Circular Dichroism and Mossbauer Spectroscopy for Chemists

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Lecture – 16
Origin of Chirality

Hello and welcome to this next segment of CD Spectroscopy and Mossbauer Spectroscopy for Chemist. My name is Arnab Dutta and I'm an Associate Professor in the Department of Chemistry, IIT, Bombay. So, previously we are discussing the different aspects of chirality, we found chirality is being present in nature for long time and over there we found in biology, chirality comes through the different fundamental molecules that is found in biology.

These are amino acids, carbohydrates and nucleic acids and over there in the previous segment we have discussed how the molecular recognition happens partly through this chirality? Especially through lock and key mechanism or antigen antibody interaction, over there we have found that this chirality controls the extent of different interactions like hydrogen bonding, hydrophobic interaction, salt bridges and weak forces.

And this chirality controls it by creating a directionality in this particular molecule. Because over here, when you have a chirality you can either have a L-amino acid or D-amino acid and their faces are in different orientation. So, with that they can create a lot of interactive measures and regulate it which particular system will be much more preferred. And by that they can differentiate out of hundred molecules which of the molecule it would like to interact.

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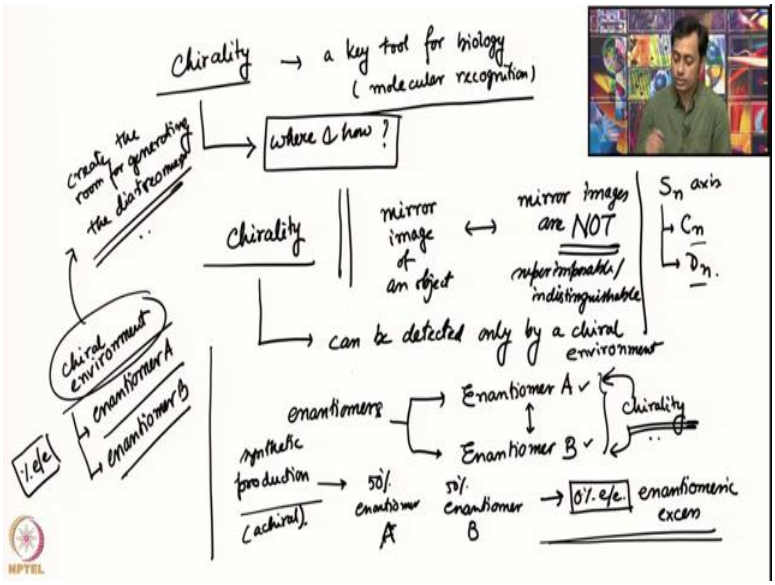

So, with all these things coming into the picture now we understand, yes, chirality is a key tool for biology in terms of molecular recognition. Now, the problem we are facing that to have this fundamental question, where and how this chirality become a part of this biological system? That is the question we would like to answer in this particular segment. So, before going into those details let us look into chirality one more time.

So, when we say chirality again by definition it is a mirror image of a particular object and it is such that the mirror images are not are not super impossible and indistinguishable. That is what you learn and from a symmetry point group we know which says that the molecule cannot have any particular S_n axis present in that molecule. Which bring us down that the molecule should belong to C_n or D_n point group, n can be also 1 for the case of C_n.

So that we have learnt so far and one thing we also found that chirality can be detected only by a chiral environment. Otherwise, the 2 mirror images which are known as enantiomers and say I have two different enantiomer, enantiomer A and enantiomer B which are very much similar molecule, the only thing different is the stereochemistry. They are mirror image to each other and that is not super impossible or indistinguishable.

Now, along with the properties of this enantiomer A and B, all the physical properties will be very much similar. All the chemical properties also be very closely similar. The only thing is going to be differing when you put them in a chiral environment. So, only chirality can distinguish between this enantiomer A and enantiomer B and that is why even when you actually producing a chemical.

So, during the production which typically do not use any chiral environment and what we got is 50% enantiomer A and 50% enantiomer B. So, you cannot avoid it they will always be present 50-50 and if you are doing that reaction, the production in a synthetic system which is a chiral in nature that is not chiral, what we are going to get is 0% energy axis this is called the enantiomeric excess.

So, you are not going to get any enzymatic excess, both of them will be same so, we get a racemic solution. However, if we create an environment which is chiral in nature then I can distinguish between enantiomer A and enantiomer B. So, now just imagine enantiomer A and enantiomer B, both are acidic in nature so, they are enantiomeric acids. Now, if I put a chiral environment and another enantiomeric base then these two enantiomer will interact with them.

Because the environment or the other component is chiral, these are also chiral during their interaction they will start differentiating. Because they are going to form diastereomers as the intermediate and diastereomers as you know differ in the reactivity. So, this chiral environment provides the solution to creates the room create the room for generating the diastereomers. And with that we can separate out enantiomeric A and enantiomeric B that means we can actually get an enantiomeric excess at the end.

So that is what is actually done in the actual chemistry, we try to create a chiral environment. For an example, we are actually having enantiomer A and enantiomer B almost at same level. We want to separate them we actually use a chiral column which actually creates the environment. For example, the drug design, we have gone through the different drugs like ibuprofen and all those things and over there we found this ibuprofen is chiral in nature.

But there are two different enantiomer, one is the actual drug other one remains inactive. So, if I want to separate them, we have to go through a chiral environment. Otherwise, we cannot separate the two enantiomers, we have to create an diastereomer by creating a room of chirality. So, if that is actually coming into the picture.

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And now, if I look back to the environment or I should say nature, you will see there is a huge amount of enantiomeric production. Now, the question is how it is doing enantiomeric production by the nature and however, we found most of the time they have exclusively one isomer or I should say enantiomer is preferred. So that actually gives an idea that where I am doing this reactions in the nature, they are actually creating chiral environment.

And that is first the reason in the nature when you are doing an experiment, you are getting exclusively one particular enantiomer. Now, the question is when you are talking about chiral environment in nature it began at one point of time right now it is happening in these metal enzymes which are chiral because they are made out of amino acids or carbohydrates or the nucleic acids also, in certain times they are chiral.

So, I know they are going to create a current environment and we will globally going to get exclusively or preferably one of the enantiomer. But the question remains same, where it all began? So, one of the idea was this chirality may be triggered by extra terrestrial body. That means the chirality is actually not from the earth itself. It actually has come from outside the world.

So, is there any proof? So, one of the proof that we are going to discuss today is known as Murchison meteorite. So, Murchison meteorite is actually a meteorite actually came from outside the world and it actually hits in the place named as Murchison. This place is situated in Australia and these particular phenomena that the huge meteorite is hitting on the earth at Murchison it happened in the year of 1969.

At that time, this huge meteorite hits the overall weight of the meteorite that was intact even after the heating was close to 100 kilo that means quite a large amount of meteorite. Meteorite falls on the earth all the time but most of them are so, small that they got vanquished during their coming through our stratosphere. But over here some of them actually survives and large enough quantities.

So that we can do a lot of experiment Murchison meteorite is one of them. So, when this particular meteorite hits the earth at Murchison it actually got fragmented and some of the fragments are in grams, milligrams, some of them are larger amounts like 7 to 10 kilos and all together when it combined together it is a 100 kilo mass unit. And this mass unit was collected very nicely without any contamination very quickly and transferred it to a lab and in the lab that is going tested.

So, now you will be curious to know what is their present in this particular meteorite. So, other than the common factors like rocks, the salts and the alums, one important thing comes over there, there are a lot of organic chemicals and what are those organic chemicals present over there? Those are actually serine, glycine, alanine, glutamic acid, leucine, valine. So, those are the different amino acids were found to be present in this meteorite.

And very interestingly, what we also found that other than glycine which is a achiral one, all the other amino acids which are chiral in nature they are present in enantiomeric excess. That means this molecule prefers one amino acid or the other. When you look closely found there are both L and D-amino acids are present but they are favouring the L-amino acid and one of the hypotheses is that millions of years ago, some of the meteorite falls on the earth which actually has this L-amino acid.

And at that time earth was a hot soup where we actually having a lot of chemicals around us and they start forming this initial part of the bio molecules and at that point of time, the presence of this chiral amino acid which is present in that system around that time probably coming from other extraterrestrial bodies and that actually creates that chiral environment that we are talking is very much needed.

To create this enantiomeric differentiation and this enantiomeric differentiation is then favoured and we got as a product one of the enantiomers more than the other and that is possibly what is happening over here and Murchison meteorite is one of the examples of it. But very interestingly when we are looking into the Murchison meteorite in further details,

we found these are the amino acids we already found even on earth. So, they are all present but additionally there are some other amino acids.

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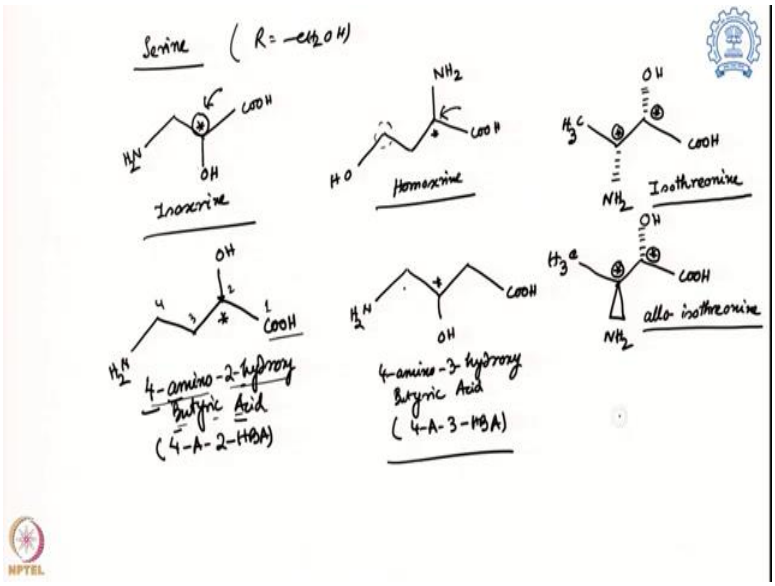

So, let us take a look what are the other amino acids present in that system? And we found they are majorly hydroxyl group bound system, so, there you can say derivatives of serine which actually has a side chain of $-CH_2OH$ hydroxyl group. So now, let us say in this Murchison meteorite which is coming from out of the world. They are actually having some amino acid which is typically not found on earth, typically not found on the biological form in the world.

So, what are those? This is a hydroxyl group secondary hydroxyl, this is the alpha carbon, the chiral carbon and the name of the system is isoserine. So, you can see that over here the amine group is moved one side up and this hydroxyl group comes over there. So, amine and oh group, you can say the swap the places from the actual setting machine. So, it is isomer of serine and it is also having a chiral centre of there.

Then comes the next one which actually contains the amino acid we know for but instead of $-CH_2OH$, this molecule is $-CH_2CH_2OH$. So, there are $2CH_2$ groups over there and this is the alpha carbon. So, let me draw that properly this is the alpha carbon and over there you can see there is one extra CH_2 comes into the picture compared to the serine. So, the name of this is homoseriene.

It has been found also in enantiomeric excess due to the presence of this alpha carbon. So, all of them are present in Murchison meteorite and not only that they are present enantiomeric excess wise that means one of the enantiomer is favoured. The next one is the following CH_3 and over here this

is a group so, NH_2 group and OH group are present over there in this molecule and this is you can say a derivative of threonine so, you call them isothreonine.

And then there is another version of this particular molecule is the following very much similar looking structure CH_3 over here COOH over here OH over here but over here, the NH_2 group change this position and over here you can see there are two different point groups in this molecule. So, obviously it is going to be chiral and again this chiral molecules was found in Murchison meteorite with one enantiomeric excess.

And the name of this particular molecule is also isothreonine. Then we have certain more amino acids present that will go one by one. This is a chiral centre over here and this known is 4-amino-2-hydroxy-butyric acid. So, take the first letter of each name and the name comes is 4-A-2-HBA. The name is coming from this way because this is the carbon number 1, 2, 3, 4 so, 4 carbon.

So that is butane chain because there is an acid over there it calls the butyric acid, number 1 positioning is from carboxylic acid that was the preference. Then number 2 is this 3 and 4 and over there you just write down the name of the position 4-amino-2-hydroxy-butyric acid. And there is another one very similar and over here the position of the OH changes it comes over here. So that is only change so the name will be very similar it is still 4-amino but 3-hydroxy, butyric acid in short form 4-A-3-HBA.

So, this is also been found in Murchison meteorite. So, you can see they are all different versions of hydroxyl base amino acid and there is one other more you can see it over here.

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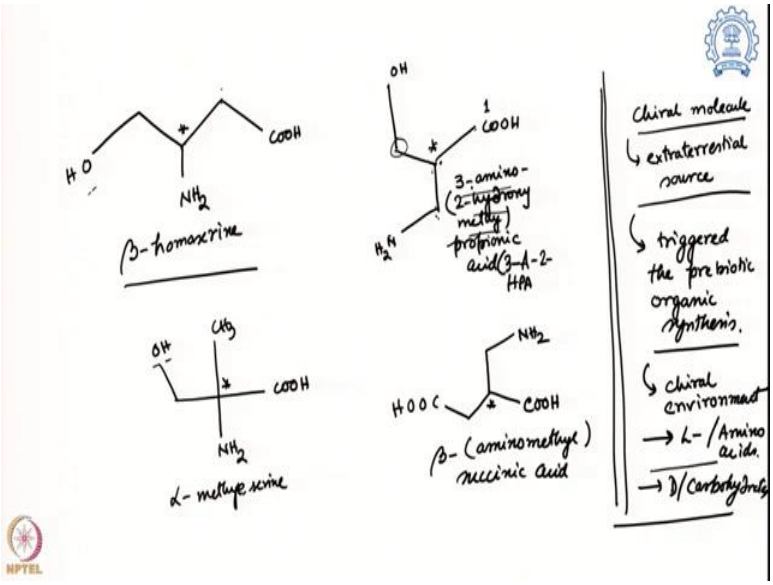

That will go to the next one is the following carboxylic acid is very much similar to the previous ones but over here OH groups go to the terminal, NH_2 group come into the middle of the molecule and this is still a chiral centre and the name of this molecule is beta-homoserine. So, you can say it is a beta amino acid is presenting alpha, beta so, beta amino acid then comes the other one.

So, over here we are just putting this carboxylic acid in one place or the other and changing where is the chiral carbon? The name of this amino acid is 3-amino, 2-hydroxy methyl, hydroxy methyl because there is a methyl group present with their hydroxymethyl propionic acid in short from 3-A-2-HPA. So, it is the number 1, carbon over here then 2 then 3 so, this is 3-amino that is why it is a 3-amino 2 position is the hydroxyl methyl group over here and the rest of the name is propionic acid 3 membrane.

So that is what is coming over here the other 2 amino acids you also found over there these are the structures. So then this is actually alpha amino acid but the name is alpha-methyl serine because we have learned that in the amino acid alpha position you have 1 hydrogen 1 r group, 1 carboxylic on amine over there, there is no hydrogen connected to this alpha carbon. So, it is a little bit modification of that and then comes this one carboxylic acid group then we have an NH_2 group over here and there is another carboxylic acid group.

So, this is a version of succinic acid and the name of that is beta-amino methyl, succinic acid and over here this is a alpha carbon. So, you can see in this meteorite molecule, we have samples from different chiral molecules which is mostly the hydroxyl group bound systems which is showing that there is possibly interaction with the water molecules to create this particular set of molecules.

And this kind of give us a hint that there is a possibility that yes, is a possibility that the first chiral molecule probably comes on the earth from as an extra terrestrial source and secondly, this probably triggered the prebiotic organic synthesis and it also showed that the initial presence of this chiral molecule creates the chiral environment which possibly lead us to the formation of L-amino acids or D carbohydrates.

So that is possibly trigger those systems and create this chiral environment around the world. So, with that in this particular segment, we have shown you that what is the exciting world of chirality and how it has been created? And now the question comes how do you monitor them? And that is why the circular dichroism come handy and give us an idea. How

we can monitor the different amounts of chirality? If one chiral molecule transfer to the other, can we follow that with CD spectroscopy or not?

So, those are the things we are going to follow in the next coming days and with that we would like to conclude this session over here. Thank you. Thank you very much.