

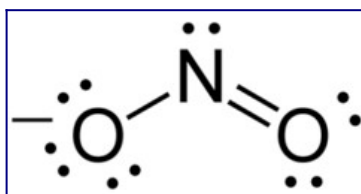
Resonance structures

Now that you understand everything in the world about drawing the Lewis structures of most covalent compounds and polyatomic ions, you probably think you're done. Well, sorry to hit you with the bad news, but you're not.

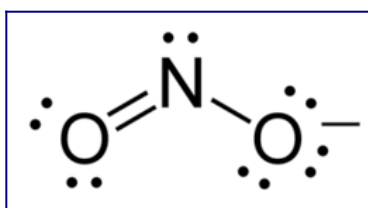
You see, you still have to learn about something important – the idea of resonance structures. Once you know that, you'll be a super-pro at Lewis structures. There will still be more to learn, but you'll be enough of a super-pro to survive your chemistry class.

What's a resonance structure?

Let's go back to the tutorial where you learned about how to draw polyatomic ions. If you were, for example, trying to draw the NO_2^- (nitrite) ion, you hopefully drew something that looked like this:



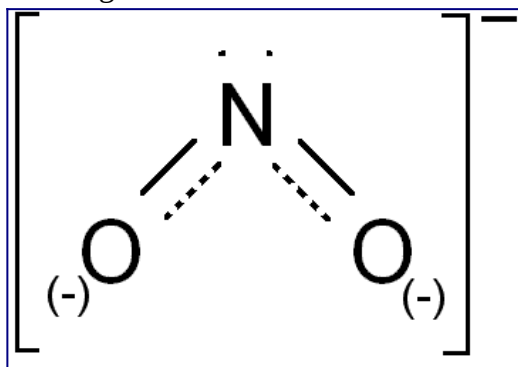
Or, maybe you got all crazy and drew something that looked like this:



Either way, all of the rules were followed and everything is OK.

However, let's think about this for a minute. In the first structure above, the oxygen on the left has -1 charge and the one on the right bonds twice. In the second structure, the oxygen on the right has -1 charge and the one of the left bonds twice. It's obvious that these two structures are both valid, but which one is *right*?

Here's the weird thing: They're both right. Simultaneously. The true structure of the nitrite ion is actually an average of the two structures and looks like this:



This leads to the question “what the heck is that thing?”

If you take a look at this weird diagram, you can see various features which the other two have in common. For example, nitrogen has a lone pair in both structures, and you can see this lone pair on nitrogen in this mutant structure. Likewise, there's an N-O single bond in both Lewis structures, and you can see this bond here.

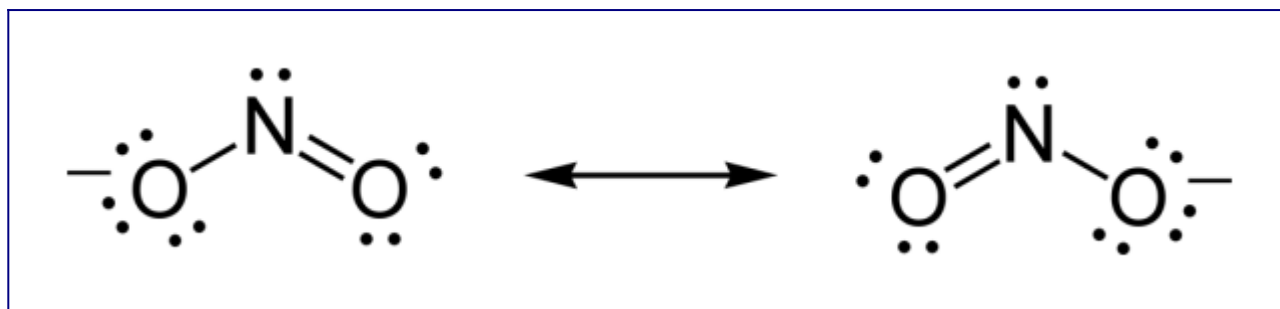
What's weird is that each oxygen has a (-) on it and there's a dashed line between N and O. The (-) symbol means that each oxygen has some, but less than a full, negative charge. The dashed line means that there's a partial bond between the nitrogen and each oxygen. How can this happen? Simple: The actual structure of the nitrite ion is an average of the two structures that can be drawn from it.

Huh?

OK... this may not make a lot of sense right now, and that's fine. You're probably OK with the idea of each Lewis structure representing the nitrite ion, and you're probably OK with the idea that the double bond can fit between the nitrogen and each oxygen atom. There's nothing new with that, so the two Lewis structures at the top of the page both make sense.

The problem comes when you do this averaging thing. Why can you do this averaging thing? What does it mean? Will my instructor make me generate something that looks like that for the test?

You'll be happy to know that you probably won't have to draw that thing because chemists aren't very good at doing it, either. Though all of us chemist types understand that the nitrite ion actually looks like that weird thing above, it's hard to visualize and work with. As a result, we draw the nitrite ion in the following way:



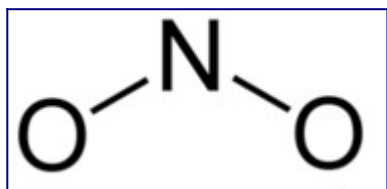
Which, as you can see, is just the two Lewis structures you would have normally drawn, except with a double-sided arrow between them.

The two diagrams shown are referred to as **resonance structures**. Resonance structures exist for molecules in which there's more than one valid Lewis structure, and in which the atoms are all connected in the same way. In the case of the nitrite ion, both of these structures have a central N atom and two O atoms on the outside, so they're said to be resonance structures of each other.

It's important to draw these resonance structures whenever you can because showing both of them indicates to others some useful information about reactivity. For example, if you look at only one of the Lewis structures individually, you may believe that only one of the oxygen atoms (the one with the negative charge) will be reactive and the other one will just sit around. By looking at both of the Lewis structures, you can see that both of the oxygen atoms will be equally reactive because they both have some of the negative charge.

How to draw resonance structures

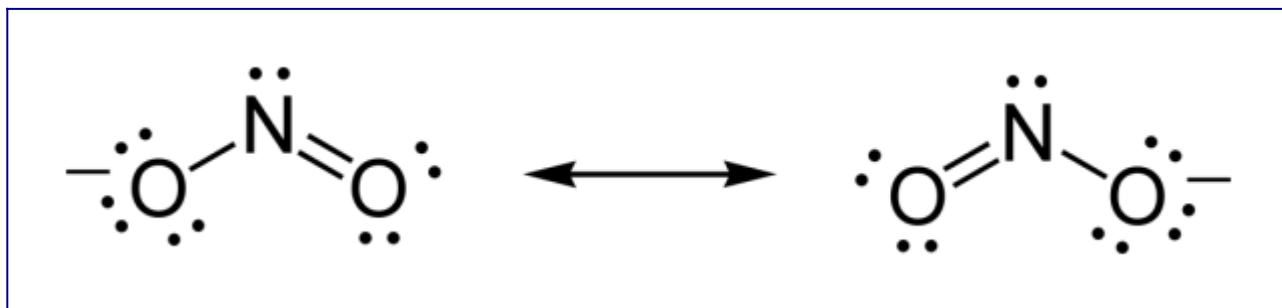
Don't worry about it. There's nothing new you need to worry about to draw resonance structures. Let's say that we're going to draw the structure for the nitrite ion and are just wandering along not thinking of resonance structures at all. When you're following the steps to draw Lewis structures that we talked about, you probably realized that the nitrite ion has three bonds (if you didn't, you need to redo the math). Here's what you'd probably draw at that point:



Yep, all the atoms are combined and no rules have yet been broken. Unfortunately, we have one more bond to add, and it pretty much has to be an N-O bond.

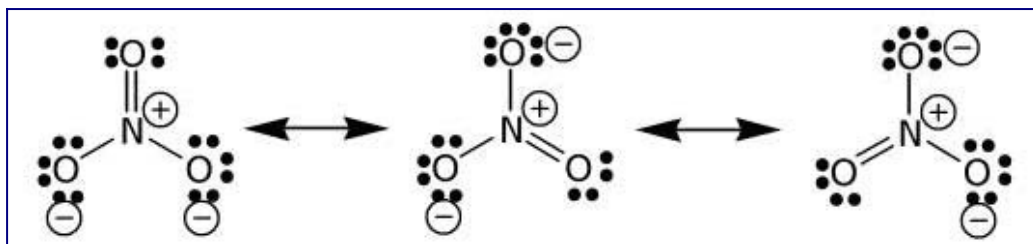
But *which* oxygen will double bond to the nitrogen atom? I could put the bond between nitrogen and the oxygen atom on the left, and everything would be cool. I could put the bond between nitrogen and the oxygen atom on the right, and everything would also be cool. Which one do I do?

If you have this kind of choice, the best thing to do is to draw two structures: One in which you follow one choice and one in which you follow the other. When you do so, you'll represent both of the resonance structures for the molecule. From that point, all you need to do is draw a double-headed arrow between them and you'll get your answer:



When will I need resonance structures?

If you are drawing a Lewis structure and find that you can put a multiple bond in two or more different locations, the resonance structures will correspond to each of these possible answers. In the more complicated example of the nitrate ion (NO_3^-), you'll find that the double bond can exist between nitrogen and one of *three* oxygen atoms, which gives rise to the three resonance structures of the nitrate ion:



When drawing resonance structures, this is the way in which you indicate the equivalence of all three resonance structures.

There are two main compounds in which you will observe resonance structures:

1. *Polyatomic ions*: It's not at all uncommon for polyatomic ions to have resonance structures. However, please don't assume that just because something is a polyatomic ion that it must have resonance structures. Whereas the nitrate and nitrite ions have resonance structures (as shown above), the hydroxide ion does not. Remember, you can only draw resonance structures when there's more than one possible place the multiple bonds can be shown.
2. *Some organic compounds*: In cases where you have an organic anion (such as the phenolate ion), it's possible to have resonance structures. In the case of aromatic (or anti-aromatic) and conjugated hydrocarbons, you may also see resonance structures. Again, not all organic compounds will have resonance structures, so only draw them if you have some compelling reason to do so.

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