Symmetry and Group Theory
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Lecture No.3
Symmetry point group: Examples Part II

I do not remember when we started but here is this one and half example more. Now think of tetrahedron CH4, I am not going to work out tetrahedron completely for you that is why that is why I called it one and half. I just show you what are the different symmetry elements? I will ask you to figure out how many of them are there partly, think of a tetrahedron now everybody knows what is a tetrahedron is right have you seen tetrahedron where? Have you been to birthday parties and decorated balloons, think of those balloons, one of 4 balloons together that 4 balloons actually form a tetrahedron provided they are in the same size?

If next time you are invited to birthday party then you do this experiments generally they like to fit 4 balloons together take one of those clusters and bust the balloon what you think it happen yeah it would not be appear that is the point, yes you watch another one what happened yeah it will be linear, you watch another one the baby is not going to be happy ok. So, what you do, so instead of doing destructive you can also be constructive right.

Take that set of two balloons right take another cluster of 4 balloons and try to tie them together what you think it will happen it will give an octahedron in front of your eyes bust any of those 6 balloons it will become TDP that is the basic for you everywhere studied basic here Valence electron pair repulsion theory that is based on spherical consideration nothing to do with the charge still you can actually demonstrate very nicely using balloons.

The only thing that you should take care of it the balloon should be better be off of same size otherwise you are going to have all kinds of destruction our friend likes. Let us talk about the tetrahedron what is the angle under 109 degrees do you all know how to draw a tetrahedron inside a cube? Yes how do you draw it first you draw a cube and then and all turn it.

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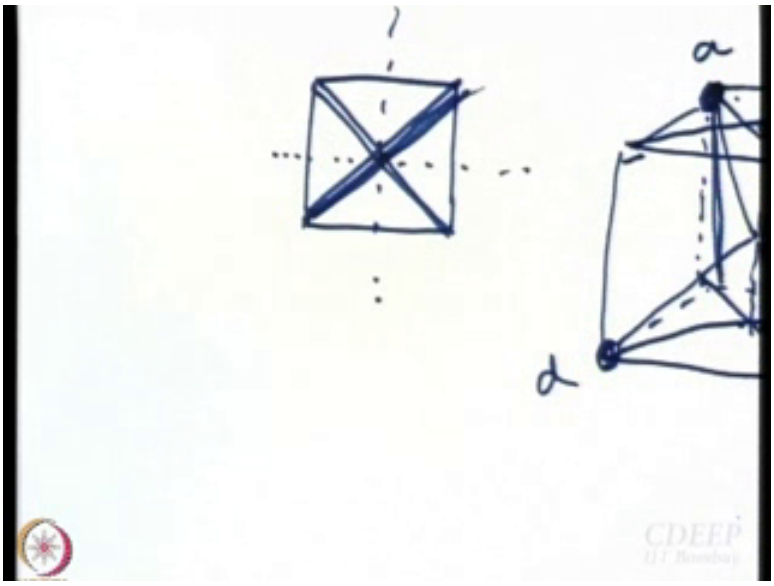

I really wish I will have another colour that anybody have a black pen ok it is one stop that I can draw without goofing up too much ok we defined this to be cube where will the points be let us start with this not here, not here, here, here and here right those would be the 4 vertices of the tetrahedron. If I want to draw the bonds what will I do workout this body diagonal, workout this body diagonal whereever they meet that is the centre. Similarly adjoin this there is a tetrahedron in the box ok.

Now let us work out the symmetry operations what is the CN? What is the principal axis of symmetry? C3, 2 is also there but since C3 is there, C3 is the principal axis of symmetry right. Where is C3? I think everybody knows along the bond how many are there 4, 4 symmetry operations or 4 symmetry elements? How many symmetry operations corresponding to C3 and C3 and C32 C2 square whatever you want to call it? So, you can rotate ones or you can rotate twice or you can also rotate thrice, rotating thrice is like C1 so you do not care about that C3 and C3 square. For every C3 you have 2 operations right.

How many total operations 4 C3's right, each bond is a C3so 8 C3 operations are you ok. Now is there any axis of symmetry? You identified C2 already, where is C2 right. Let us start at the top side take the face enter take the face centre of the bottom face and join them ok do not take any attention to the little bend here that was not intentional. Where is C2 let us name this a b c and d if I apply C2 rotational on this axis then what will happen a and b interchange and c and d interchange, are you ok with that, do you understand.

A and b interchange B and C interchange sorry a and b interchange and c and d interchange is there any other C2, now it is very easy to figure out that you understood that whereas C2 you have to join the face centres of opposite faces. How many opposite faces are there 3 they are going to be 3 C2 axis and they are going to be perpendicular to each other right. One will be like this, one like this; third like this x y z Cartesian axis is it not. Three C2 will form the three Cartesian axes.

So, how many C2 are there 3 symmetry elements or 3 symmetry operations as well as operations because C2 square once again is E identity not doing anything C1 ok so 3, C3 is done and C2 is done anything else of course you cannot see for lower one because less than 2 is 1, that there is always there. Infinite number of C1 axis that is trivial, is there any C4, S4 is there right C2 also works as S4 how many operations for S4 axis. Now that is there you should work out carefully and tell me next fine.

Now let us look for planes, is inversion symmetry there, tetrahedron inversion symmetry is there, not there right it cannot be ok. Whatever planes, you see the planes where and another line like this, this is the plane right and similarly this is another plane got it right. Now see such that it is very easy, these two planes I have the C2 axis at the intersection and you told me that there are 3 C2 axes. So, obviously they have to be 3 sets of plane so total 6 planes ok.

Now look from the top ok, look from the top how it will look, this area plane, this is another plane sorry and where are the C2 axis one C2 axis is like perpendicular, the other two one is like this and another one is like this is it not through the centre of course not at the top right. So, see these planes do not they bisect the angle between the C2 axis. So, it is a dihedral plane 6 dihedral plane.

So, you work out whatever is there and tell me what are the symmetry operations present in TD you have a big list and that is call TD tetrahedron ok. I want to finish today this with discussion with my favourite molecule and there is Allene, remember about the structure of Allene what is the structure Allene?

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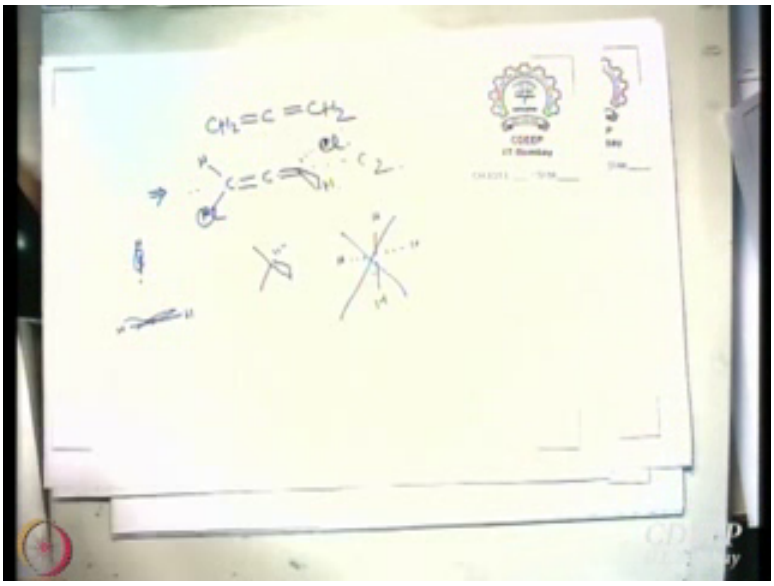

I am forgetting which one is zoom and which one is normal it was written here. I will just write the simple chemical structure first CH2 11 C 11 CH2 this is Allene ok. Those who did not know forgot know now. Now see what is the hybridization of the central carbon SP right you are gone P orbital like this and another P orbitals like this ok, so, if you look at the structure this is what the structure is, let us see this 3 hydrogen atoms are in the plane then these two hydrogen atoms will be above and below the plane ok right.

Now let me quickly draw another tetrahedron that is a tetrahedron looks, what does this Allene look like, its look like you have taken a tetrahedron and you have a kind of dragged it, is it not. You have dragged it out so from what carbon somehow make 2 carbons and you made it long. So, we understand that this symmetry of Allene will be reliable to symmetry of tetrahedron TD it is just that many of the symmetry operations will now be gone. Because we are essentially done you have induced a distortion to start with the much more symmetric structure TD you have a distortion along the axis.

So, many of the symmetry operations will be gone let us see what are the symmetry operations that is survive. I think what is easiest to see is planes, this is the planes these HCH will define a plane is it not HCH will be define a plane. So, this is one plane perpendicular to paper and this here is another plane in the plane paper ok with that is there any other plane. How many planes are there in the tetrahedron? 6 here we have only two ok. Now let us look for the C2 axis, if C4 will be there of course C4 will not be there it will be disturbed it, C4 is gone.

We were only hope is C2 how many C2 are survive out of 3 and these two planes are survived ok. How many C2 are survived can you tell me that, I can see one very easily, is there any other to figure out is there any other let us look at the molecule from the this side. If you look at the molecule from this side what you will see, you have this hydrogen here, Melagenic ok sorry. This is hydrogen this hydrogen and if you look from this side the hydrogen horizontal.

Earlier one is better I do not know he just do this looking from this side, this hydrogen is here this hydrogen here and then both the hydrogen's will pointed away from you right. These two points away from you, now is there any C2 actually this is a C2 and this is a C2 all the 3 C2's survives. It is just that one look different from the other ok, let us close this point today next day what we will do is we start with this but we will look 3 dimensional module and there you understand very easily where the C2 is there.

The other thing that what will do is even in fact try to do it at home. You have drawn tetrahedron inside a box inside a cubic box can you try to draw this thing Allene inside another box. Is just that it is still not be a cubic box anymore right it is going to be a cuboidal box. Try to draw this inside the cuboidal box you can see the C2 right away. And the next day you are going to show you the model anyway and then I ask you another question and I am not going to leave you as easily.

Next question is now I substitute this hydrogen with a chlorine and I substitute this hydrogen with chlorine does that make it a C1 molecule. I see some noise it does not C2 Axis survives one single C2 axis will survive even in that I think I we will understand it better when we see the model that we will do that next day.