TRU Open Press

Aromaticity

Transcript

Instructor: David

00:00:00:00 - 00:00:14:73
Instructor: Okay, so aromaticity. Aromaticity is a special chemical property that describes oddly very stable organic compounds. This stability is generally enhanced by resonance across the whole structure.

00:00:14:73 - 00:00:32:89
Instructor: So here as we can see, we have a very popular molecule known as benzene, which is an aromatic compound. But there are four main criteria that help us identify this. As we can see here, the molecule is planar, we have conjugated, cyclic and that it follows Hückel's rule.

00:00:32:89 - 00:00:45:99
Instructor: We'll go through all of these and understand what we mean by these things. So, as we can see there, also pyridine also follow all of these four because it's also an aromatic compound. Okay, so what do we mean by planar?

00:00:45:99 - 00:00:54:31
Instructor: Planar means the molecule. All the atoms inside the molecule are SP or SP2 hybridized. So that's the first part.

00:00:54:31 - 00:01:16:43
Instructor: So, let's say we have carbon one, two, three, four, and five, and carbon six. Okay, so SP2 means it is planar. So, by planar, we mean it's bonded to a total of three atoms or has an extra lone pair.

00:01:16:43 - 00:01:36:51
Instructor: So, as we can see here, carbon here has a hydrogen. So, there's another hydrogen here, another hydrogen here, another hydrogen here, and here in the final one, we can put it there. As we can see, all the carbons here are connected to a total of three things.

00:01:36:51 - 00:01:49:08

Instructor: Although there's a double bond here, it is still connected to another carbon, so it still counts as SP2. So, benzene follows this rule, so we can say, yes. Okay, what do you mean by cyclic?

00:01:49:08 - 00:02:08:40
Instructor: Cyclic is a molecule where the first carbon is connected to the last carbon in the molecule, whether it is indirectly or directly. So, in the case of benzene, as we said, this is carbon one and this is carbon six. This bone right here is what connects carbon one to carbon six.

00:02:08:40 - 00:02:28:43
Instructor: And so, it is a cyclic molecule, and all the other carbons are connected. We see pyridine, it's a little different. Let's say we have pyridine as carbon one here, carbon two, carbon three, and five.

00:02:28:43 - 00:02:46:91
Instructor: As we see, three and four are connected to each other through nitrogen, but it is still connected to each other. We'll still call that as a cyclic molecule where all the carbons are connected to each other. We'll also talk about planar for pyridine.

00:02:46:91 - 00:03:13:39
Instructor: As we can see, nitrogen is going to have a lone pair right here. This molecule is also planar because we see the carbons similarly to in benzene are connected by three things, so we can write the hydrogens down hydrogen right here. Let's see, a hydrogen that comes this way.

00:03:13:39 - 00:03:32:55
Instructor: So, all the carbons are connected to three different things and the nitrogen also to a carbon at the left to a carbon at the right and it has a lone pair right there. That is also planar, so we can tick for both. Okay, so next thing, Hückel's rule.

00:03:32:55 - 00:03:51:43
Instructor: Hückel's rule is kind of a formula that you have to follow. The formula for Hückel's rule is 4N plus 2 is equals to amount of Pi electrons involved in bonding or resonance for the molecule. So, let's see what we mean by that. Okay.

00:03:51:43 - 00:04:08:73
Instructor: So, first, we're going to look at pyridine. So, Pi electrons count there are two Pi electrons in every double bond. Here we're going to have two, then we're going to have two, and we're going to have two here.

00:04:08:73 - 00:04:17:29
Instructor: Now, these are lone pairs, but they do not count in the Pi electrons. These lone pairs actually are hybrid... In the hybrid

00:04:17:29 - 00:04:31:35

Instructor: orbital and so you will not count them. So, this molecule has a total of six. If you do 4N plus 2 is equals to six Pi electrons, then N is equals to one.

00:04:31:35 - 00:04:52:27
Instructor: We will explain how this rule helps us as we go. Okay, so as we can see, N is equal to one. Now, N if N is an integer, which means one, two, three, four, and all other integers, then we call the molecule as aromatic, only if it follows all the three other rules.

00:04:52:27 - 00:05:09:71
Instructor: But if N is a decimal or a fraction, then it's not going to be aromatic. So, as we see in this case, it is aromatic because N is equal to one, but we still have to confirm if it's conjugated. But for now, let's look at Hückel's rule, but for benzene.

00:05:09:71 - 00:05:30:62
Instructor: Okay, so 4N plus 2 is equal to the number of Pi electrons. If we count the amount of Pi electrons inside benzene as well, we are going to see that benzene has a total of six. Like we said, each double bond carries two Pi electrons.

00:05:30:62 - 00:05:43:38
Instructor: So, if we count the amount of double bonds, we have three and three times two is six. We know that 4N plus 2 is equal to 6. So N, our integer is also equal to one.

00:05:43:70 - 00:05:54:29
Instructor: Now we know that both our molecules follow Hückel's rule. We'll also take that. Next, we have conjugation.

00:05:54:29 - 00:06:11:03
Instructor: What do we mean by conjugation? Conjugation is when all the atoms inside our ring or inside our molecule have empty P orbitals for electrons to be passed on through them. Okay, so we'll look at our molecule and see if that is true.

00:06:11:03 - 00:06:32:91
Instructor: Generally, a pattern you can follow for conjugation to tell if your molecule is conjugated or not, is if there's a pattern of double bond and single bond, then double bond again. So, we can see, let's see for our benzene molecule. If we start here, then we have a double bond, which is followed by a single bond, which is followed by a double bond, and a single bond and a double bond, and a single bond, then back to our first double bond.

00:06:32:91 - 00:06:44:07
Instructor: So, this pattern is a way for us to recognize if our molecule is conjugated or not. We can say because we see the pattern in this molecule, it is conjugated. Okay, we'll look at pyridine now.

00:06:44:07 - 00:06:58:87

Instructor: So, pyridine, also, we have a double bond, a single bond, a double bond, another single bond, a double bond, and another single bond. So just like benzene, pyridine also follows that pattern. So, we can also say that pyridine is conjugated.

00:06:58:87 - 00:07:12:48
Instructor: So, we'll be taking both of them. Okay, so it looks like both our molecules follow all the four criteria of aromaticity. And so, we can proudly say that they are both aromatic.

00:07:12:48 - 00:07:30:42
Instructor: So, let's say you open your quiz and you see these three molecules there. We're going to see how we can approach to solve these questions if we're asked to find out if these molecules are aromatic or not. So, first thing I'll do if I see this molecule on my test is I'll look for these four criteria that we set.

00:07:30:42 - 00:07:43:36
Instructor: I'll try to identify first if this molecule is cyclic. As I can see it, it is cyclic because all the carbon molecules are connected to each other. We can do a little thing to make sure that makes sense.

00:07:43:36 - 00:07:57:71
Instructor: We can call this carbon one. Then we have two, three, four, five, six, seven, eight. As we can see, all the molecules are connected to each other.

00:07:57:71 - 00:08:09:65
Instructor: For me, this molecule is cyclic. Second, is this molecule planar? Remember, planar means that the molecules are SP2 or SP hybridized.

00:08:09:65 - 00:08:27:15
Instructor: When I look at this molecule, I immediately see two carbons that are SP3 hybridized. So here, this carbon, which we have carbon one, is connected to four different things, carbon one. It's connected to four different things as we can see here.

00:08:27:15 - 00:08:46:65
Instructor: So immediately this molecule is not planar. Also, we have the same thing happening here with carbon eight. So, we have the same thing happening with carbon eight that is connected to four different things, a carbon here, a carbon down here, another carbon here, and a hydrogen.

00:08:46:65 - 00:09:08:03
Instructor: After I see these two things in a test, I don't have enough time. So, the moment I see one of these four criteria that do not fit the aromaticity template or idea, then I'll move on to the next molecule. So, as I can see here already, not all the molecules are planar, and so this is not aromatic.

00:09:09:95 - 00:09:24:17

Instructor: So, as I can see here, this molecule is not aromatic. Now for the next molecule, I'll approach it similarly to the first molecule. First thing I'm going to try and see is if this molecule is cyclic.

00:09:24:17 - 00:09:44:01
Instructor: While I look at it, I can already tell that it's cyclic because all the molecules are connected to each other. Now, this carbon is indirectly connected to this carbon through the oxygen, but it is still connected and so it is still cyclic. So, we have our carbons there numbered now.

00:09:44:01 - 00:09:53:91
Instructor: All right. Second thing we're going to look at is if this molecule is planar. As I can look at the molecule, I can already tell that it's planar, but we can go through it together.

00:09:53:91 - 00:10:06:53
Instructor: As we can see here, this carbon is connected to three things. So, it's connected to hydrogen, the oxygen up top, and it's connected to another carbon down here, three things. This carbon we have the same thing.

00:10:06:69 - 00:10:22:35
Instructor: Same thing there. Same thing there. And when we look at our oxygen, our oxygen is connected to three things and has two lone pairs up top.

00:10:22:35 - 00:10:38:89
Instructor: As we can see, our carbon here, carbon three has the same planes connected to one carbon here, hydrogen, and then the carbon here. Carbon four, same thing is connected to the oxygen the carbon here and then hydrogen. As we can see, all of our carbons are connected to three things, all of our carbons are planar.

00:10:38:89 - 00:11:04:13
Instructor: Now when we look at our oxygen, our oxygen is connected to two carbons but has two lone pairs. You might think that because it has two lone pairs, it has four things on it, and so it's not planar. But when it comes to oxygen molecules, one of our lone pairs is in a hybrid orbital and the other one is the one that is in the p-orbital.

00:11:04:13 - 00:11:13:39
Instructor: When it comes to aromaticity, we're focused on the lone pairs or electrons that move in and out of the hybrid... of the p-orbital,

00:11:13:39 - 00:11:34:44
Instructor: So, our oxygen is in reality connected to three things, not four. Okay. Now all of our atoms in this molecule are SP2 hybridized, and so we can also say that it's planar.

00:11:44:26 - 00:12:06:58
Instructor: Now, to see if our molecule is conjugated, remember, the pattern for conjugation is double bond, single bond, double bond, single bond, double bond, and so on

and so forth. When I'm working and I see my molecule, I'm going to look for that. As I can see here, I have a single bond, a double bond, a single bond, a double bond, and a single bond.

00:12:06:58 - 00:12:41:35
Instructor: This pattern as we can see is visible like we saw in the benzene previously, and so we can say that our molecule is conjugated. For the last part, if our molecule follows Hückel's rule, Hückel's rule is 4N plus 2 is equal to the number of Pi electrons. We will now count the amount of Pi electrons that our molecules have.

00:12:41:35 - 00:12:54:23
Instructor: As we can see here, each double bone is two Pi electrons. Here we have one, two, two times two give us four. Now, when we look at our oxygen electrons.

00:12:54:23 - 00:13:15:45
Instructor: Like we said, we are concerned only about the electrons inside the p-orbitals, and so, these will not count, and lone pairs have two Pi electrons. So, we're going to have a total of six Pi electrons. So, we're going to have N is equals to (6 -2)/4, which means N is equals to one.

00:13:15:45 - 00:13:25:52
Instructor: Now, N is an integer and so this molecule also follows Hückel's rule and so is also... and so is aromatic.

00:13:36:48 - 00:13:48:20
Instructor: Okay, let's move to the next molecule. Okay, so I know when you look at this molecule, you already think what I'm thinking. This molecule is not cyclic.

00:13:48:20 - 00:14:09:62
Instructor: So, we don't have to bother with all of the other criteria, which is planar, conjugated, if it's cyclic, or if it follows Hückel's rule. So, we can immediately say that this molecule is not aromatic. Okay, as we can see here, it's non-aromatic, just because we can see immediately that this molecule is not cyclic.

00:14:09:62 - 00:14:20:10
Instructor: How do we see that it's not cyclic? Because of the random weird space right in the middle here. When you see a space like this, you know that it's not cyclic because carbon one is not connected to carbon six.

00:14:20:10 - 00:14:44:47
Instructor: So, when you're in a test and you're giving questions similar to these, you want to save the most amount of time you can. And so, when you look at a molecule, especially when the question has to do with aromaticity, you look at a molecule, you should always look for what is missing between those four roles. The moment you find which of them is missing, you can identify whether it's non-aromatic or aromatic.

00:14:44:47 - 00:14:54:63
Instructor: So, if missing, non-aromatic, I present, then next role. If all four are present, then you're aromatic. Good. Okay, onto the next page.

00:14:54:63 - 00:15:05:35
Instructor: As we can see from this molecule, there are no weird spaces, and so we can say that this molecule is cyclic. So, we can count the carbons now. Okay. Next thing we're going to look

00:15:05:35 - 00:15:23:21
Instructor: at is if this molecule is planar. Now, to tell if it's planar, we're going to try and find out if it's SP or SP2 hybridize if it's not, let's say if it's SP three above or SP4, which we won't look at. But then it's not planar.

00:15:23:21 - 00:15:34:45
Instructor: For our first carbon, as we can see, it is planar because it's connected to three things. Next, our second carbon, also planar. Same thing for the third one because there's a hydrogen right here.

00:15:34:45 - 00:15:46:93
Instructor: And a hydrogen here for a fourth carbon. All of our carbons are planar. Now, we will not look at the oxygens because we are only concerned about the atoms inside the ring.

00:15:46:93 - 00:16:01:25
Instructor: Now the next thing we're going to look at is if this molecule is conjugated. We're going to look for a pattern again, single double or single double single. Good. Here we have single double single.

00:16:01:25 - 00:16:24:39
Instructor: As we can see, we have a single double single and so we can see that our molecule is also conjugated. We'll just write it down, cyclic, check, conjugated. Also check and planar. Check.

00:16:24:43 - 00:16:36:63
Instructor: For the fifth molecule, we're going to look at if this molecule is cyclic or not. As you can see, this molecule is cyclic because there's no weird space. We're going to cut the carbons now.

00:16:43:00 - 00:16:58:98
Instructor: Okay. The next thing we're going to look at is if this molecule is planar. So, as we can see, from the first carbon, it is connected to only one hydrogen because it has an ETP orbital, as we can see demonstrated by the plus sign right there.

00:16:58:98 - 00:17:21:83
Instructor: The same thing is seen with carbon two, so hydrogen right there, and for the rest of our carbons, we just have one hydrogen connected to them because of a double bond

there. Our molecule is planar. For the next thing, we're going to look at for the single double single pattern to confirm if our molecule is conjugated or not.

00:17:21:83 - 00:17:41:15
Instructor: As you can see here, we have single, single, and so this molecule is also conjugated and so we can move through our fourth criteria. So, for the fourth criteria, we're going to look at Hückel's rule. So Hückel's rule is 4N plus 2 equal to the amount of Pi electrons.

00:17:41:15 - 00:17:51:29
Instructor: Remember, a double bond means two Pi electrons. For this, we're going to have N is equal to zero. N is equal to zero.

00:17:51:29 - 00:18:11:33
Instructor: Zero is an integer and so it also follows Hückel's rule. This molecule can be said to be aromatic because it's followed the four criteria. As we can see, this molecule follows all the four criteria, and so we call it as aromatic.

00:18:15:65 - 00:18:23:61
Instructor: Okay, good. Now we're going to look at our six molecule. Okay, so we're going to look at our sixth and last molecule.

00:18:23:61 - 00:18:32:75
Instructor: As we can see from now, no weird spaces, and so cyclic. Now we'll count the carbons. Okay. Next thing we're going to look

00:18:32:75 - 00:18:47:07
Instructor: at is if this molecule is planar. So as we can see, this molecule is planar just by looking at it, we will not look at the oxygen because it is not in the ring. This carbon is going to do three things, same as this one, where we have the hydrogen.

00:18:47:07 - 00:19:06:59
Instructor: Same as this one, we also have a hydrogen here, same as this, hydrogen, and hydrogen here. Okay, so next thing we're going to look for is the single…single double pattern. So, as you can see, we have a single here, a double here, a single here, double and a single.

00:19:06:59 - 00:19:15:73
Instructor: And so, this molecule is also conjugated. Okay, so far, we have three of our criteria which have been checked. Now we're going to look for the fourth one, which is Hückel's rule.

00:19:16:02 - 00:19:40:80
Instructor: Hückel's rule is 4N plus 2 equals to the number of Pi electrons. We'll write that equation right here and we're going to look at our molecule. As we can see from this molecule, we are going to look for the amount of lone pairs that are inside the molecule,

connected inside the ring, in this case, which are none, and we're going to look at the amount of double bonds that are inside the ring, which in this case, are two.

00:19:40:80 - 00:19:54:80
Instructor: Each double bond counts for two Pi electrons. As we can see, two here plus two, which is going to give us four. We have four for the number of Pi electrons that we that are in this molecule.

00:19:54:80 - 00:20:16:18
Instructor: For the next thing, we're going to try and find out what N is. We will isolate N inside this equation, and so we're going to get N is equals 1/2. 1/2 is a fraction and is not an integer, so this molecule does not follow Hückel's rule, and so it is not aromatic.

00:20:18:30 - 00:20:39:06
Instructor: For a molecule to be aromatic, it has to follow these four criteria, you must remember. The first one being cyclic, the second one being planar, the third one being conjugated, and the fourth one being following Hückel's rule. If your molecule ever on an exam follows these four, then immediately write down aromatic.

00:20:39:06 - 00:20:44:66
Instructor: If it's missing one of them, then your molecule is non-aromatic. Thank you.