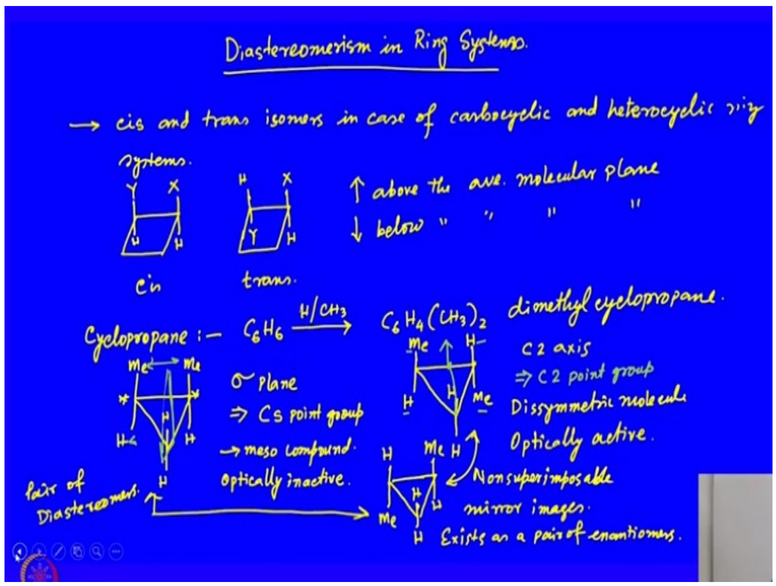
Symmetry, Stereochemistry and Applications
Prof. Angshuman Roy Choudury
Department of Chemical Sciences
Indian Institute of Science Education and Research, Mohali

Module No # 05
Lecture No # 26
Diastereomerism in Ring System – Part 01

Welcome to the course entitled symmetry, stereochemistry and applications. So in this week on sixth week we are going to discuss about the diastereomerism in ring systems and pi systems.

(Refer Slide Time: 00:30)



So let us start discussion with the diastereomerism in the ring systems. So what we know is that in case of ring systems it is possible to have Cis and trans isomers in case of carbocyclic and hetereocyclic ring systems. So what do we mean by this cis and trans is that, Suppose if we draw any molecule suppose this is cyclobutane and if the substituents suppose X and Y are on the same side then we call that the Cis compound.

And if the substituents X and Y are on the opposite side then we call that has trans isomer. So in this ring system some groups are consider to the above the average molecular plane. And some groups are below the average molecular plane, so you can easily understand that beyond cyclopropane, cyclobutane cyclopentane cyclohexane and so on will have the carbon atoms not in one plane they will be residing in different set of planes.

So therefore based on the orientation of those groups above and below we identify them as Cis and trans isomers. So now if we try to understand these isomers in terms of whether they are enantiomers or diastereomers or meso compounds we need to understand it in a systematic manner. So let us start by considering a cyclopropane system because cyclopropane is the smallest ring having a formula C3H6.

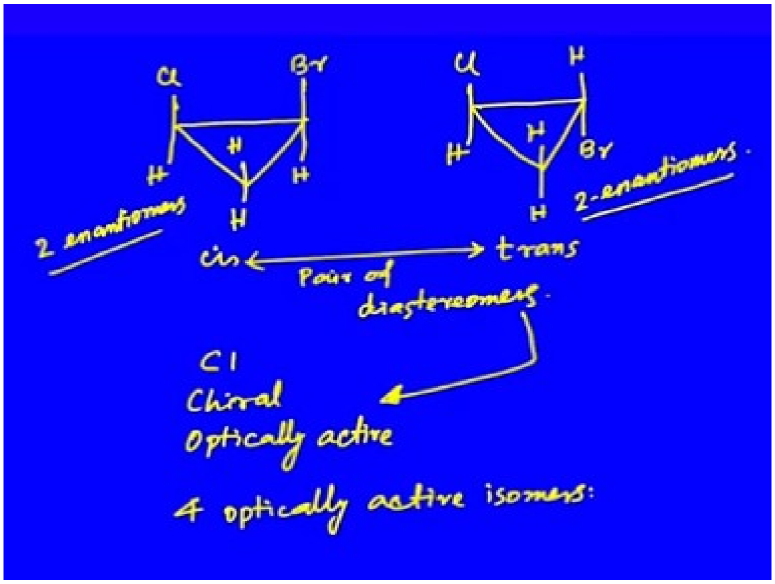
So when we replace 2 hydrogens by some group say methyl group we would get C3H4(CH3) whole 2 so that is dimethyl cyclopropane. Now these dimethyl cyclopropanes can have 2 different isomers where you can have the methyl groups both up and the other isomer where the 2 methyl groups are opposite that is 1 up and 1 down. If we look at these 2 molecules what we see that this Cis isomer has a sigma plane.

The sigma plane bisects the molecule like that so this methyl-methyl mirror image hydrogen-hydrogen mirror image and contains that particular carbon atom. So since the molecule has a sigma plane, this belongs to Cs point group. So although these 2 centers are chiral centers this represents a meso compound hence it is optically inactive. What happens when we consider the trans compound?

This trans compound has a C2 axis that C2 axis is passing through the midpoint of this C-C bond and containing that carbon atom and if we rotate the molecule about that C2 axis the upper methyl will come as lower methyl upper hydrogen will come as lower hydrogen. So this molecule has a C2 axis, it belongs to the point group C2 and what we see here is that this molecule is a dissymmetric molecule.

And hence this is optically active. If you draw the mirror image of this molecule then we will see that the mirror image is this one. So these 2 are non-super imposable mirror images, this trans molecule exist as a pair of enantiomers and this Cis and trans compound, they are a pair of diastereomers. So now here what we have is that the 2 substitutions that we have discussed are the same. So now I would like you to see what, happens if the substituents are different?

(Refer Slide Time: 08:34)

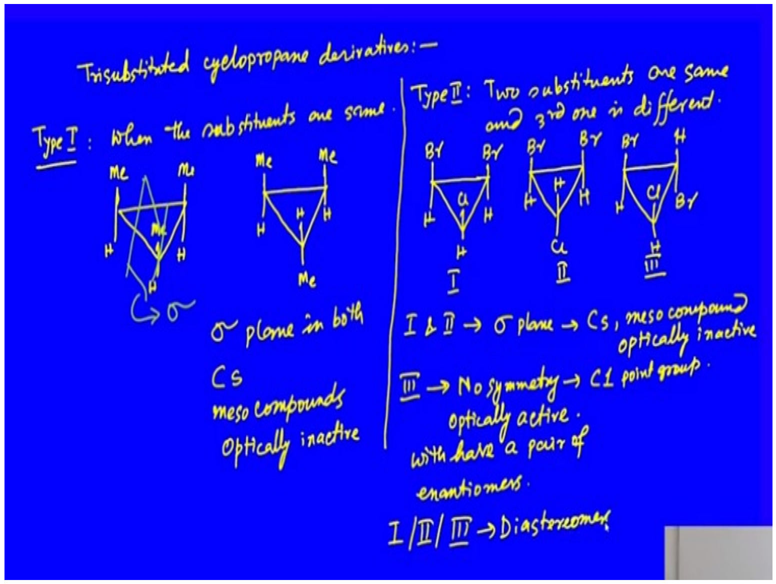


Suppose in a cyclopropane compound you have chlorine and a bromine substitution. So this is the Cis isomer and this is the trans isomer. Suddenly these 2 are pair of diastereomers as they are not the mirror image of one another. And then what we see is that the symmetry that cis is compound had the sigma plane is not missing because those 2 groups are different. So this molecule does not have any symmetry other than C1 symmetry.

Therefore this molecule and its mirror image are pairs of enantiomers so this molecule is chiral, optically active. Same is true for trans molecular also because the original compound which has 2 methyl group had C2. Now because of 2 groups being different that C2 does not exist and therefore this molecule is also a chiral and optically active. So the Cis isomer will have 2 enantiomers and the trans compound will also have 2 enantiomers.

And hence this compound will have 4 optically active isomers, right. Now let us see the situation where we have 3 substitutions.

(Refer Slide Time: 10:58)

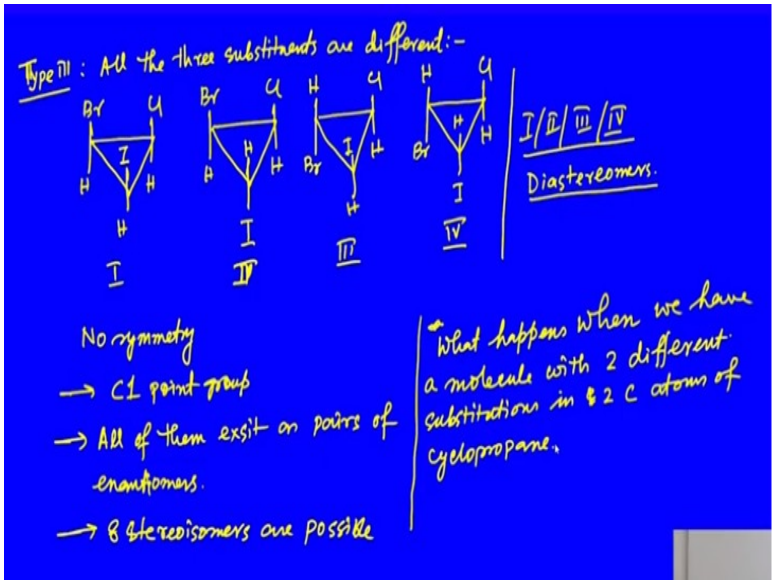


Tri-substituted cyclopropane derivatives. So there are few possibilities, type 1 when the substituents are same. So you can have compound like this, all 3 methyl groups are up and the other one where 2 methyl groups are up and one methyl group is down. So what we see here is that both the compounds have sigma plane, right, because if you see the mirror plane which is actually bisecting the molecule and passing through that C-C bond you have a sigma plane in the molecule.

So both the molecules have sigma plane therefore in both so, they are belonging to point group Cs. And hence they are meso compounds and optically inactive. But then there is other type possible, which is type 2, where 2 substituents are same and third one is different. So these compounds are 3 different possibilities. So what we see here is that in 1 and 2 they have a sigma plane and hence they belong to point group Cs.

So they are meso compound and optically inactive whereas the compound 3 does not have any symmetry so it actually belongs to C1 point group this is optically active. So therefore this 3 will have a pair of enantiomers, the relationship between 1, 2 and 3 are would be distereomers right.

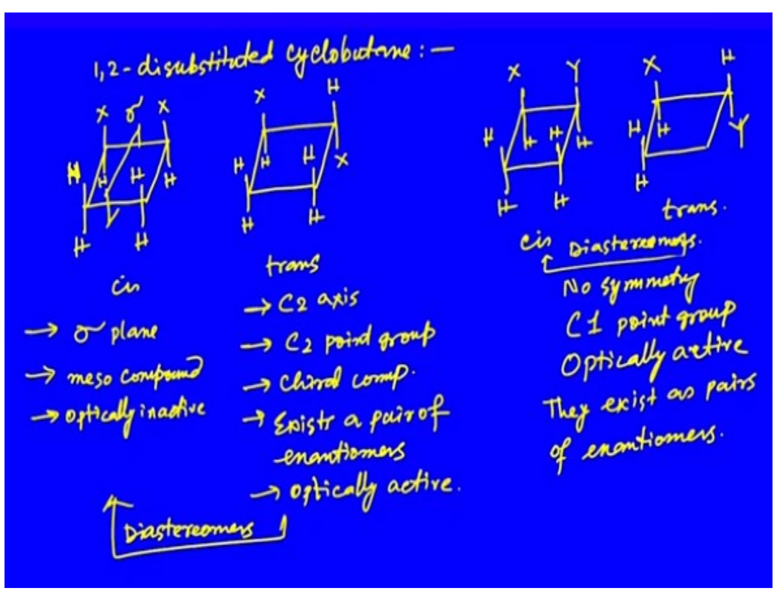
(Refer Slide Time: 16:23)



Now the third type of the cyclopropane derivatives will be those where all the 3 substituents are different. So this has 4 different types and what we see in these molecules that all of them they do not have no any symmetry. Which; means all of them belong to C 1 point group therefore all of them exist as pairs of enantiomers. So therefore total 8 stereoisomers are possible and what is the relationship between 1, 2, 3 and 4? These 1, 2, 3 and 4 are diastereomers.

So now I would leave the last part of this for you to figure out what happens when we have a molecule with 2 different substitutions in 2 carbon atoms of cyclopropane. So with this we would like to move to the next part. So the next higher cyclic alkene is the cyclobutane.

(Refer Slide Time: 20:20)

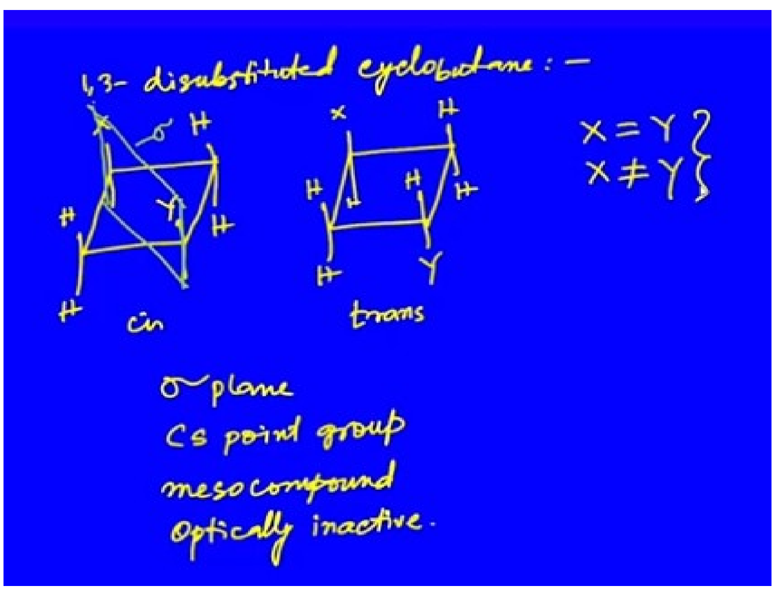


So we would start with the discussion with 1, 2 disubstituted cyclobutane. As you can understand that cyclobutane will have 4 carbon atoms and of course the molecule is not planner here we are assuming the molecule to be planner and then writing the substitutions. So this one is the Cis isomer of 1, 2 di-substituted and the next one I am drawing here is the trans isomer to disubstituted cyclobutane.

So what we see here in case of the Cis compound once again this Cis compound as a sigma plane which bisects the molecule like that. This Cis is a meso compound, optically inactive whereas the trans compound has a C2 axis. Therefore it belongs to C2 point group and hence it is a chiral compound, exist as a pair of enantiomers and optically active. Now let us see if in this case when the substituents where same. If the substituents are different what happens?

This is the Cis isomer and this is the trans isomer so here in both Cis and trans there is no symmetry. Therefore it belongs to C1 point group and hence they are optically active they exist as pair of enantiomers. So here this 2, Cis and trans they are distereomers, here also Cis trans they are distereomers, each one of them exist as a pair of enantiomers. So now let us see what happens when we have 1, 3 disubstituted cyclobutane.

(Refer Slide Time: 24:45)



This is Cis and this will be trans. So in this 2 compounds there are 2 possibilities whether X equal to Y or X not equal to Y. That means it is dimethyl or 1 is chloro and one is bromo or 1 is methyl and 1 is chloro and so on. What we see in this case is that the Cis compound and trans compound both of them have sigma plane passing through the X and Y groups. So both of them belong to Cs point group therefore they are meso compounds and optically inactive. This relationship is valid for both X equal to Y and X not equal to Y so we will continue from here in the next lecture.