Hello, everybody. I want to tell you the interesting and in some ways strange story about how chemists draw phosphorus and sulfur atoms in molecules. So for example, we have a phospho diester molecule over here, we have dimethylsulfoxide. And we have sulfuric acid. What I want you to notice is the central phosphorus and sulfur atoms have more than eight electrons in the valence shell when they're drawn in this way. So for example, the phosphorus here has five bonds or 10 valence electrons. The sulfur and dimethylsulfoxide has four bonds for a total of eight plus a lone pair, equaling 10 valence electrons. Sulfur in sulfuric acid actually is surrounded by six bonds to double bonds to single bonds, for a total of 12 valence electrons. What is going on? Do you remember carbon, nitrogen and oxygen can only have eight valence electrons? What's going on with sulfur and phosphorus? Well, when I was in college, I'm going to tell you how this was explained. It was explained to me that what we needed to remember was that phosphorus and sulfur are in the third period of the periodic table. What that means is that we've got three s and three p orbitals, atomic orbitals on those atoms, but we also have the possibility of involving the three d electrons or or excuse me, the 3d orbitals on those atoms. carbon, nitrogen and oxygen only have s and p orbitals. So you can't have more than just for bonds or in other words, eight electrons in the valence shell phosphorus and sulfur, you can involve the three d orbitals, and therefore expand those valence shells. And that's what we were told. That's what we thought. Turns out, that was wrong. Modern calculations have revealed that the three d orbitals are in fact too high end energy to be involved in any part of bonding in these types of molecules. So that the phosphorus and sulfur atoms are actually only using the three s and three p orbitals. So this is the way we should be thinking about these molecules is kind of interesting because what it does is it increases the number of charges that we see. So for example, in the case of the phosphor diaster, we put a full positive charge on phosphorus and both of these oxygens have a negative charge. When we think about the sulfur and dimethylsulfoxide, we also put a positive charge and that means that it's stead of being neutral, the oxygen has a negative charge. When it comes to sulfuric acid, look at this, we put a plus two positive charge on sulfur. And both of these oxygens have a full negative charge, very different picture. Another way to think about this is that what we're saying is that these atoms, the phosphorus, and the sulfur atoms are actually SP three hybridized. There are no d orbitals. There are not extra bonds, and the valence shells contain eight electrons. Okay, that's kind of amazing. Turns out that I can use my computer and I can calculate these structures and show you exactly what we mean. So sure enough, if we look at the phospho diaster that's over here. We noticed that that phosphorus atom is in fact tetrahedral, as one would predict, based on being SP three hybridized. We can then look at where the electrons are. And we notice that the two oxygens both are really red. They both have a negative charge. And we see in here, we see that this charges color right here is indicative that sure enough, there is a positive charge. There is a positive charge here on phosphorus as predicted by this structure.

If we come over here to dimethylsulfoxide,

we noticed that the sulfur atom is in fact tetrahedral, just going to be a lone pair up here, but this is in fact, tetrahedral. And when we asked where the electrons are, like what we see that oxygen has a negative charge, it is absolutely red. And look at this blue color associated with this sulfur atom as indicated by this positive charge. Finally, when we come over here to sulfuric acid, sure enough, that sulfur atom is tetrahedral. In geometry, we've got electron density, which also is entirely consistent with this structure, notice how dark blue that is that is positively charged for sulfur. And both of these oxygens are carrying a negative charge, as indicated by this structure. So the bottom line is, as my computer is confirmed, the calculations are indicating that these structures are the ones that best represent what these molecules really look like. Okay, here's the weird part.

We know that as scientists

But we haven't changed. For a long time, this was the way these molecules were drawn in not only the chemical literature, but also in, you know, anything you see online. And the fact of the matter is that hasn't changed. So it's kind of embarrassing. But even though scientists know better, they've decided that they're not going to change something they've been doing for a long time. I pulled these pictures offline today. And what I wanted to show you is that sure enough, this is the phospho digester. The same functional group that you see in this molecule up above is in the backbone of DNA. And I don't care where you pull the picture from. You'll notice it's always drawn, such that we have a phosphorus double bond that indicates there might be 10 electrons around phosphorus. We know that's not true. So as scientists we know that's not the accurate way to be describing these Molecules yet we do it anyway because we haven't changed. So like I said, this is kind of embarrassing, but I wanted you to be aware of this. Because when you're looking at either popular media, you're looking at the chemical literature or your biochemistry class, you're going to see these functional groups drawn in this fashion. Unfortunately, that's not the right way to think about them.

The right way to think about them

is shown below.

So when you see the structures that are drawn above, one should remember that this is a way you need to think about these molecules because that is how you will truly understand their interactions and what's going on.