Course on Stereochemistry
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Module No 02
Lecture 06: Chirotopicity and Stereogenicity

Let us come back to the in continuation of those chirality, the protection formula. So far we have covered stereoisomerism and then the different formula, perspective formula that are used to depict the three-dimensionally ed three-dimensional molecules into a two-dimensional plane and the rules associated as in changing the formula in the two-dimensional plane. The 1st time, the 1st lecture, we introduced the concept of chirality okay?

Now it may sound that we have the repeating the whole thing again but it is not a repetition because the concept of chirality kept involving. As I told you, kept evolving means initially something was said and then it has to be revised. Initially the definition of chirality was that it has to have a chiral centre. That means a carbon with 4 different groups. Then because of the presence of mesotartaric acid people found that even when chiral centres are present, they may be optically inactive.

So they are not chiral. And the 3rd problem, I give you an example yesterday. Multiple examples would be given in subsequent classes where we can show that there are molecules where no such carbon atoms are present but the molecule is chiral. So the problem was actually associating the chiral centre with chirality. And it was Mislaw a very famous stereochemist along with Alyell and others, they are all famous scientists dealing with stereochemistry.

The actually dissociated this concept of chiral centre association with chirality. They said that chirality has nothing to do with the presence or absence of chiral centre. It is the symmetry criterion which dictates the chirality and we have gone through what are the symmetry criterion is. We said that the molecule has to be disymmetric in order to be chiral. What is disymmetry? Dissymmetry is devoid of the I, the Sigma and the S axis okay?

Now by the way, these are called improper elements of symmetry. So the molecule has to like improper elements of symmetry in order to show chirality. What about the the proper axis of symmetry or the proper element of symmetry which is called the C axis, the simple axis of symmetry? I said that that may be present that may not be present. Okay? So that is why if I do a statement that all disymmetric molecules are chiral, that is the correct statement.

All asymmetric molecules are also chiral, that is also a correct statement but to have chirality, asymmetry is a must is not a correct statement because you are introducing another extra parameter that is the C axis okay? Now that means that there are molecules where C axis is present but the other improper elements of symmetry are absent and they are chiral. So what is the simplest example?

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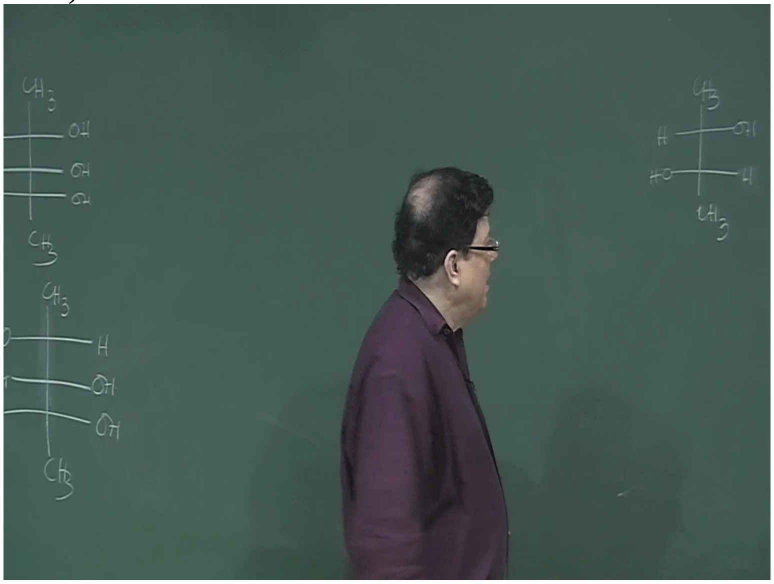

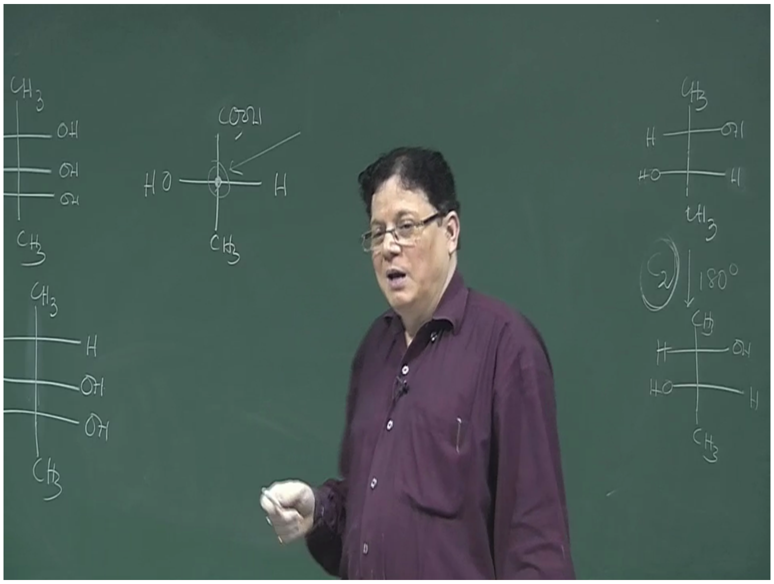

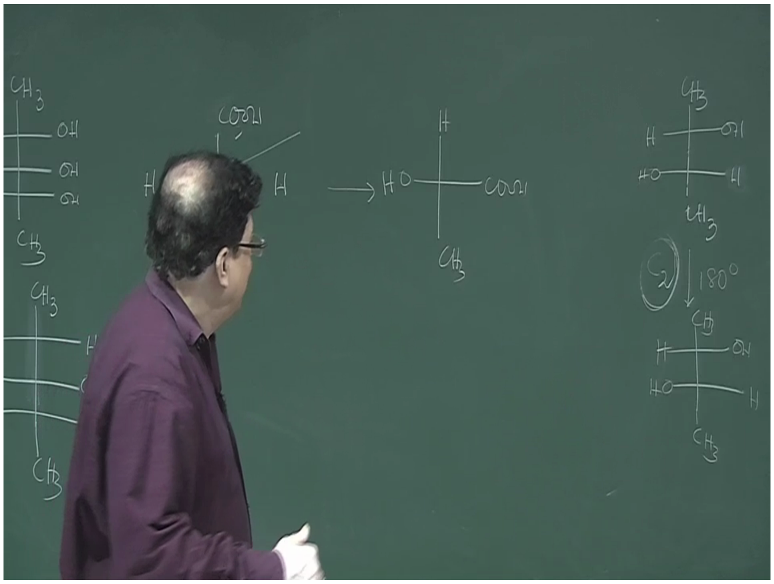

The simplest example is this tartaric acid molecule. If you look at this tartaric acid, the Fisher projection of a an optically active form of tartaric acid okay? This does not have any I axis, this does not have any S axis, this does not have any Sigma. So it is optically active but it has a C2 axis because if you put an axis here and you rotate it by 180 degree, remember just now I have said that Fisher projection formula can be rotated in plane by 180 degree.

So if you have an axis like this and you rotate the molecule by 180 degrees then you, what you get is the same molecule. So this molecule has a C2 symmetry going through this point, vertical to this plane of the board. You rotate it by 180 degree which is allowed in Fisher projection, you get the same molecule, okay? So it has got a C2 symmetry.

So it has got C2 symmetry but it is optically active. So this is the very simple example of a molecule, a chiral molecule possessing a C2 symmetry. Okay? So there are plenty of examples like that where C axis is present but the molecule is chiral. But I wanted to just show you a very simple example about this concept that why C axis was ultimately excluded from chirality. Okay?

Now again, what happened? This chirality when the molecule is chiral, the general notion that comes into our mind that it is chiral because there is some point of chirality in the molecule. Actually that originates from the again the same is concept of a chiral centre, attached to it 4 different groups. Again I repeat what I said.

That when I said a molecule is chiral, it as if it means that there is something in the molecule which is responsible for the chirality. Okay? But chirality when what Mislaw said is that a chiral molecule, when I say a molecule is chiral, in totality it is chiral. There cannot be any centre in the molecule which is only chiral and the others, the rest are not.

It is like saying that if I wear a blue shirt, then every piece of the blue shirt is blue okay? So if I say that a molecule is chiral, then every point in the molecule is chiral. So you cannot say that there is a centre here which makes it chiral. Okay? Like a blue shirt. You cannot say that the shirt is blue because there is a blue point inside the shirt. The whole thing is blue.

This is what is called all pervasive property. So chirality is a all pervasive property. So the problem was that when we are equating this chiral centre with the chirality, the existence of a chiral centre with chirality, already a mistake has been made because without chiral centre, molecules can be chiral. The 2nd mistake that was made is that associating that you are saying that a molecule is chiral because of the presence of a centre, a chiral centre in a molecule.

So that was the 2nd mistake. So Mislaw said that the carbon atom where there are 4 different groups which are attached, you cannot call them as chiral centre because that is that is causing some misconcept in the minds of the student. The student thinks that because there is a centre as I said because there is a blue centre, the whole piece of cloth is blue, that is not correct.

Similarly, a molecule is chiral because there is a chiral centre in the molecule. That is also not correct. So then the question is what should we call that carbon where there are 4 different groups? Now the literature up till now is totally confused because many people still say the atom which, a carbon atom where 4 different groups are chiral centres. But Mislaw said or the modern stereochemist, they said that that should be called a stereogenic centre.

A stereogenic centre is a centre where interchange interchanging the position of 2 groups gives rise to a stereoisomer. Okay? Again I repeat, what is a stereogenic centre? A stereogenic centre is a is an atom which is attached to different ligands and if you interchange the position of the groups of the ligands, you get a stereoisomer okay?

Like suppose this is what is called maybe the tartaric acid. This is lactic acid, not tartaric acid. CO2H, CH3, OH and H. This is one particular form of lactic acid okay. Now this carbon, earlier it used to be known as chiral centre. Now as I said, again people still say it as chiral centre, books also write it as chiral centre. So the International union of pure and applied chemistry, that means IUPAC which is the highest board who actually gave the nomenclature system, then they also clarified the (())(10:11) system of absolute configuration.

So what do they say? They actually took a middle path. They said that this may be called a chirality centre okay? But as I said, at this level, you can continue with the chiral centre but at the same time, you should be aware of the fact that this chiral centre, real pure stereochemistry people, they do not like this word. Instead, they use the word stereogenic centre. They are more comfortable with the word, stereogenic centre.

And one more reason is because the presence, when I say this as chiral centre, it immediately gives a visualisation that the molecule is chiral but that may not be as I said in tartaric acid, that may not be, in tartaric acid, mesotartaric acid, you have in active isomers optically inactive isomers. So that is why they did not like this word, chiral centre. So they introduced the word stereogenic centre.

They say that when a carbon has these 4 different groups, what it gives rise is stereoisomerism, not chirality. Chirality is an associated, and extra, bonafide bonus of having these 4 different groups. But that bonus maybe their, may not be their okay? In mesotartaric acid, the bonus is not there. That is why they wanted to dissociate. They said the presence of these carbons gives rise to what is called stereoisomerism and the definition of stereogenic centre, that meant that gives, that is the genesis of stereoisomerism. That is why that is called Stereogenic.

If you interchange these 2 groups, what you get H here and CO2H there. And what did I say just earlier in Fisher projection? Interchanging the groups gives you a stereoisomer, in this case an Enantiomer. One exchange is not allowed. If you do that, if you do this one exchange, what you are going to get is a stereoisomer, in this case this is the mirror image of this one.

That I have shown in the earlier lecture okay? So this is a stereogenic centre. The definition is an atom where interchange which is attached to different ligands, ligands are basically the substituents or the atoms attached to that atom, if you interchange the positions of 2 groups, remember 2 groups, then you get another stereoisomer. So then that centre which you are considering, is called a stereogenic centre. Okay?

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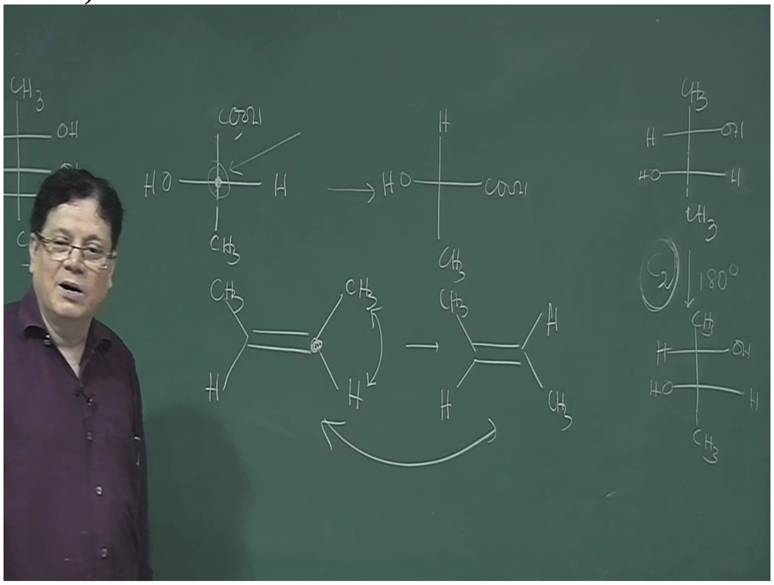

Interestingly, stereogenic is also associated with double bonds. If you have this compound, this is what is called sistobutane no look at this carbon. If you interchange the position of methyl and hydrogen, what will happen? You will get what is called the trans to butane, trans to butane. And what is the relationship between these 2? They are stereoisomers but they are not mirror images. So they are Diastereomers okay?

And what is the definition of stereogenic centre? That interchanging the position of the groups gives you a stereoisomer. So by definition of stereogenic centre, this carbon is a stereogenic carbon. So now the stereogenic carbon covers not only the earlier the chiral centre, it also covers the SP2 hybridised carbon like this. Okay?

So that is what is what are called stereogenic centre and molecules possessing stereogenic centre with the phenomena is called stereogenicity. Okay this phenomena of of showing of interchanging groups giving Diastereomers, give different Diastereomers or Enantiomers or in general stereoisomers, this phenomenon is what is called stereogenicity okay?

Now as I said that chirality is an all pervasive property. That means when you take a chiral molecule, every point in the molecule is chiral. You cannot say that there is a chiral centre in the molecule. You see, the concept is very important. If you say there is a chiral centre in the molecule that means other centres are not chiral you are saying.

But that is not true. In a chiral molecule, every point in the molecule is chiral okay? So every point in the molecule is chiral. And then this scientist, Mislaw and I think there is another one, his name was Segal, Mislaw and Segal they introduced the concept of along with stereogenicity or stereogenic Centre, they introduced another concept which is called Chirotopic or Chirotopicity okay? Chirotopic or Chirotopicity.

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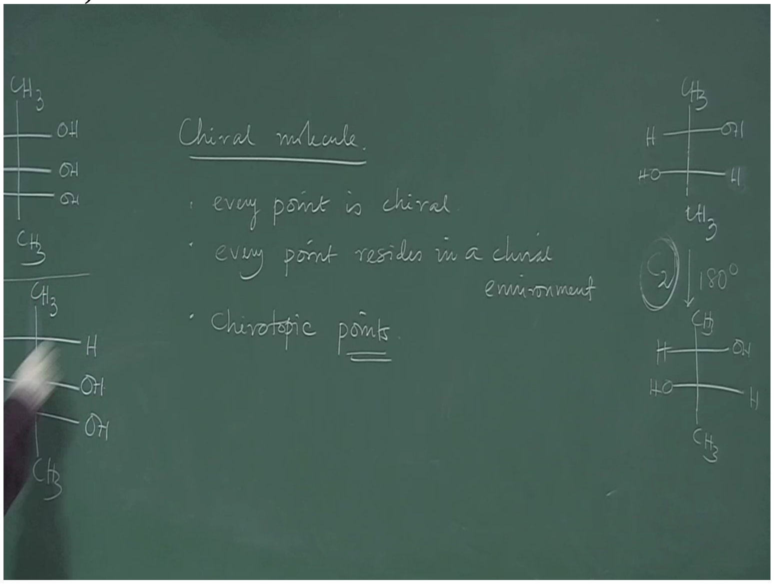

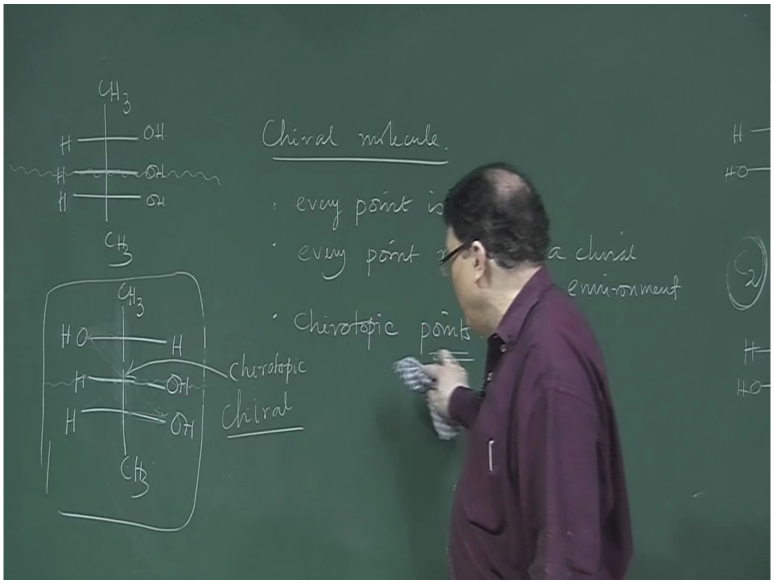

Now what is that? They are saying that in a chiral molecule, in a chiral molecule, every point as I said, every point is chiral. Or they reside in a chiral environment. I can say, every point is chiral. That means every point resides in a chiral environment and he names this as, these points are, he named it as chirotopic points. Like if I look at this molecule, 1st of all whether this molecule is chiral or not. This molecule, whether this is chiral or not.

Usually one way off, in Fisher projection, usually what you check is the plane of symmetry, whether plane of symmetry is there not because that is the easiest one to check. Like the top molecule, I can immediately say that it is not a chiral molecule because it has got a plane of symmetry passing through this. This is the mirror image of the this, that is the mirror image…so top molecule is not chiral.

That fish because it has got the Sigma. Okay? If you are little bit advance, you can say because it has got S1 okay? This molecule on the other hand if you do this in operation by setting this molecule, you do not see that. You do not see the mirror image, halves. So this is not a plane of symmetry. Now, the another mistake or misconcepts friends may have is that what about the centre of symmetry?

It appears as if this OH and this OH if I drop the line from here, bend it backwards, I should reach to this H OH. This H also should be like that. This is also the carbon if I drop this and send it back, I should reach the carbon, the same methyl. So as if this this molecule is having a centre of symmetry. But that is wrong. Why that is wrong?

Because again because of the problem that it is a two-dimensional representation of a three-dimensional formula okay? What is the geometry of these bonds? This is actually beta bonds. Remember, horizontal bonds are above the plane of the board and that is called beta bonds. Okay? So that is beta. So if you join this and then extend it backwards, this bonds should, if this bond is alpha, then it is not problem it is not a problem.

But because this is horizontal bonds, this is still beta, so you, so this is a wrong concept because you are starting from a beta, you join this point, you should end up in the alpha position when you go backwards but because of the two-dimensional representation, you might suffer from this list concept. Arrey, I am seeing it, this centre of symmetry but that is not there.

So it does not have any centre of symmetry. It actually centre of symmetry should not be considered in Fisher projection. It always leads to different problems like these, of this alpha beta nature because that is not shown in the projection, which one is alpha, which one is beta. So better always look at the Sigma whether it is present or not.

So this Sigma plane is not present in this in this molecule. So this is chiral molecule. This is a chiral molecule. So according to the definition, a chiral molecule, every point is chiral or that belongs to a chiral environment and that point is called a chirotopic point. So if I ask that what is this point now, this carbon? This carbon is Chirotopic. Why?

Because this molecule is chiral. As simple as that. So every point is Chirotopic. Okay? Now the question is, what is the relationship between stereogenicity and Chirotopicity? They are closely associated, you see you will see now. This is Chirotopic now the question is, is it stereogenic or not? Now how to proceed or how to answer that. What you do?

You interchange the position of 2 groups and see that, are you getting a stereoisomer, a different stereoisomer compared to the original or not. If you end if you get the same thing, that means that becomes non-stereogenic okay? So let us do that. So let us interchange the position of H and OH okay?

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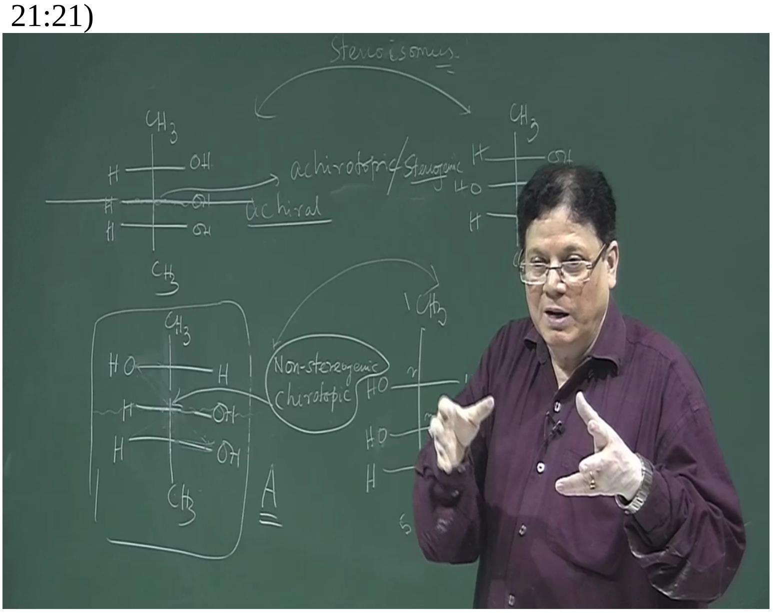

So this is methyl without disturbing the others. So I interchange. I interchange the position of these. This is OH, this is H, this is methyl keeping the others intact, OH, H. Okay? So what I did? I interchanged these 2. And now my task is to see whether this is this is same as this or this is different as this. If that different then this will be stereogenic, if they are same than they will be non-stereogenic. Then that will be non-stereogenic. So how to prove that?

Now we have 1 rule in Fisher projection again, 180 degree in plane rotation is allowed. So now you do a 180 degree in plane rotation. So I rotate it in plane which is allowed by the way. So you do it. So now if you do that, see for beginners, I would say that better you number it, 1, 2, 3, 4, 5. So if you rotate it in 180 degree, the 5 methyl will be here at the top. This is the methyl at the 5 position.

The 5th methyl and this is the methyl which was at the numbered which would reach at the number 1. So where will be the number 2? Number 2 will be here, 180 degree. So after 180 degree rotation, this OH which was in the left, that comes to the right. So the left ones will come to the right, the right ones will go to the left okay? This is the number 3, this is 1, this is 2, this is 3, this is 4, this is 5.

So now you place the groups. The OH is this number 2 OH will be now on the right, number 3 OH will be on the right because this is one 80 degree rotation and number 4 OH which was on the right, that will be on the left. So now you see, the relationship between suppose this is A molecule and this is after rotation this is after after interchange and then rotation okay?

This is molecule B. What is the relationship between these 2? They are same. So if they are same, this centre is non-stereogenic. So this is an example of a molecule which has got a non-stereogenic but Chirotopic centre. Okay? And I can have very reversed situation. See this molecule is an achiral molecule. This molecule is an achiral molecule.

Remember I have said that in a chiral molecule, every point is chiral. I did not say the reverse thing that in an achiral molecule, every point is achiral. That I did not say okay? Because that has much more implications and that gives a very wrong concept that in an achiral molecule because in a molecule there are local environments which can create chirality locally.

That is why when dealing with achiral molecules, you have to be very careful. You cannot say that in an acheiral molecule, each point is acheiral. But in a chiral molecule, we can always say that each point is chiral, is point is a Chirotopic point okay? The non-stereogenicity, there can be, a point can be Chirotopic but the centre can be non-stereogenic.

Now let us come to this molecule. This molecule is achiral okay. This molecule is acheiral and it has got a plane of symmetry and passing through the that middle carbon, that C3 carbon and if a plane of symmetry, if the symmetry element passes through a carbon, (symmet imp) that improper element of symmetry, improper, that means I, Sigma and S. In this case we are talking about Sigma. It is passing through the middle carbon.

So this carbon is an achirotopic. That means it is not Chirotopic. So what is not a Chirotopic point? The point in which these improper elements of symmetry are passing. So they are achirotopic points. Because the Sigma, Sigma plane is passing through this carbon, so this is not a Chirotopic point, this is achirotopic point. And what is this and now what is the stereogenicity of this carbon?

Again to prove that what you have to do, you do an exchange here. So bring the OH onto the left side and these 2 OHes are on the right side, methyl, hydrogen, hydrogen, methyl. Now whatever you do. Even if you do the 180 degree rotation, what will happen? These 2 right-handed OHes will go to the left-hand or the left side and this left OH will go to the right side.

So they will never match because here actually all the 3 OHes are on the same side. You cannot do that no? You cannot have that situation by 180 degree rotation. So they are 2 stereoisomers. So the relationship between these 2 are stereoisomers stereomers stereoisomers. Okay? So basically now, so this carbon is what?

This carbon is achirotopic but it is stereogenic. Okay? So that means there are different situations that can arrive that can have, a carbon can have. A carbon can be Chirotopic and stereogenic, a carbon can be stereogenic but achirotopic, I gave you an example and a carbon can be non-stereogenic but Chirotopic. So all these are possible.

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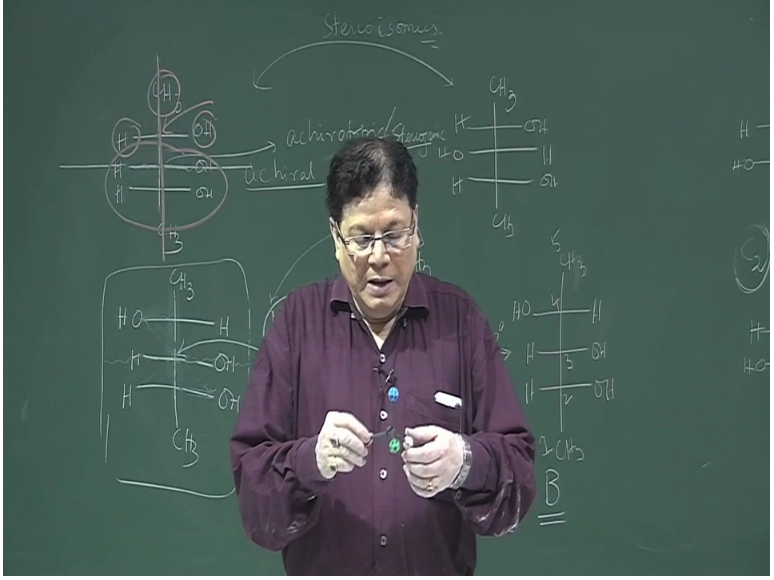

So these are very important concepts in this isomeris that this shows the connectivity between isomerism and between the chiral environment that is residing inside a molecule because we always suffer from this concept that in acheiral molecule if I have a fluorine, if I have this molecule, okay? So let us again look into this molecule and the concept of Chirotopicity and stereogenicity.

If you look at this molecule, this is a carbon bearing 4 different groups. So naturally, this is a chiral molecule. And now what happens to the all the individual atoms here? This carbon is Chirotopic. Because the molecule is chiral, so every point has to be Chirotopic, this white atom is Chirotopic, so is the green, so is the red, so is the blue.

But what is the difference between these atoms vs the carbon atom which is holding these 4 ligands? This carbon atom in addition to Chirotopic, it is also stereogenic because a few interchange the position of the green and the blue, or the white and the red, you get another stereoisomer. So this is Chirotopic as well as stereogenic but all other atoms are only Chirotopic but not stereogenic. I hope this concept will be clear more as we handle more systems. Thank you very much.