the the bee analogy, use the two kids playing with toys analogy. Then go ahead and. Describe the covalent bond. I know you feel comfortable, you don't want to do it, you just want me to move on but induce off in favor of actually doing it. You are, after all, the co-host. Very good. Excellent, excellent. All right. Sorry for interrupting. Let's move on. Let's pick another pick him out of many of them. Go ahead. OK, OK, Flori, let's let's do Flori, let's have two Florian Adams come together, but first describe for us. The electron configuration for the fluorine atom co. Oh, the flooring has nine protons. It's number nine in the periodic table, which means it has nine electrons. OK, go electron configuration for flooring. You said very good that there are two electrons in the first shell, right? Yeah. And nine subtract two a seven.

John: So that means there are seven electrons whizzing around in the second shell and the capacity for the second shell is eight. That's right. So you have only 70 electrons.

John: That means there's room for one more electron. If you were to do an electron dot structure for fluorine, what would it look like?

John: Ok. Yeah. You had the s symbol for atomic symbol for flooring. Write that out in the capital letter and then surrounding it.

John: You would use dots to represent the electrons. You'd go. Dot, dot, dot, dot, dot, dot, dot.

John: Right. You'd have three pairs of electrons in one singlet. All right. Two plus two plus two is six plus one is seven, eight. So think of that. The flooring has a singlet electron. Let's call it an unpaired electron. And if one florin has one unpaired electron, you know, another fluorine atom will also have one unpaired electron. So let's look at everything from the point of view of that unpaired electron within a fluorine atom. There you are, minding your own business. One day along comes another fluorine atom.

John: And there you are in the second shell. And when you look down to the nucleus, you don't see the plus nine. You actually see something more akin to a plus seven because there are those inner shell electrons in your way, but you're enjoying a +7, which is holding you pretty darn well.

John: That's all within your own, Adam, you that unpaired electron in the second shell of the floor in atom. Now you look upward and you see another fluorine atom coming your way. And you look up at that fluorine atom, you see something rather remarkable. You see the same thing because it's in the fluttery, madam. And that's remarkable. But you see three pairs in one singlet.

John: You know, it's not really the singlet that you see. It's the empty space that you see. And you look in there and you go, you know, in that empty space. If I were there. Gosh, if I were only there, I would be enjoying a plus seven nuclear charge. I'm negatively charged. I'm seeking out positive charges. And there's a plus seven. Wow. And you go. But wait a second. I already have a +7 right next to me in my own Atem.

John: But getting a little greedy here, you'll look up to the other fluorine atom and you'll see you could actually have your cake and eat it too. You could have two plus sevens, your own and somebody else's. And so the two Floren atoms come together in you, that electron squeeze into that empty space of the neighboring fluorine atom.

John: Oh, you see, you have partners that other singlet who has its own intentions because it was looking at the empty space beside you.

John: And everybody gets together. That electron fills up the space next to you and you fill up the space next to that electron. And those valence electrons are being shared between the two fluorine atoms in both. Those valence electrons are now enjoying a +7 from both sides.

John: That's a capital, Hjelm from the point of view of those electrons and that Yem is an electrical force. That now binds those to fluorine atoms together. They are bonded. What we have here is called a covalent bond. OK, now notice what's happening here with a covalent bond.

John: We happened to be working with atoms that are those that tend to gain electrons. And these are the NON-MIDDLE atoms. The situation we just described here can occur when you have a non-metal and a non-Middle coming together. They've got to be non metals and these are atoms that love to gain electrons because let's face it, what's happening in both these cases that the two Floren atoms are each gaining an electron. The ionic bond you had someone who like to lose an electron next to someone who like to gain electrons, so for the ionic bond you have a metal and non-metal. Right. Well, you can have a medal in a medal get together when we describe that as the metallic bond. Now, what we're talking about is having a non-metal in a non-metal together. And we've got all the bases covered describing here. The third type of chemical bond where atoms are being held together. And invariably it's an electrical force. Right. But there are little twists in the story of of how that electrical forces at play.

John: For the attic bond, there ain't no sharing for the metallic bond. Everybody's lost their electrons.

John: And for the covalent bond, you have sharing a sharing of the electrons. Any questions? So what we've just described are two atoms of the same kind coming together. And note that these are non-middle atoms, but you can take different non-middle atoms, different kind of non-middle atoms and put them together. Let's pick. How about oxygen? All right. OK. Oxygen. We're gonna do oxygen. Describe the electron configuration for an oxygen atom. Go. Oh, I'm sorry. Auction it has eight protons with eight surrounding electrons.

John: Hey, excellent. OK. So you got two electrons in the first shell and you've got six electrons in the second shell. Now, how are those six electrons organized? I mean, in terms of like being paired and not paired.

John: You got to think about that, huh?

John: Yeah. Think of the double seats on the school bus. You have six electrons, the first four are going to pile into that bus and occupy their own seat. There's gonna be no pairing upon the input of the first four electrons into that second shell. But we've got two more electrons to throw in there. And the fifth electron comes in and sees the four seats already filled. It's going to have to Paris somebody. Okay, so that's one pair. And then the sixth the electron comes in. It's gonna have to do the same thing. Pair with somebody else. So for the oxygen, you've got two pairs of electrons.

John: And to unpaired, that is to say to singlets.

John: Great for the hydrogen atom. Recall. It had one unpaired electron in its valence shell for the fluorine atom. It also had one unpaired valence electron for the oxygen. We find it has to.

John: Singlet electron's, unpaired valence electrons, right? That would mean it has two electrons to share. So once upon a time you had an oxygen atom minding its own business with its in its outer shell. Two pairs of electrons paired up. That's four. And two singlets. I'm using the words interchangeably singlet or unpaired. Same, same. And there it was minding its own business when along came a hydrogen atom.

John: The hydrogen atom with just one singly electron and an electron looked to the empty space next to one of the singlets and oxygen saw. +6, if it could only be there, it could enjoy a plus six nuclear charge plus six because the two inertial shielding electrons hide the +8 in the nucleus. Got that? So it comes along and it binds by covalent bond. You now have a covalent bond between the oxygen in a hydrogen, but we're not done. The oxygen has to singlets.

John: And so along comes a second hydrogen atom. And it's valence electron falls into that empty space next to that other singlet and you form a second covalent bond.

John: Here we've got a situation where there is an oxygen atom now co violently bonded to two hydrogens and what he call that.

John: Each two o water. Excellent, also known as dihydrogen monoxide di meaning two hydrogens, dihydrogen monoxide, one oxygen, dihydrogen monoxide grate. And to foreshadow something we're coming up to a bit later in this episode. Notice that for that water molecules. Look, look there at the oxygen atom. Yeah, yeah, yeah. And on the outside you can see there are still too. Paired electrons, two sets of electrons that are that are paired.

John: They're not bonded to anything. They're just paired out there in the valence shell of the oxygen atom. Right. So you've got those two paired electrons and they're not bonding, but you have those two singlets from the oxygen that are now bonding. They are bonding in the total number of, let's say, for better water, like for better word things that the total number of things emanating from the oxygen atom. Well, you've got a pair going this way.

John: A pair go into another way and then you have a covalent bond to hydrogen in another direction and a second covalent bond to hydrogen and yet another direction. There are four things emanating off of that oxygen atom. Two of them are paired electrons and two of them are the covalent bonds and noticed there are two electrons within any covalent bond and we can call them the paired bonding electrons.

John: Ok. We're going to come back to that. What do you want to do? One more. OK. Pick an atom. Any atom. Carbon. OK. Carbon. Right. What is the electron configuration for a carbon at home? Excuse me? Six protons, six electrons which you get from the periodic table, of course. Go ahead. Carbon. Yeah. Yeah.

John: Yeah.

John: Excellent. Excellent. So you've got six electrons. Two of them are buried in the first shell and you've got four electrons in the outer shell. Roger that. Okay, great. Describe the electron dot structure for carbon. Yeah, yeah, yeah. Excellent. You've got four dots to worry about. Four electrons in the second shell and they're gonna be singlets. Right. Because remember, they're four double seats on that bus and yet only four electrons, they're gonna all occupy their separate seats. Great. Yeah. And so you have a C in the middle. Carbon. And then NSW. Dot, dot, dot, dot. Right. Cool. All right. So you see there with a carbon atom, you have four singlets. Another way to say it is there with a carbon atom, you have four empty spaces. Think of the double seats on the bus. You have four empty seats. Now, don't you? Now, you could have the electron come in and fill that seat. But what if that electron were attached to a hydrogen atom? Right. So once upon a time, there is this carbon atom with its four singlet electrons. And along came this hydrogen atom with its one singlet electron. And it went right into one of those empty seats.

John: And you now have a coal Vaillant Co, Sharee Valence electrons, covalent bond between that carbon in that one hydrogen. It did it once many more times. Could it do it? Yeah, three more times for a total of four times. Recognize that carbon can form for bonds to for different hydrogen atoms. So I think you're getting the trend here. Carbin tends to form for bonds. Oxygen tends to form to bonds and flooring tends to form one bond, covalent bond. But we haven't talked about is nitrogen. Go ahead in your spare time, figure out the electron configuration for nitrogen and you will see that it has three singlets, which means nitrogen can form three covalent bonds. Cool. Yeah. Look at the periodic table. Look at the sequence from boron carbon to nitrogen to oxygen to fluorine to neon. Boring conformed. Three covalent bonds, carbon conform for nitrogen, three oxygen to fluorine, one neon none. Yeah, it's a periodic trend. The number of covalent bonds that an atom conform a non-metal atom can form is given by its atomic group. Interestingly, the elements above and below carbon in the periodic table all tend to form for covalent bonds. The elements above and below nitrogen tend to form three covalent bonds. The elements above and below oxygen. Well, there's nothing above oxygen tank, below oxygen. And his is two everything below fluorine. Those all form one covalent bond and everything below helium in neon. They don't form covalent bonds. There's no room in their outer shell.

John: Awesome. Oh, here we need to talk about double covalent bonds and triple covalent bonds with heck is that. Let's go back to oxygen. You ready? I mean, are you really ready?

John: Ok. Oxygen. The electron configuration for oxygen. We now know is in the outermost shell. You got two pairs into singlets. Right. The oxygen is able to form two bonds. And we saw with water it formed a bond with two different hydrogen atoms and got H2O. But what about this story? Once upon a time, there was an oxygen atom with two singlets, electrons. And along came another oxygen atom, also with two singly electrons. Mm hmm. Yeah. And you formed a covalent bond between that oxygen and the other oxygen.

John: Got it.

John: But each oxygen still has another singlet. Remember, each oxygen conform to bonds. And so those two other electrons joined together to form. Get this. Wait for it. A second covalent bond. Yeah. You could have two covalent bonds between just two atoms. Oxygen atoms in particular here. And we tend to represent a covalent bond as just a straight line between the two atoms being conveniently bonded. So to represent the double bond, we draw two lines between the oxygen and the oxygen. Would you suppose is more difficult to break apart a single bond or double bond? That's right. With a double bond, you got a lot more forces involved there. And so if you wanted to pull those two oxygen atoms apart. Good luck. There's a lot of force to overcome. It's more difficult. So the the double bonds tend to be stronger if you go through the same discussion with nitrogen, which has three singlets. It forms three bonds. You can actually have nitrogen atom bond three times with another nitrogen atom. And we call that a triple bond, which is exceedingly strong.

John: That's why the nitrogen molecule in to. Is so incredibly stable. The nitrogen molecule is incredibly stable and. It makes up almost about 80 percent of our atmosphere here on Earth. Wow. So covalent bonds, the versatile covalent bonds in my mind. I like Lego bricks. You know, you can just start putting the atoms together and you can start building.

John: Atom by atom. And what exactly is it that you're building? Well, we saw with hydrogen and oxygen. We built a water molecule with carbon, hydrogen, hydrogen, hydrogen hydrant. You built an S.H. for molecule, which is methane with nitrogen at three hydrogens. You have ammonia. We're building what are called molecules. They have been using this term now molecule that can formally introduce you to it. A molecule is another word for a covalent compound.

John: All right. A bunch of atoms held together by covalent bonds.

John: How you doing? All right, Abe. That's that's pretty good. Yeah, we are now in the section where we're gonna talk about the shape of molecules. Right. So what we just went through describing the covalent bond. Pretty powerful stuff, just like Legos are pretty powerful. We just described how those Lego bricks stick together, right from the Legos. You know, you can build just about any structure. The same thing here. By virtue of the covalent bond, you can build just about any structure molecules, really. Big and small, big molecules such as deoxyribonucleic acid A.

John: That's pretty important. But let's spend a little bit of time talking about the shapes of these little beasties that we call molecules. Good place to start is with the methane molecule. Methane is S.H. for. You have a carbon in the middle surrounded by four hydrogens. Here's what you can do. Try drawing that on paper.

John: And you're gonna be tempted to put the carbon rate in the middle and straight up, you have hydrogen to the east, you'll have another hydrogen to the west, you'll have another hydrogen down south, you'll have another hydrogen. Measure the angles between those hydrogen atoms.

John: It's 90 degrees. You have it on a flat piece of paper. Northeast, southwest. The thing is, though, molecules aren't two dimensional. That piece of paper you just wrote it on. That's two dimensional, not good molecules. Sorry about this are three dimensional.

John: And here here's an important thing that's all important. But pay attention to what's on the outside of any atom starts with L.

John: That's right. The electron. There are electrons on the outside of any atom. Right.

John: So look at that methane molecule. Now focus on the hydrogen atoms surrounding the carbon and what's on the outside of any one of those hydrogen atoms starts with L.

John: El Electron, yeah, they're electrons. Now, put yourself in the point of view of that electron. Pick one hydrogen atom. Okay, that one. All right. You are now the electron whizzing around that hydrogen atom. And interestingly enough, you're also being shared with the carbon because that's a covalent bond. But let's let's move forward. That electron on the outside of that hydrogen atom bears a negative charge.

John: Now look over to your adjacent neighboring hydrogen atom. What do you see?

John: It, too, has an electron whizzing around on the outside. How do you feel about that and how does it feel about you?

John: Yum, yum or yak yak?

John: Remember, negative charges repel negative charges. I hate. You are. Repelled actually by that other hydrogen. In fact, you're repelled by all the other three hydrogens that are there. What are we talking about? We're talking about a carbon in the middle with four hydrogen atoms extending from that carbon. Now, from the point of view of a hydrogen. It looks to the neighboring hydrogen's and it would like to be as far away as possible. Now, I'm very proud of you. When you drew that methane molecule on the piece of paper, you put a carbon in the middle and you put a hydrant up north. Hightstown s a hydrant to the east, a hydrant to the west. You did not.

John: Bunched them all together to one side of the carbon. You know, the carbon. And then you would do, do, do, do, do to all the hydrogen scrunch together to one side. Know you intuitively knew that those hydrogens would spread out to be as far as part as possible. And that's why you have a 90 degree angle between them on your piece of paper.

John: Good job.

John: But in a three dimensional world, you can do better than 90 degrees for these hydrogen atoms wanting to get as far apart as possible.

John: They want something greater than 90 degrees and you get that when you're in three dimensions.

John: Enter the tetrahedron, a teacher amines for Hedren means face, it's a geometric shape that has four faces painted.

John: It looks like a pyramid, but it's not a pyramid. A pyramid has a square at its base. If you want to get technical, if you want to make a tetrahedron, just get some bread dough and pinch it between your fingers, your thumb and index finger and both hand and you're gonna get yourself a tetrahedron. It's a four sided dice.

John: It's three dimensional to. Consider what's going to happen with that methane molecule said. Each of those hydrogens are going to occupy one of the vertices of that foresighted Dyce. And they will stretch themselves out into three dimensions to get us far apart from each other possible to form this tetrahedral shape.

John: You'll find a picture of the tetrahedron I know in the book you can find pictures of Tetrahedron online and gosh, we'll even put a picture of a tetrahedron in the show notes, conceptual signs, dot com. Right.

John: It's a pyramid with triangles on all faces. So the shape of a methane molecule, we find it's not flat. The shape of that molecule is that of a tetrahedron. Why?

John: Because the hydrogen atoms are trying to get as far apart from one another as possible in a three dimensional space. The tetrahedron allows for that. The angle between the hydrogens in a tetrahedron is on the order of one hundred and nine degrees and one hundred and nine degrees. That's bigger than 90 degrees.

John: All right. That's methane. Any questions?

John: Oh, okay. Oh. Another example of dub dub dub. Pick a molecule, any molecule.

John: You're good.

John: Okay. Okay. Water. Let's do water. Mm hmm. Right. So what do we get with water? We've got an oxygen and we've got two hydrogens. The oxygen is conveniently bonded to two hydrogens. Right. What are the total number of things? Lack of a better word coming off of that oxygen atom.

John: Well, we got a pair going this way. A pair going that way. A bonded paragon one way and a bonded pair go into that. We have for a total of four things coming off of that oxygen atom.

John: Right. Guess what shape they're gonna form? Whenever we have four things coming off of a central atom. Oh, OK. Let's not use the word thing. Let's get them. Let's get technical, but let's create a word. I don't know. How about substitute? I know I say that to friends and they any time s of stimulant. Amy, is the chemistry term in the world of chemistry. The word substitute means a thing coming off of a central point. All right. So bear with me here. There are four substitutions coming off of that oxygen atom named them.

John: Ok, good. There's a hydrogen coming off, one hydrogen there and there two. What are they? All those paired electrons? Yeah, they're not bonded to anything. They're just paired. And you know, those are electrons in the outermost shell of oxygen. OK. Really? OK. There for there for substitutions coming off of them. And you suppose they want to be 90 degrees from each other, like if you were to dry flat on a piece of paper. No, no, no, no. It's three dimensional. That's right. So those four substitutes are going to spread themselves out into eight to to touch. To to touch. He. Huge. Huge. Yeah. Tetrahedron. They're going to form a tetrahedral shape. Cool, or let me say.

John: Tetrahedral geometry. Because when we talk about the word shape. We actually mean something very specific when you want to talk about the shape.

John: Of a molecule.

John: You don't pay any attention to the non bonded pairs. You pay attention only to the atoms. Not that should make sense. You wanna know the shape of a water molecule? Well, you got to look at the relative orientation of the hydrogen, oxygen and hydrogen. Right. OK. Well, one hydrogen occupies one bertice of that tetrahedron, oxygen in the middle and the other hydrogen occupies another bertice.

John: Eight and a lone pair occupies the third and another lone pair occupies the fourth bertice. But let's now ignore the lone pairs and focus just on the hydrogen and oxygen atoms.

John: Measure the angle between those and you're going to come up with one hundred nine point five degrees. The shape of a water molecule is bent.

John: As opposed to linear all falling on a straight line. No, there's this bend to the water molecule. You've seen it all the time. Whenever somebody draws a water molecule, it's not in the hydrogen, oxygen, hydrogen drawn in a line. No, they for some reason draw the hydrogen, oxygen, hydrogen at an angle. And up at that angle should be because it is one hundred nine point five degrees. Why? Because that's the angle you'll get between two vertices of a tetrahedron. That's why. Yeah.

John: So the shape of a molecule is a study of the relative orientation of just the atoms.

John: Now, although we ignore the lone pairs, you need to understand the lone pairs play a very important role. If it weren't for those lone pairs on the oxygen, the hydrogen's would be 180 degrees apart from each other in a line they would. But you have these the repulsion between the the entities at the at the vertices that the bonding pairs and the lone pairs that they move as far apart from one another as possible. And what we have described here.

John: There's a thing called Valence Shell Electron paire Repulsion. Vesper for short. Valence Shell, we're talking about electrons in the valence shell electron pair.

John: Now they're two types of electron pairs. They're the pairs that are just a lone pairs. They're not bonded to anything. And then they're the pairs that are actually within a bond, within that covalent bond. You've got two electrons and they're paired. Right. So there are two types of paired electrons. The bonded in the non bonded valence shell electron pair repulsion electrons repel each other. So it just means they want to be as far apart from one another as possible within three dimensional space.

John: Ok. OK, let's do another one. Pick, pick, molecule, any molecule. Make it simple.

John: Ammonia, OK, ammonia, ammonia is an H three, right? Go through the whole process. You'll find there are three hydrogens coming off that central nitrogen. And on top of that nitrogen, you've got a lone param name. So how many things? Let's get technical humming substitutions do you have coming off of that nitrogen 4.

John: You got four you got three hydrogen atoms in a lone pair. Right. And they're going to spread themselves out as far apart as possible. Electron propulsion and that geometry is gonna be ta ta ta ta ta, everybody. Ta tetrahedron. Yeah, it's gonna be a tetrahedron. Now what do you find at the vertices of that tetrahedron for an ammonia molecule?

John: Let's say at the top Bertice, you've got a lone pair. How did the bottom three vertices corners? Yeah, you got hydrogen atoms. So the geometry of ammonia is tetrahedral. But what about the shape? Just focus on the atoms. But a blind eye to that lone pair that's up on top. And you'll have a nitrogen atom in, you'll see hovering above three hydrogen atoms. And it's kind of like a pyramidal shape, isn't it? What do they call that? I think they call that triggered pyramidal. Call it what you want. Understand what it is.

John: In your head of the game. Big time.

John: Ok. Let's start this next section with a bit of review. Let's look at the hydrogen atom. Remember what happened there when two hydrogen atoms got together? They each have an electron that they share with the other. And when they both do that, you'll have two electrons in between. The two in those electrons are being shared by those atoms, much like two toys being shared by kids. It's the attraction those kids have for the toys that pulls them together. The toys are like glue. Likewise for the hydrogen, it's the attraction. Those nuclei of the hydrogen have for those shared electrons that holds those two hydrogen atoms together. Their mutual attraction for the electrons that they share is a force. And we call that the covalent bond. But we talk about sharing. Now understand that hydrogen atoms are hydrogen atoms and they all have the same properties because they're the same atom. What might happen if you had a covalent bond between two different types of atoms? All right, let's pick hydrogen on one side and oak flooring. OK, flooring on the other. And let's look at the covalent bond forming between hydrogen and fluorine. OK. Electron let let's say you're the electron in the hydrogen atom. Right. And you look down to the nucleus and you see a plus one. And that's pretty good.

John: That hold you there. But then you look over to the fluorine and that empty space in the second shell of the fluorine atom has an effective nuclear charge. Of +7. That is to say, from that point of view there in the second shell, you look down to the nucleus and it looks like a +7. I know it's +9, but through two electrons in your way, right? So there you are, the electron and eune the hydrogen atom. Jump over to the fluorine. And you fill the empty space within that second shell of the flooring atom and you have chert, a covalent bond between a hydrogen and a fluorine, two different atoms. It works. Yeah. OK. But now let's talk about what those two bonding electrons, witness bonding electrons, those the two electrons, the pair of electrons that are holding the hydrogen and the fluorine atoms together. Those two electrons, they look toward the hydrogen nucleus and they see a plus one. But when those two electrons turn around and look at the fluorine nucleus, they see a +7, an effect effective nuclear charge of about plus seven. So wait a second one way. There's a plus one pulling on you and the other way there's a plus seven pulling on you who you see. You'd have a preference for the seven.

John: Very much so. And what we have here is a situation where with two different types of atoms, the sharing is not even. You have uneven sharing. The flooring has a greater attraction for those electrons or from the electrons point of view, they look down at the floor nucleus and they see a greater nuclear charge. They are pulled in preferentially toward the fluorine. So if we want to represent that, the idea that those electrons are not being shared evenly, that those electrons tend to spend most of their time close to the fluorine, there's a way to do that. When you draw the bond, you can just put two dots as the covalent bond between two atoms. Now, should those two dots be evenly spaced between those two atoms or might you draw them such that they're a bit closer to the fluorine? Yeah. And when you do that drops. So those electrons appear to be a bit closer to the fluorine. You're acknowledging the fact that the fluorine has a greater nuclear charge. It's pulling them in toward it. This is a concept called electron negativity. Big word, electro negativity. It means the pulling power, the pulling power of an atom pulling power, pulling when you pull apart the ability to pull on electrons that are being shared, those two electrons between the hydrogen flooring, the fluorine is able to pull harder on those two bonding electrons.

John: That is the hydrogen. The fluorine has a greater electron negativity, the greater pulling power, and it pulls those two bonding electrons toward it. Now, what's happening here is the electron from the hydrogen is now spending most of its time around the fluorine. It's not being shared evenly and because it's spending more of its time round the flooring that Flori now effectively has a bit more negative charge than it normally does. It's an extra electron that came from the hydrogen. You know, if we're going toward the argument of a ionic bond now, aren't we? But not quite, because there is still significant sharing that occurs. But what we find is that the fluorine atom tends to pick up this slightly negative character. In the hydrogen, because it's frankly losing electron to fluorine becomes slightly positive in character. And so we can represent that by using the Delta lowercase Greek delta symbol. And we see the Florida as Delta negative, which means slightly negative in the hydrogen's delta positive, which means it's slightly positive. There's uneven sharing.

John: And in this situation, the Florian's side is slightly negative and the hatred inside is slightly positive.

John: This is what physics types call a dipole. And if you were to look at that bond between the hydrogen fluorine, you would say, oh, look, it has a dipole because one side slightly negative and one side slightly positive. And what we're talking about here is bond polarity. If you have perfect sharing between the two atoms, there's no polarity at all. But when you have two different atoms with two different electro negativities pulling powers, then you end up with what we call a polar covalent bond. Now, relative to the periodic table, the atoms of elements to the upper right side of the periodic table, such as fluorine, chlorine and oxygen, those are the atoms with the greatest elektronik activity, the greatest ability to pull electrons toward themselves. Remember the nonmetallic? They tend to gain electrons that's pulling electrons towards themselves. The farther to the upper right and the periodic table, the greater the electron negativity. Conversely, to the lower left of the periodic table, you have atoms of elements that have low elektronik activity. What you gonna get when you take an atom with a low elektronik activity such as sodium and put it together with an atom with a high electron negativities such as fluorine or chlorine? That's right. The ionic bond that switchy get. Mm hmm. But what do you get if you take to non-Middle Adams and you put them together? You're gonna get a covalent bond.

John: But if you have something like carbon and fluorine together, they have different electronic activities. You're gonna find the flooring with its greater election activity is gonna pull on the electrons, the bonding electrons away from the carbon, the flooring because of its greater pulling power. It gains a slight negative charge while the carbon gains a corresponding slight positive charge and you have a polar covalent bond. Perhaps the best example to talk about is with the water. Recall that the shape of a water molecule is bent. So let's look at each of the hydrogen oxygen bonds. One at a time. Think of water h o h. Now let's look at the bond between hydrogen and the oxygen, ask yourself, which has a greater electron negativity. The hydrogen or the oxygen you could use are derald from the periodic table to see that oxygen is closer to the upper right than hydrogen. And so the oxygen has a greater elektronik activity. It's going to pull on the bonding electrons away from the hydrogen and thus becomes slightly negative so that hydrogen oxygen bond is a polar covalent bond. Do when hydrogen oxygen bonding. You can do the other. And that too is going to be a situation where the oxygen is slightly negative and the hydrogen is slightly positive.

John: And so what's happening here is the oxygen is literally pulling on those shared electrons from the hydrogens to become slightly negative in itself. So the oxygen side of any water molecule is going to be slightly negative. It comes down to the greater effect of nuclear charge of that oxygen atom. And the hydrogen side of your water molecule is going to be slightly positive. So you can have a bond, that's poller. But what we're looking at here is actually an entire molecule that's poller looking at the shape of that molecule. You'll find the oxygen side is slightly negative and the hydrogen side is slightly positive. So what might happen with another water molecule? Well, it's going to be the same thing. It's going to have the same shape. It's going to have the same atoms, each two. Oh, and the hydrogen oxygen bond is going to be slightly negative on the oxygen side. Positive on the hydrogen side. Multiply that by two because you have two oxygen hydrogen bonds and you've got the oxygen side is slightly negative and hydrogen side of your molecule slightly positive. Great. Yeah. Same same cause it's the same molecule. It's a water molecule. And that's the case for all water molecules.

John: No. Take two water molecules. And put them together.

John: They're molecules, that means they're unique entities in and of themselves.

John: And we've been talking about the intra. Molecular forces, what's going on within the molecule, the covalent bonding within the molecule in this added nuance that that covalent bond can be poller because of uneven sharing, that's all going on within a water molecule. And as a consequence, you have the oxygen side slightly negative in the hydrogen side, slightly positive. But what about in ter- molecular forces, not intra molecular but inter molecular, which means between separate molecules. How might two separate water molecules feel about each other?

John: Well, you know what? The oxygen side, slightly negative on one water molecule in the hydrogen side is slightly positive on another water molecule. Don't opposites attract? Yeah. So the oxygen side of one molecule is going to.

John: Attach itself to the positive side of another water molecule. There is going to be an attraction between the two.

John: How strong?

John: Not that strong, the covalent bond, if the covalent bond is a strength of 100, this interaction between these two water molecules. It's going to be about five, but it's real. It's very real. And it's what makes water so tricky. Water loves to stick to water. Water molecules are sticky. And now we know why. Because of the polar covalent bonds within each molecule.

John: And because the water molecules are so attracted to each other, that means transforming it from a liquid to gashes phase. It takes a lot of energy. And that means here at room temperature. Water H2O.

John: Is found in the liquid phase.

John: Remember, in the liquid phase, the molecules are all tumbling over one another in the gashes phase. You have fully separated them from each other. It's difficult to fully separate these water molecules from each other. Why? Because they're attracted to each other. They're sticky. What? Oh, OK. Let's do one other molecule and then actually we've got this whole discussion of covalent bonding finally wrapped up. Let's do. Carbon dioxide. All right, so that's CO2. And if you go through the Vesper, you'll find CO2 is a linear molecule. You have oxygen, carbon, oxygen all in a line. And in fact, there are double bonds between the carbon and the oxygens. All right. Let's look at one of those covalent double bonds between carbon and oxygen in the periodic table. We see that oxygen has a greater elektronik activity than the carbon. So the oxygen is going to pull those bonding electrons away from the carbon toward itself. Has greater pulling power, a greater elektronik activity, and so that oxygen's gonna be slightly negative in the carbon's gonna be slightly positive. That's one bond. Let's do the other. The other is on the opposite side of the molecule in the opposite direction. So you'll have that oxygen on the opposite side pulling electrons toward it. And the carbon goes, oh, kay, I'm going to give you my electrons. But but, but there's an oxygen on the other side of me that that that's pulling them back the opposite way. One oxygen is pulling electrons toward the right, but the other oxygen is pulling them back to the left. It's a wash. It's a tug of war where two people are pulling on a rope with an equal force in opposite directions. The rope goes nowhere. Likewise here with the carbon dioxide, the electrons go nowhere.

John: When Oxygen tries to pull him this way, the other oxygen just pulls them right back.

John: There's a balance.

John: And that has everything to do with that, the carbon dioxide molecule is linear, unlike the water molecule, which is bent having the linear shape.

John: Makes it so that those poles. Are equal and opposite. And thus cancel each other out. That's how it is that the carbon dioxide molecule is non-polar. So how might two carbon dioxide molecules feel about each other? There's no stickiness involved and the two molecules might just bounce off one another and not stick. And that's what we know to be the case with an a gashes phase, which is exactly why carbon dioxide is a gas at room temperature. Exhale your breath.

John: Carbon dioxide coming out of your mouth is a gas. Hold a glass up to your breath and do the same thing.

John: And you'll see that the water condenses on the glass. The same temperature. The water is a liquid. Water is a liquid because the molecules are sticky. Carbon dioxide is a gas because the molecules are not sticky. They're non-polar.

John: So let me ask you. Which is heavier.

John: A carbon dioxide molecule.

John: Or water molecule.

John: Well, let's add it up.

John: Water. You have oxygen that's 16. A massive 16 from the periodic table. Hydrogen, that's one. You have two of them. So to the total mass of a water molecules. Eighteen atomic mass units.

John: What's carbon dioxide?

John: Carbon is 12 of the massive 12 for the periodic table. Oxygen is 16. From the periodic table 16+, 16 is 32. Plus twelve is.

John: 44. The mass of a carbon dioxide molecule. It's 44. What is a mass of water? It was 18. Carbon dioxide. Is over twice as massive as water. Carbon dioxide is over twice as massive as water. And yet. It's a gas at room temperature and water is a liquid. How can that be?

John: Oh, well, a quick summary. You see the hydrogen oxygen bond in the water molecule is poller because the oxygen pulls on the electrons away from the the weaker hydrogen oxygen has a stronger electron negativity and the shape of the water molecules bent. It's not linear, it's bent. So that means the two dipoles within those two bonds don't cancel each other out. In fact, they add up to some real number, which makes the oxygen side of the water molecule negatively charged in the hydrogen side, slightly positively charged in-character, which makes it so that two water molecules stick. Don't worry about the mass. It's the stickiness that matters.

John: But why is water bent?

John: Why does water have that bent shape? Of course, it's because of the two lone pairs on the oxygen. You know, if it weren't for those two lone pairs on the oxygen, water wouldn't be bent. Water would be linear like carbon dioxide in the dipoles would cancel out.

John: And the water would be non-polar and the water would be a gas at room temperature. And we wouldn't have our oceans. In fact. We probably wouldn't have us either. Which is why.

John: We can be most thankful for those lone Perry electrons on the oxygen of a water molecule, which makes the water molecule bent, which makes the water molecules sticky, which makes water a liquid at room temperature.

John: That's. Good chemistry. Good chemistry to you.

John: Themusic by Zach Jefferey Musical Flourishes by Sea Pro Music Production Assistance from Greg Simmons and thanks to you, the listener, our co-host for this special episode on covalent bonding, a note of appreciation to all instructors using conceptual academy. Thank you for your support and to the hardworking student. Thanks to you as well for your learning efforts, which we see as the path to making this world a better place.

John: There's a bigger picture that's good chemistry. Good chemistry to you.